NEREUS

Núcleo de Economia Regional e Urbana
da Universidade de São Paulo

The University of São Paulo
Regional and Urban Economics Lab

Lecture 16: Transportation Plans

Prof. Eduardo A. Haddad

What if freight costs in Brazil were reduced? *("tau question")*

What if investments in transportation in the country increased? *("K question")*

What if the state government decided to implement a portfolio of investments in transportation in Minas Gerais?

What would be the potential impacts in the different regions of the state?

Macroeconomic analysis (non-spatial)

Output elasticity of (public) expenditures on infrastructure

$$\ln Y_t = \phi \ln G_t$$

Similar impacts for different projects

- GDP growth
- Magnitude proportional to the “size” of the investment

Brazilian economy is characterized by a high degree of spatial inequality

Theoretical inconsistencies between competitive regimes conceptualized in space-less and spatial economies

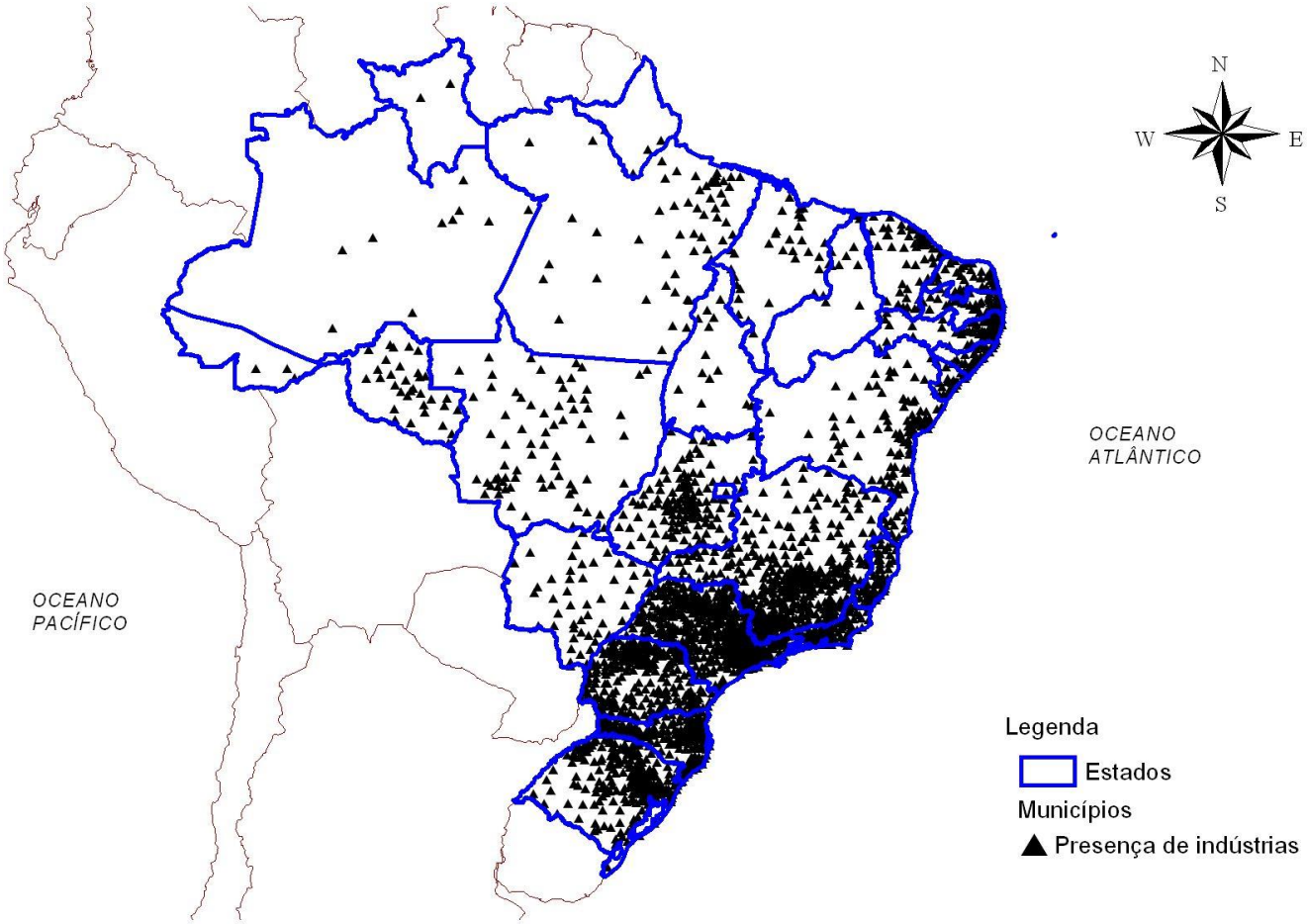
New Economic Geography

- Role of increasing returns and transportation costs (Fujita *et al*, 1999; Fujita and Thisse, 2002; Baldwin *et al*, 2003)
- Dominant result: core-periphery (**spatial heterogeneity**)
- It helps explaining reality

Notion of some intermediate form of space?

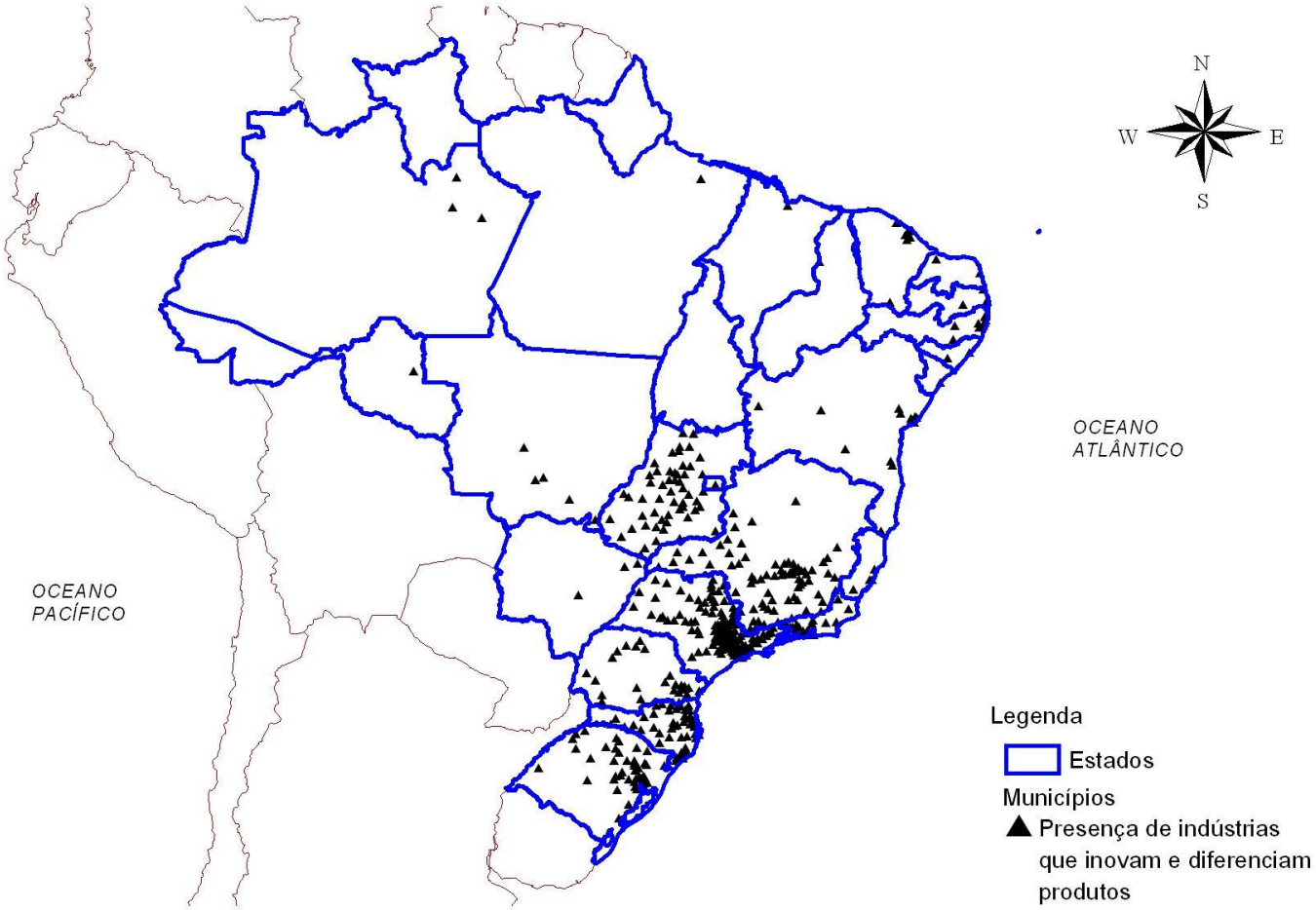
- High transportation costs would enable firms to exploit increasing returns to scale within less than complete national markets
- Asymmetries in competitive advantage between regions (central position)

Presence of Local Manufacturing Units: Brazil, 2000



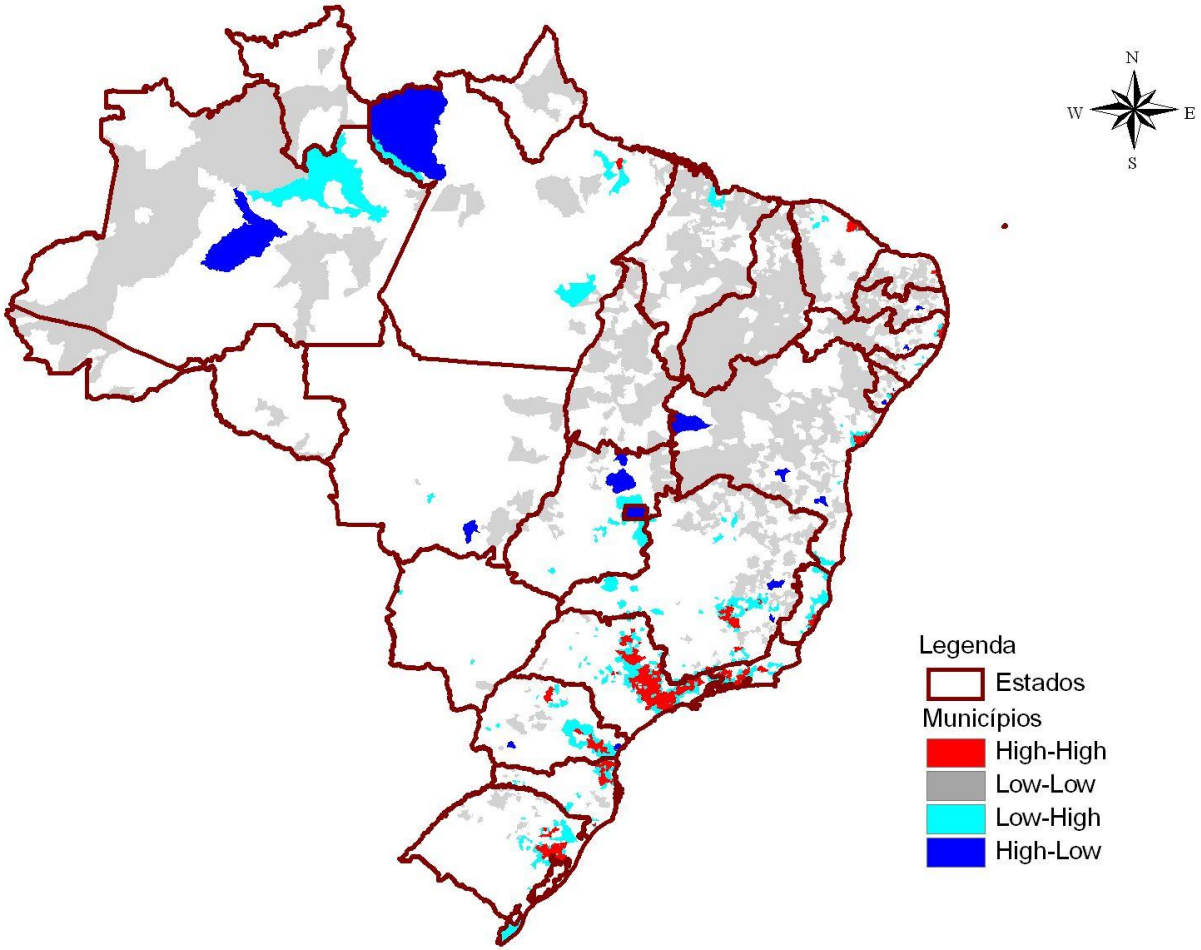
Source: Lemos *et al*. (2005)

Presence of Local Manufacturing Units that Innovate and Differentiate Products: Brazil, 2000



Source: Lemos *et al*. (2005)

Manufacturing Concentration: Brazilian Municipalities, 2000



Source: Lemos *et al*. (2005)

Polarization by São Paulo

State of São Paulo – 35% of national GDP

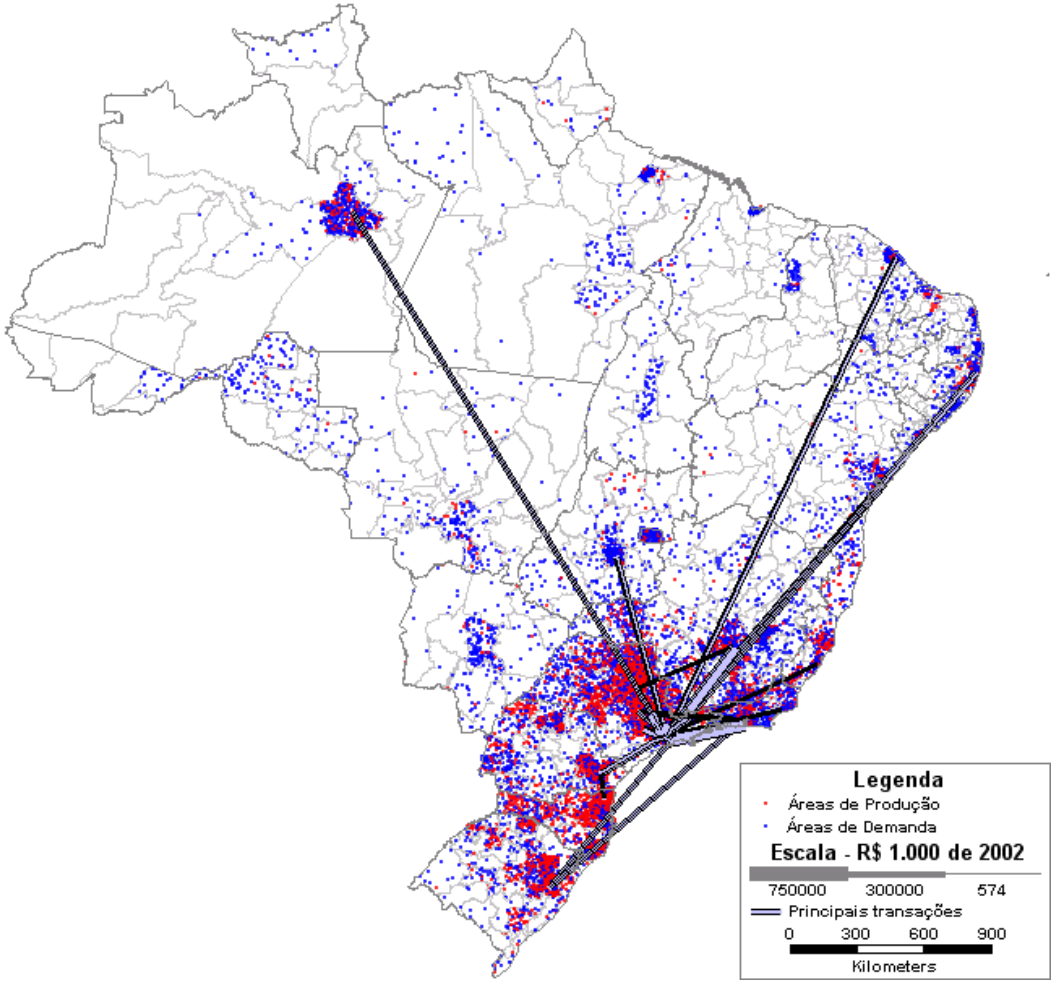
Asymmetries in the distribution of productive activity, with the primacy of São Paulo, serve to strengthen existing competitive advantages

Sector/products with higher technological content

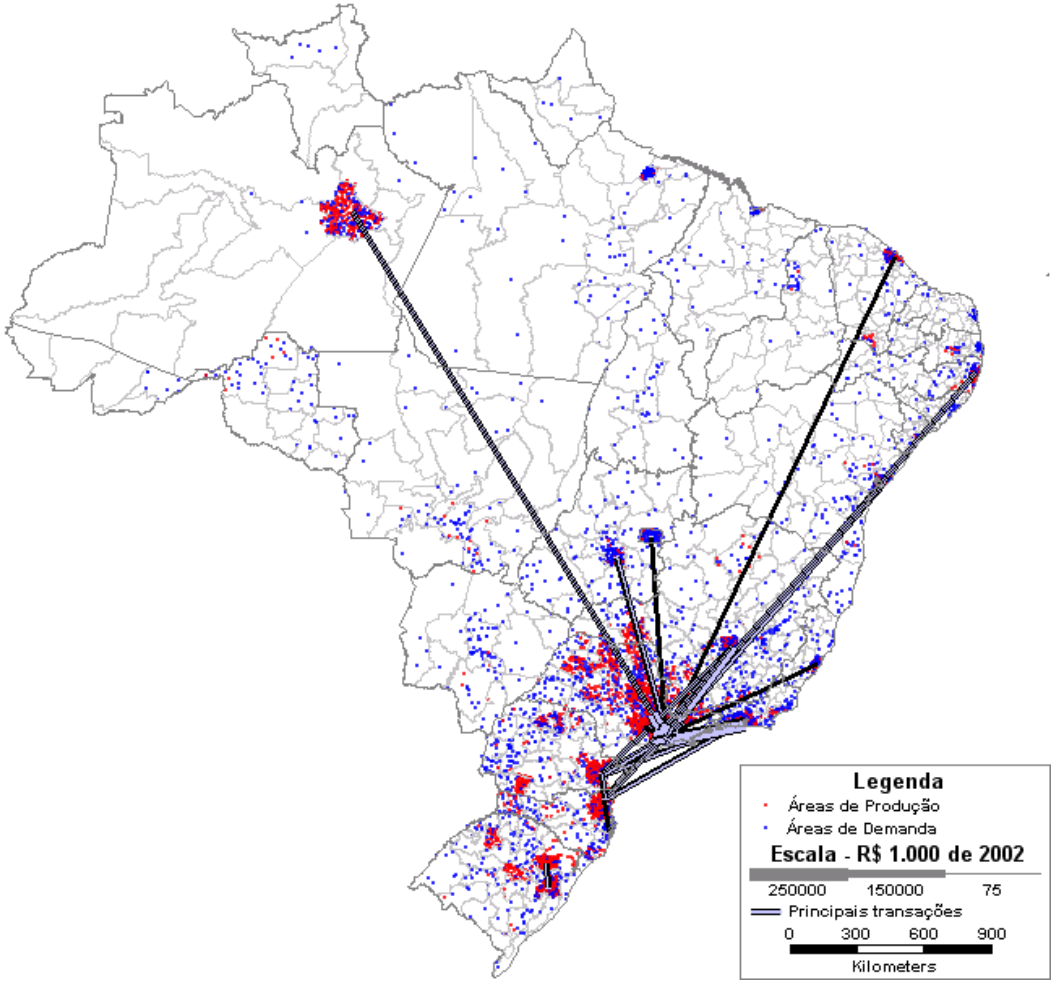
Presence of other relevant industrial areas outside São Paulo

It provides some intermediate perspectives between a core-periphery model

Machinery:
Output, Demand and Interregional Trade



Electrical Equipment:
Output, Demand and Interregional Trade

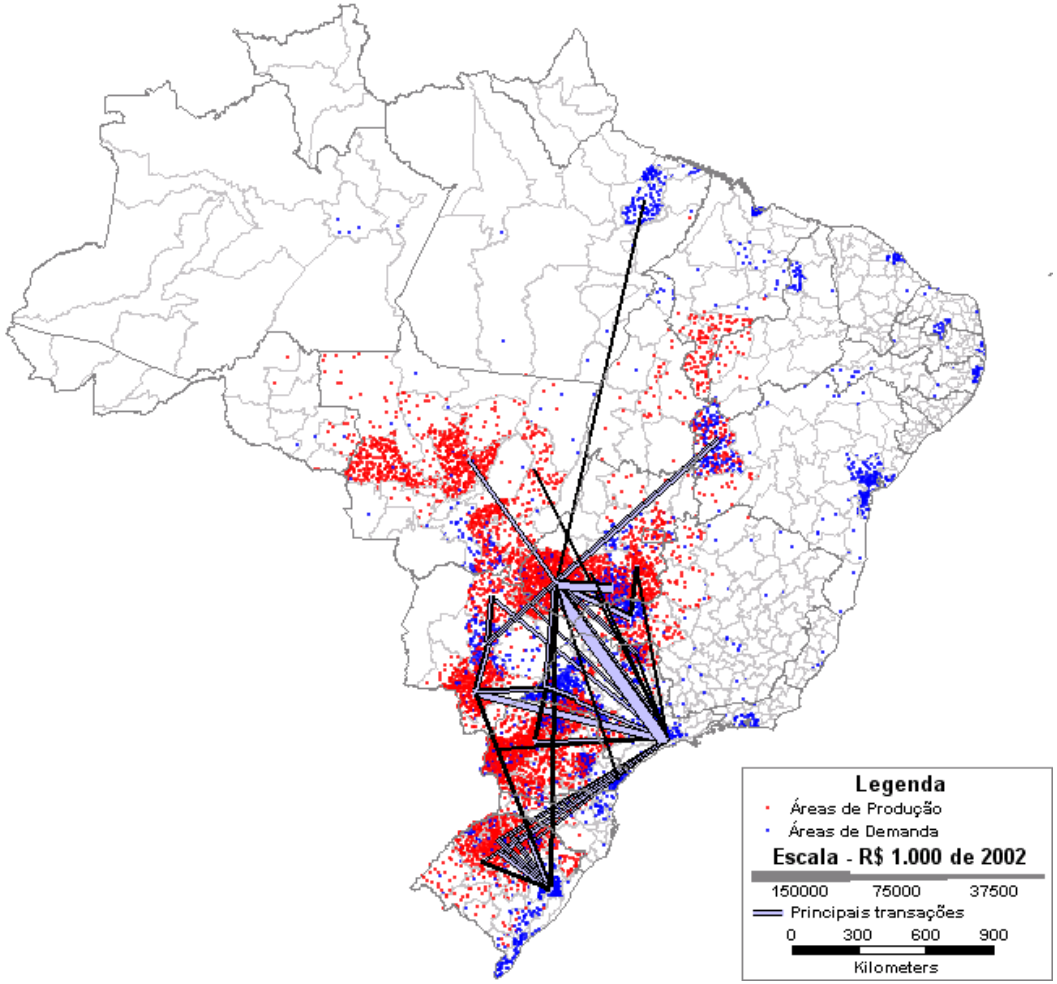


Two main integration axes (1)

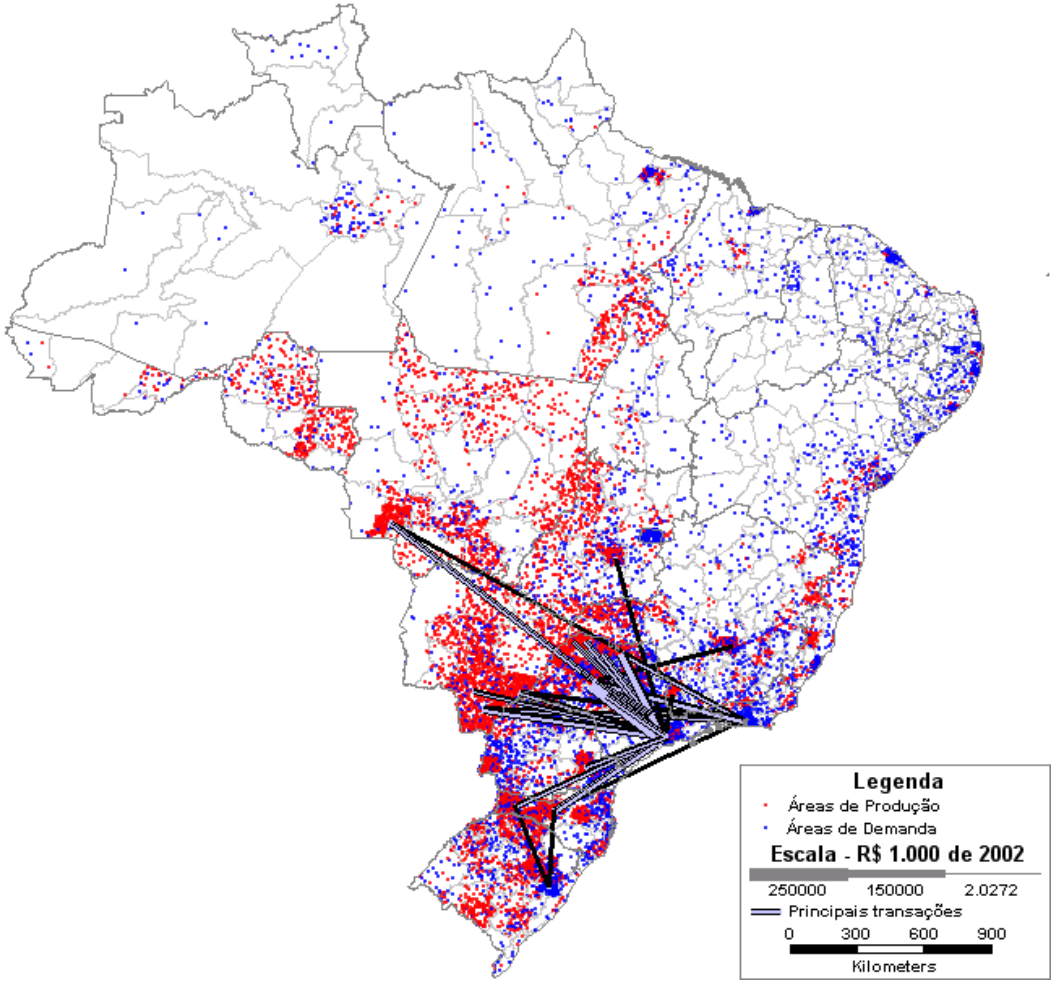
1. East-West axis

- Integration of more specialized spaces
- Lower degree of spatial competition
- Economic spaces in the Southeast as “natural” market areas for the agricultural and agricultural-related output of the Center-West

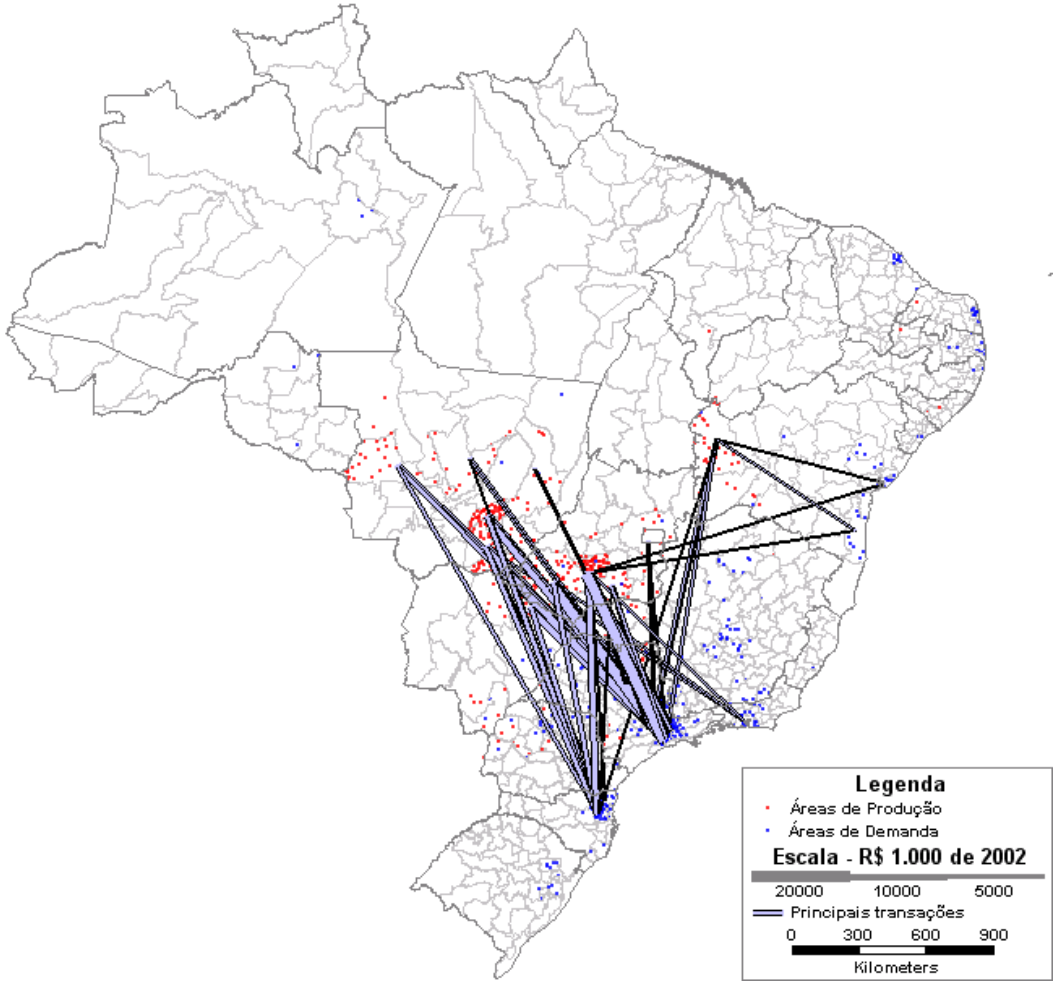
Soybean:
Output, Demand and Interregional Trade



Beef industry:
Output, Demand and Interregional Trade



Cotton:
Output, Demand and Interregional Trade

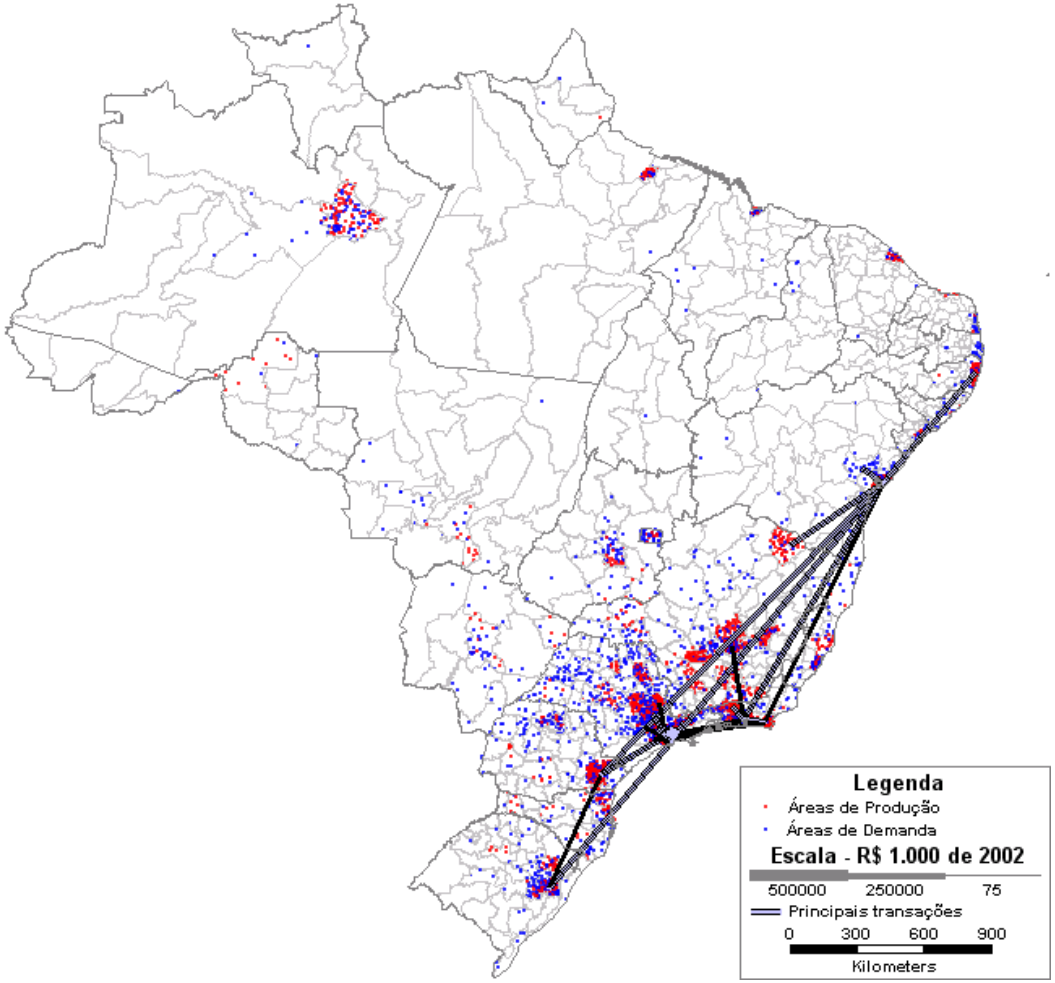


Two main integration axes (2)

2. North-South (coastal) axis

- Integration of more complex, industrialized spaces
- Higher degree of spatial competition
- Denser economic spaces in the Southeast, with stronger agglomeration economies
- Transportation infrastructure under full capacity use; prone to congestion effects

Chemical Products (Non-petrochemical): Output, Demand and Interregional Trade



Transportation costs may be seen as one of the main obstacles to growth in Brazil…

Brazilian transport infrastructure is deteriorating fast from lack of investment and maintenance, showing an increased number of critical points, or bottlenecks, in most of the corridors

Decay in the transportation system curtails economic growth, hampering competitiveness both in the internal and external markets

Deterioration of Brazil's transportation network in the last years contributed to high operational costs, obstructing the competitive integration of the country

... hampering competitiveness both in the internal and external markets

Estimated Soybean Export Costs
(US$/metric ton; 1st quarter 2006)

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

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

Source: U.S. Department of Agriculture, Brazil Soybean Transportation, Aug. 2006 (*apud World Bank, 2006)*

There were recent government initiatives in Brazil to promote investments in infrastructure…

Programa de Aceleração do Crescimento (PAC), unveiled at the end of January 2007

- Investments in logistic infrastructure are estimated in USD 58.3 billions in the four-year period 2007-2010, USD 33.4 billions (57.3% of the total) only in road infrastructure

Projeto Piloto de Investimento (PPI)

- Allows the government to reduce the primary surplus by an equivalent amount to an increase in infrastructure expenditure

Plano Nacional de Logística e Transportes (PNLT)

- Federal government has also signaled its intention in reviving long term planning in transportation in the country

At the state level, few initiatives have taken place in the realm of transport planning ("*Pelts*")

... whose *ex ante* impacts needed to be properly assessed

There is a growing need for economic and socio-economic models for helping improving road management (World Road Association, 2003, p. 7)

In a context where the public administrations experience a stronger and stronger demand on social policy, and where road budgets tend to be tightened or even scaled back, the economic evaluation – and optimization – of road investment actions and/or policy becomes a recurrent requirement

This exercise provides an attempt to meet this requirement

Multimodal Traffic Volumes, 2007

Source: PNLT

Levels of Service – Brazilian Road Network, 2007 (volume/capacity)

Source: PNLT

The B-MARIA-MG model has been developed for assessing regional impacts of transportation policies

Starting point: B-MARIA (Haddad, 1999) and its extensions

- Well documented
- Critical reviews
- Various applications

Need to undertake structural modifications to achieve the goal of this paper

- Haddad and Hewings (QREF, 2005)

Mainly developed for the *Pelt Minas*

General features of the model

Interstate bottom-up CGE model for Brazil, with **focus on Minas Gerais**

- 109 regions (75 within MG)
- 8 sectors/goods

Interregional flows of goods and services

Interregional factor mobility

Explicit modeling of transportation costs based on origin-destination pairs

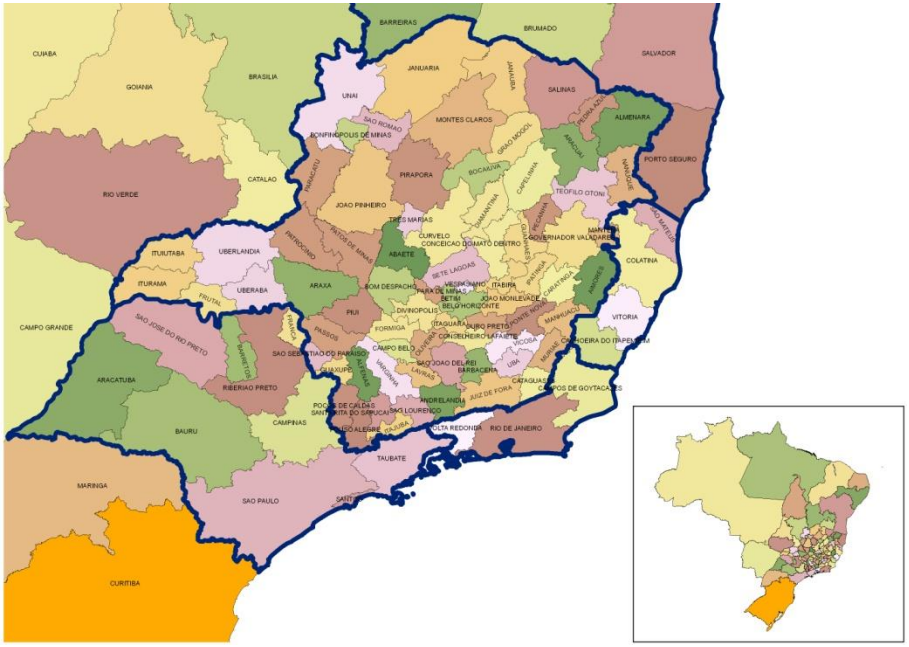
Integrated with a geo-coded transportation model (**HDM-4**)

Regional and Federal government

Regional labor markets

Non-constant returns to scale (agglomeration economies)

Regional and sectoral settings in B-MARIA-MG



Regional setting

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

Sectoral aggregation

Transportation services use scarce resources from the economy

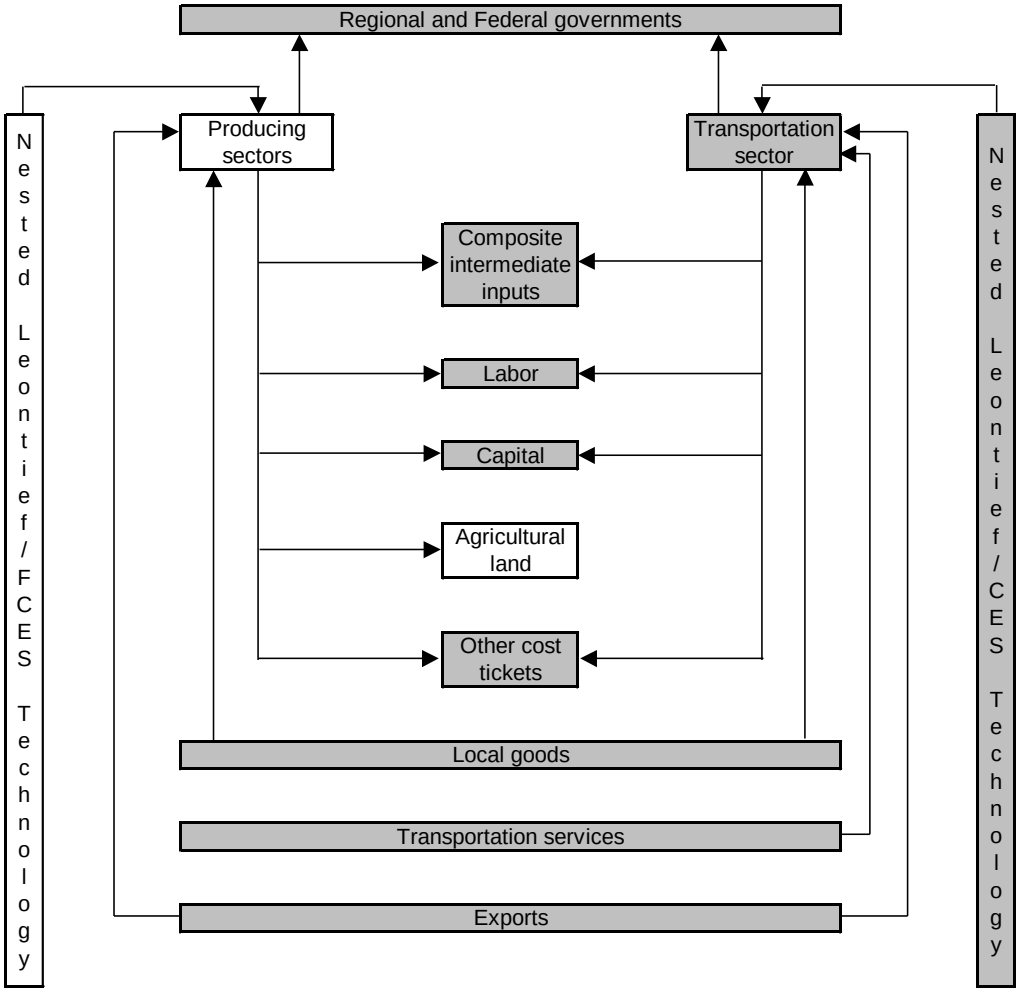
In B-MARIA-MG, transportation services are produced by a regional resource-demanding optimizing transportation sector

A fully specified production possibility frontier (PPF) has to be introduced for the transportation sector, which produces goods consumed directly by users and consumed to facilitate trade, i.e. transportation services are used to ship commodities from the point of production to the point of consumption

The model is calibrated by taking into account the specific transportation structure cost of each commodity flow, providing spatial price differentiation, which indirectly addresses the issue related to regional transportation infrastructure efficiency

Space plays a major role

Regional production technology in B-MARIA-MG: highlighting the transportation sector



Innovation: modeling integration to HDM-4

Prices paid for commodity *i* from region *s* in region *q* by each user equate to the sum of its basic value and the costs of the relevant taxes and margin-commodities

The role of margin-commodities is to facilitate flows of commodities from points of production or points of entry to either domestic users or ports of exit

Margin-commodities, or, simply, margins, include transportation and trade services, which take account of transfer costs in a broad sense

The margin demand equations show that the demands for margins are proportional to the commodity flows with which the margins are associated; moreover, a technical change component is also included in the specification in order to allow for changes in the implicit transportation rate

In the case of imported goods, the implicit transportation margin refers to the costs at the port of entry, while for exports it refers to costs at the port of exit

Demand for transport services

The general functional form used for the equations of margin demand, for different users, is presented below

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

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

Linkage variables

The explicit modeling of transportation costs, based on origin-destination flows, which takes into account the spatial structure of the Brazilian economy, creates the capability of integrating the interstate CGE model with a geo-coded transportation network model, enhancing the potential of the framework in understanding the role of infrastructure on regional development

Two options for integration are available, using the linearized version of the model, in which equation (1) becomes:

$$xmarg(i,s,q,r) = amarg(i,s,q,r) + \theta(i,s,q,r) * x(i,s,q)$$

Considering a fully specified geo-coded transportation network, one can simulate changes in the system, which might affect relative accessibility (e.g. road improvements, investments in new highways).

A matrix of interregional transport cost can be calculated *ex ante* and *ex post*, and mapped to the interregional CGE model. This mapping includes two stages, one associated with the calibration phase, and another with the simulation.

Matrix of interregional transport costs estimated…

Data on the Brazilian network were obtained from the database developed for the PELT Minas (Fipe, 2007)

This data set, in the form used in this research, includes not only the highway network, but also railroad network and other modes of lesser importance for Minas Gerais, enabling the examination of **multimodal alternatives**

All data manipulation and network calculations were carried out using the general and the transport planning modules of the TransCAD software (Caliper, 2000)

Motorized vehicle speeds and operating resources are determined as functions of the characteristics of each type of vehicle and the geometry, surface type and current condition of the road, under both free flow and congested traffic conditions.

... under a multimodal perspective (HDM-4)

Railroad costs used in this study are based on actual freight values charged by operators

Thus, transport costs for each origin-destination pair were initially calculated by specific transport mode, in BRL/ton.

Following that, these costs were weighted by the tonnage use in each transport mode, providing the necessary information for calibration of the model

Calibration procedure takes into account...

The process of calibration of the B-MARIA-MG model requires information on the transport margins related to each commodity flow

Aggregated information for margins on intersectoral transactions, capital creation, household consumption, and exports are available at the national level

The problem remains to disaggregate this information considering previous spatial disaggregation of commodity flows in the generation of the interregional input-output accounts, and the further available information – transport model, matrix of weighted multimodal transport costs, and national aggregates for specific margins

... key elements of the Brazilian interregional economic system

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

a) the type of trade involved (margins vary according to specific commodity flows);

b) the multimodal transportation network; and

c) scale effects in transportation, in the form of long-haul economies.

Simulation strategy

Changes in the matrix of interregional transport costs are calculated in the transport model, so that an interface with the interregional CGE model is created

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

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

With θ equal to one implying that the left-hand-side is equivalent to the specific margin rate. A percentage change in the margin rate can then be mapped into the technology variable. Thus, in percentage-change form, amarg(i,s,q,r) becomes the relevant linkage variables!

We illustrate the analytical capability of the unified framework...

The case study under consideration refers to two projects of improvement of federal highways – BR-262 and BR-381 – in the State of Minas Gerais

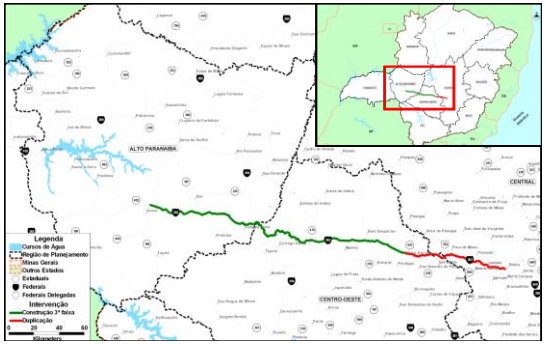
The following analysis suggests a strategy of application of the framework developed here for the evaluation of a project in a systemic context, in its **operational phase**

The impacts of the investment phase are not considered in these illustrative exercises

The guidelines that have been used to justify the choice of these specific tracks of the BR-262 and BR-381 highways to be improved are based upon the grounds of the **strategic location of this network links in the national transportation system**, which constitute two of the main corridors related to the more dynamic regions of the country.

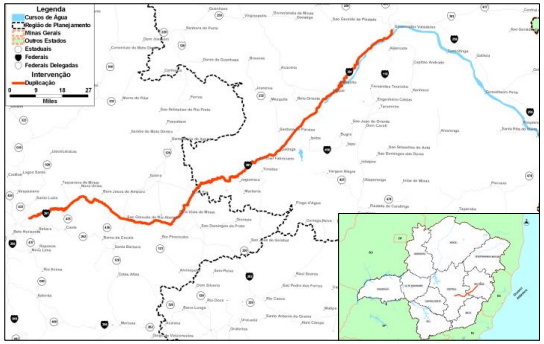
... in the evaluation of specific transportation projects contemplated in the PAC program

BR-262



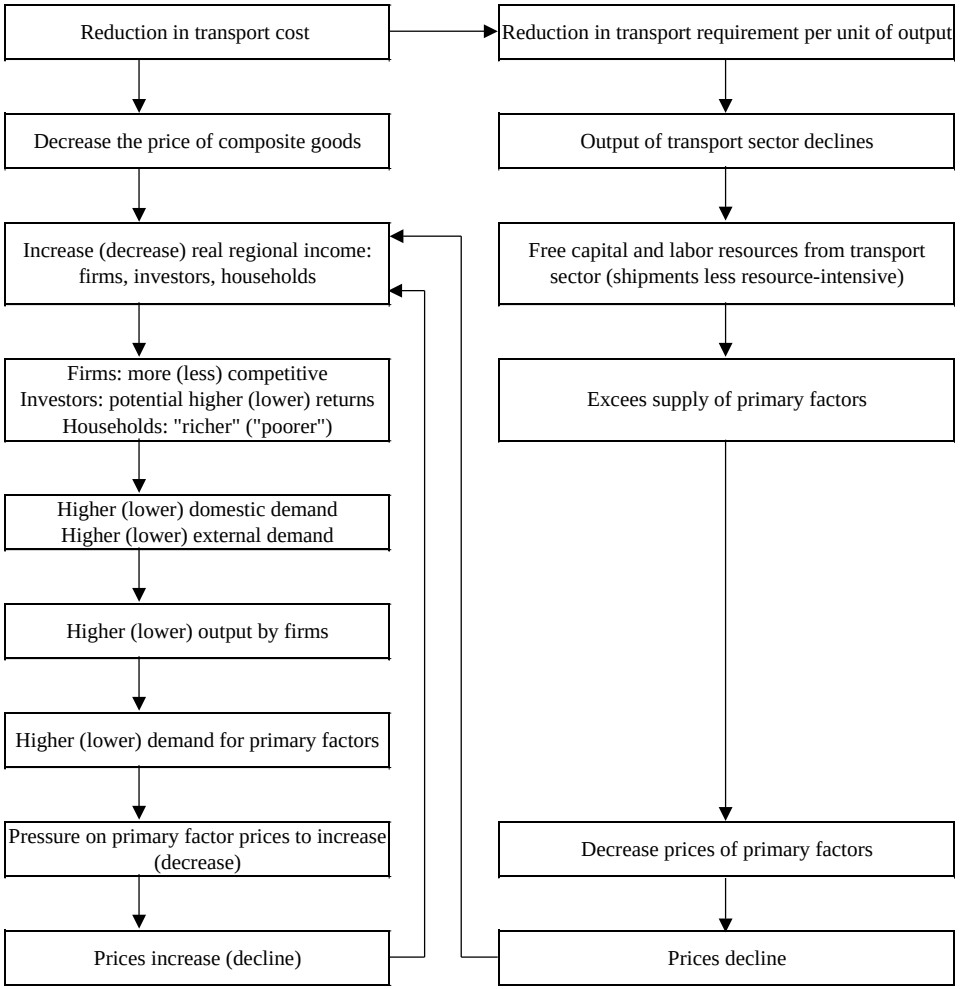
- ✓ Total length: 441 km
- ✓ Total costs: BRL 554 millions
- ✓ Duplication of the existing road link between Betim and Nova Serrana, and the construction of climbing and passing lanes between Nova Serrana and Araxá
- ✓ The BR-262 project constitutes a major improvement on the **east-west integration of the country**, linking the coast of the Southeast to the more agricultural areas of the Midwest
- ✓ Spatial competition occurs in a lower degree
- ✓ More specialized spaces

BR-381

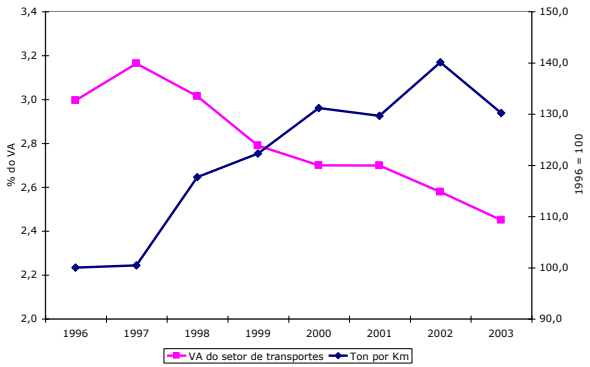


- ✓ Total length: 304 km
- ✓ Total costs: BRL 1,395 millions
- ✓ Duplication of the track between Belo Horizonte and Governador Valadares
- ✓ The BR-381 project has a strategic role in the **integration of the Northeast with the Southeast and South** of the country
- ✓ Spatial competition occurs in a higher degree
- ✓ Denser economic spaces are directly involved in the spatial process

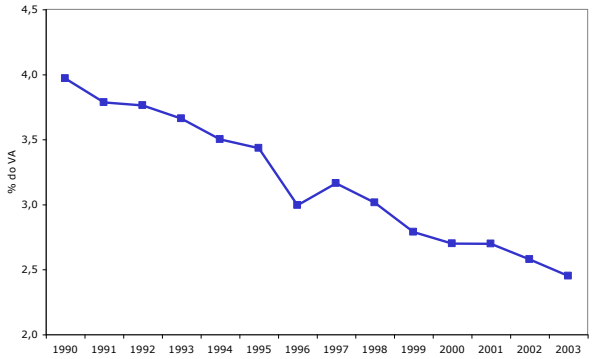
Functioning mechanisms of the simulations



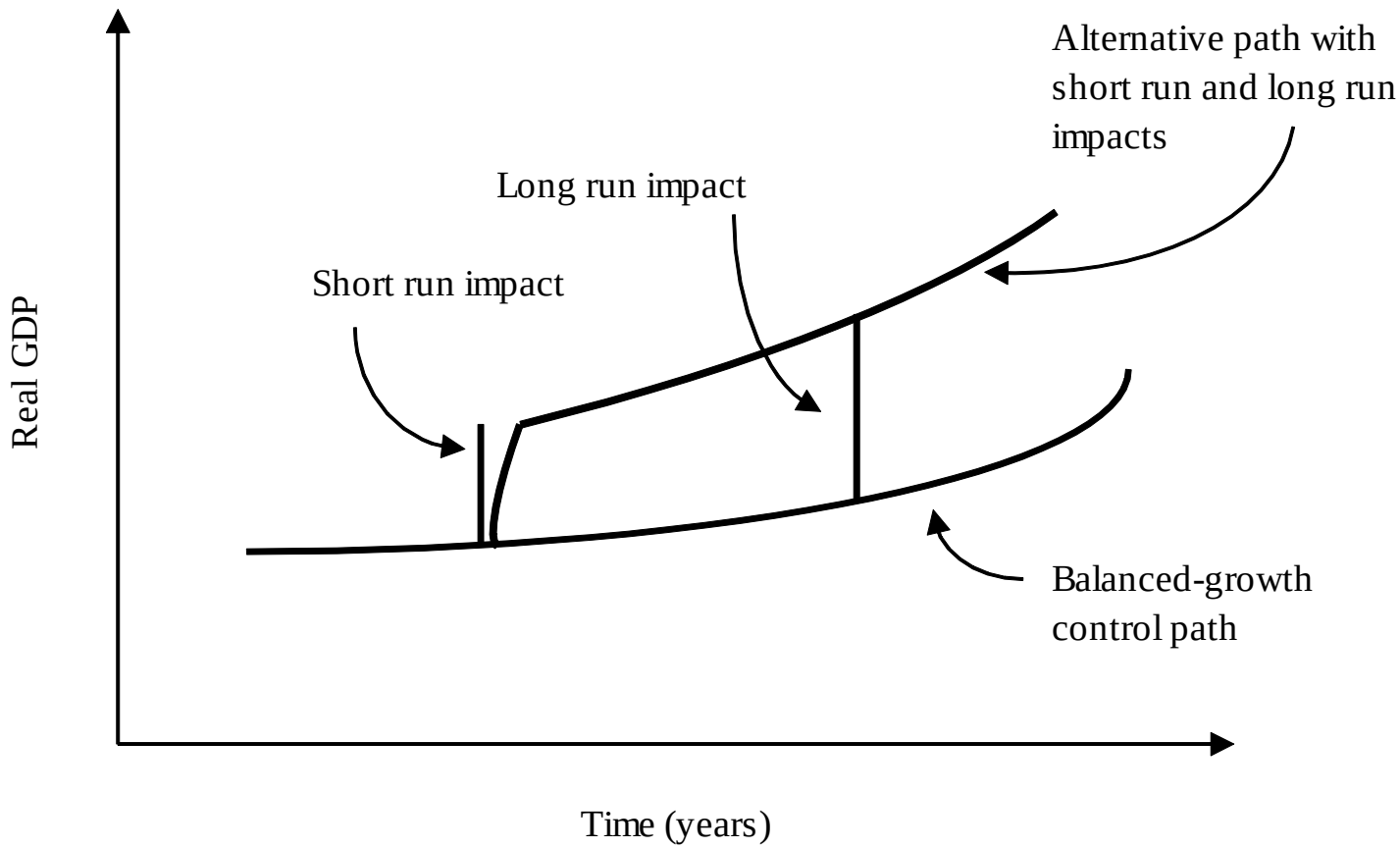
Recent evolution of transport sector



Share of transport sector in VA



Conventional multi-period modeling



Aggregate results

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

What do the aggregate results tell us? – BR-262

Gains in efficiency (real GDP growth) are positive in both the short run and the long run, while welfare gains (equivalent variation) are revealed only in the long run.

Noteworthy is that in the long run the effects on GDP are magnified.

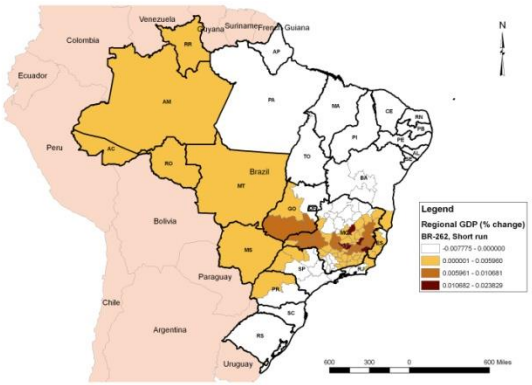
GDP components – BR-262

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

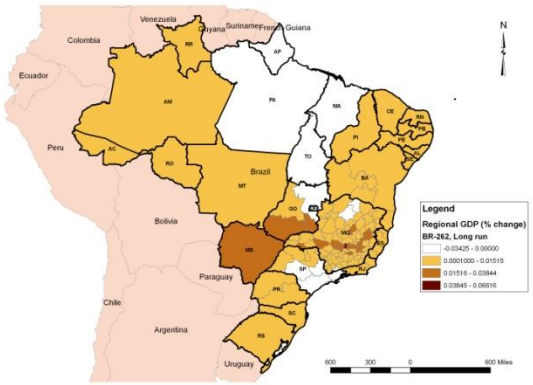
In the **long run**, though, this situation is reversed: while stronger penetration of imported products is verified, due to the reversal of the terms of trade result, domestic absorption becomes the component in chief, leading GDP growth.

Spatial GDP effects – BR-262

Short run



Long run



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

What do the aggregate results tell us? – BR-381

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

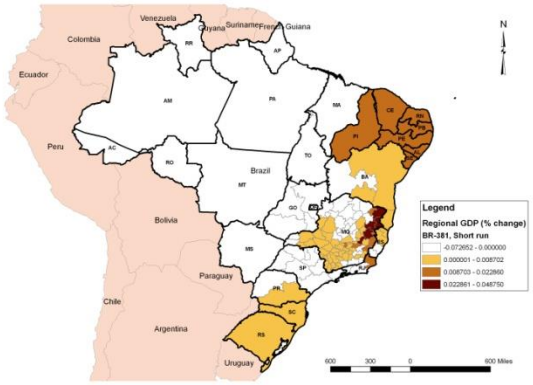
Real GDP in the long run is projected to decrease, after the duplication project starts to operate.

Lower growth with decreasing reginal inequality.

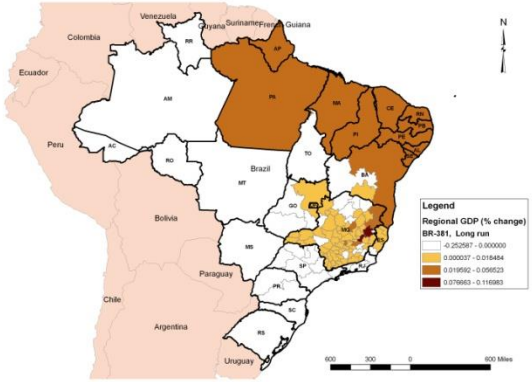
- Localized spillover models (Baldwin *et al*., 2003)

Spatial GDP effects – BR-381

Short run



Long run



There is thus clearly a situation where spatial competition plays a prominent role. Given the favorable scenario for relative production costs in the Northeast, in a given transport infrastructure context of systemic low quality, that region increases its spatial market area, in deterrence of the richer Southeast, which suffers from the network effects.

Final remarks

Isolated projects may promote undesirable outcomes if not considered within a context of a well-specified program of investments.

The integrated nature of transport systems may induce policymakers to achieve mistakes when designing programs without sound knowledge of this property.

How about different levels of government?

- Policymakers in Minas Gerais may have special interests in such projects, given their strategic role in the state transport network.

State results – Minas Gerais

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

What do the State results tell us?

Common patterns appear related to aggregate effects of both projects with Minas Gerais.

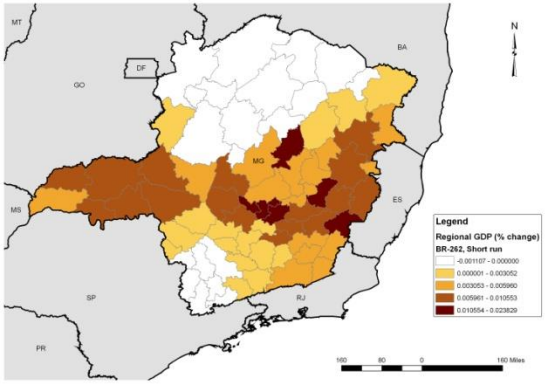
In general, positive outcomes are stronger in the BR-262 project than in the BR-381 project. However, **they go in the same direction for most of the indicators**.

- Overall, gains in **efficiency** (real GDP growth) are positive, with bigger impacts occurring in the long run.
- **Real tax revenue** also follows the same pattern.
- **Competitiveness indicators** suggest improvements in the terms of trade with other countries, and a reduction in the *Custo Minas* – measured in terms of the state GDP deflator.
- Both projects are **pro-concentration**, but it happens to a lesser degree in the BR-381 project.
- Both projects are also **pro-poor**, projecting reductions in the headcount poverty index for the State of Minas Gerais.

Spatial GDP effects – Minas Gerais

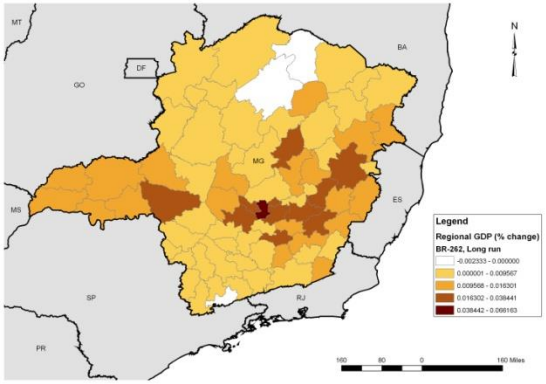
Short run

BR-262



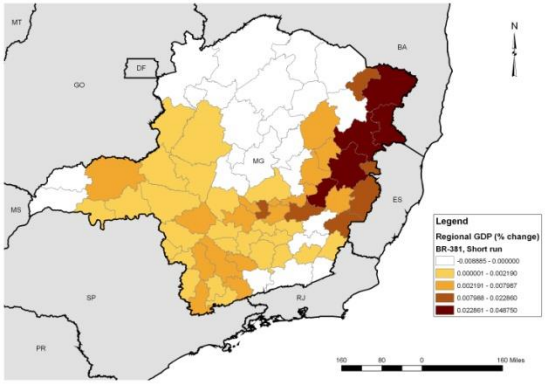
Long run

BR-262



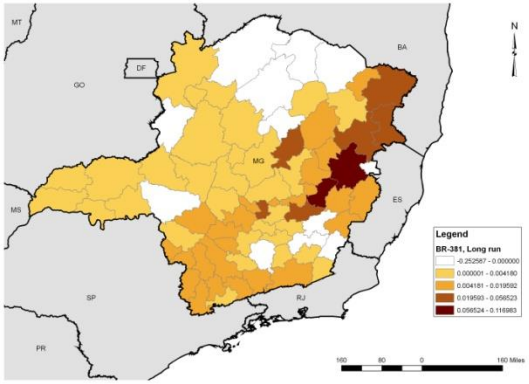
Short run

BR-381



Long run

BR-381



Overall, the stronger effects on the areas of influence of the projects are clearly perceived. Moreover, these effects tend to spread over time, as suggested by the smaller number of regions presenting negative performance in the long run.

PELT Minas

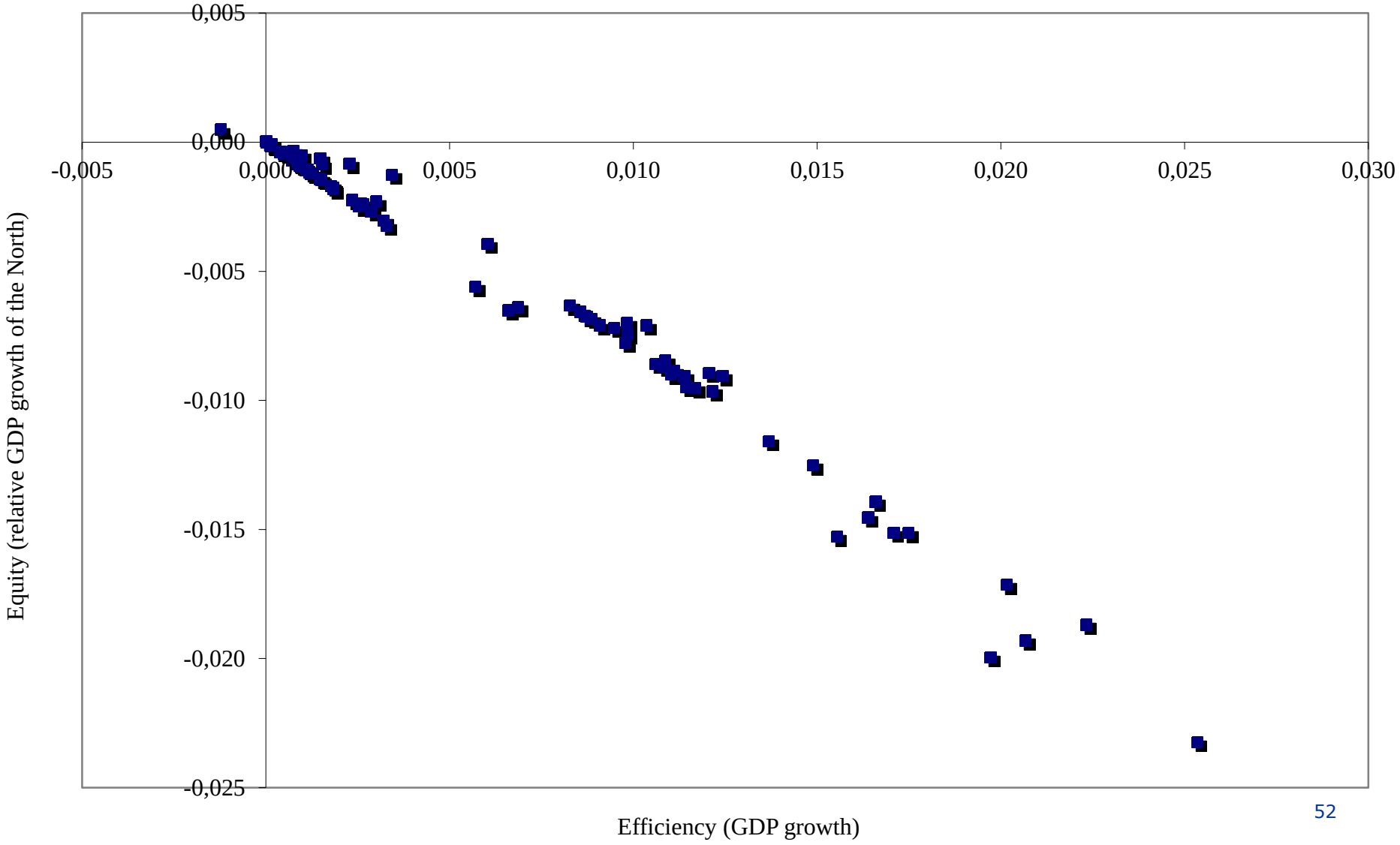
The *Plano Estadual de Logística e Transportes* (PELT Minas) included **75 projects**: three are three investments in waterways, five in railways, three in pipelines, and 64 in roads.

Effects on **efficiency** (measured in terms of real gross regional product growth) and **regional disparity** (measured in terms of the relative growth of the poor regions in the north of the state and the state as a whole; a negative value indicates that the poor region is growing at a slower pace).

The results reflect a long-run environment in which the equilibrating mechanisms draw heavily on the balance of real wage differentials through labor mobility.

There is a clear tradeoff between efficiency and regional equity. Projects that produce higher impacts on GDP growth also contribute more to regional concentration.

Regional Equity-Efficiency Tradeoff of Transportation Infrastructure Investments in Minas Gerais, Brazil



Reaching the planners – hierarchical project analysis

	WEIGHTS		WEIGHTS		WEIGHTS		WEIGHTS
SOCIOECONOMIC	A	SUBSTANTIVE	A1	AGGREGATES	A11	GDP	A111
						Employment	A112
						Tax revenue	A113
						SUM	1,00
				RETURNS	A12	GDP	A121
						Employment	A122
						Tax revenue	A123
						SUM	1,00
				SUM	1,00		
		ACCESSORIES	A2			Trade balance	A21
						Regional competitiveness	A22
						Cost of living	A23
						Regional concentration	A24
						Urban concentration	A25
						Consumption	A26
						Welfare	A27
						SUM	1,00
		TARGETING	A3			Region 1	A31
						Region 2	A32
						Region 3	A33
						Manufacturing	A34
						SUM	1,00
		SUM	1,00				
TRANSPORT SYSTEM	B					Average speed	B1
						Operational cost	B2
						Average cost	B3
						SUM	1,00
SUM	1,00						