

**NEREUS**

Núcleo de Economia Regional e Urbana  
da Universidade de São Paulo

The University of São Paulo  
Regional and Urban Economics Lab

---

## Lecture 17: Urban Infrastructure

Prof. Eduardo A. Haddad

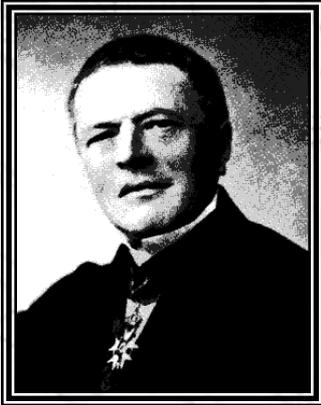
---

What if the São Paulo subway system did not exist? ("*tau question*")

---

What if the government decided to build an inter-municipal bus corridor in the São Paulo Metropolitan Area?





## Antoine Augustin **Cournot**, 1801-1877

“So far we have studied how, for each commodity by itself, the law of demand in connection with the conditions of production of that commodity, determines the price of it and regulates the incomes of its producers. We considered as given and invariable the prices of other commodities and the incomes of other producers; **but in reality the economic system is a whole of which all the parts are connected and react on each other.** An increase in the income of the producers of commodity *A* will affect the demand for commodities *B*, *C*, etc., and the incomes of their producers, and, by its reaction, will involve a change in the demand for commodity *A*. **It seems, therefore, as if, for a complete and rigorous solution of the problems relative to some parts of the economic system, it were indispensable to take the entire system into consideration. But this would surpass the powers of mathematical analysis and of our practical methods of calculation, even if the values of all the constants could be assigned to them numerically.”**

*Cournot, Researches into the Mathematical Principles of the Theory of Wealth (1838), translated by Nathaniel T. Bacon (New York, 1929), p. 127.*

# Cournot's Problem

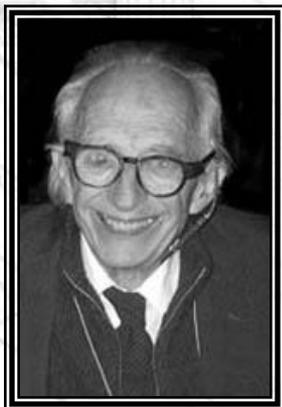
---

Friedman (1955) highlighted the task Cournot (1838) had outlined in his *Researches* as the proper way of dealing with the interrelationships in an economic system.

The development of economic analysis of **concrete problems** should pursue a 'general equilibrium' framework.

Cournot recognized that the existing **mathematical, statistical and computational** benchmarks, at the time of his writings, were far from sufficient for approaching the problem in a general equilibrium context.





## Walter **Isard**, 1919-2010

“The recognition of the **spatial element** in the formation of a general equilibrium in a complex space-economy already dates back to early work of Lösch, **Isard** and Samuelson (...)”

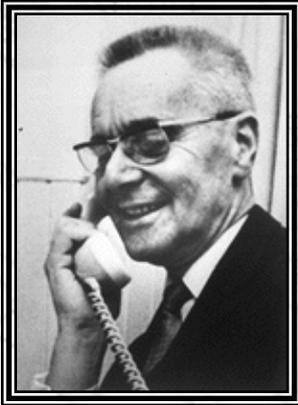
*Van den Bergh et al. (Eds), Recent Advances in Spatial Equilibrium Modelling (1996), Springer-Verlag (Berlin), p.*

v

“The future will be characterized by computerized, multiregional, complex simulation models that endeavor to unravel the complex tapestry of **interregional interconnectedness.**”

*Isard, Methods of Interregional and Regional Analysis, 1998, p. 397*





## Jan Tinbergen, 1903-1994

“I do think, however, that the utility of models goes beyond their didactic value. **They are a real and essential element in the preparation of well-coordinated policies.** But they cannot do this job all by themselves. Models constitute a framework or a skeleton and the flesh and blood will have to be added by a lot of common sense and knowledge of details. Again, as a framework they can be of vital importance. (...) A need generally felt by model builders and their critics is the need for refinement, that is, for the introduction of many more variables. In a way this experience again was a lesson also to economists in general, since often their arguments run in terms not showing this degree of detail.”

*Tinbergen, Prize Lecture, Lecture to the memory of Alfred Nobel, December 12, 1969*

# From pure theory to applied theory and practice

---

## ***Why build (relatively) complex models?***

Issues are complex; it serves no good purpose to pretend that they are not.

Existing, commonly-used policy tools do not come anywhere close to capturing some of the most important channels through which exogenous and policy shocks are transmitted to location-specific economic agents.

Models are issue-specific; trying to “force” a model to answer questions that it is not designed to address hampers our ability to address relevant policy questions.

# Developing countries: Reach the planner

---

Models are not built only to produce numbers but also to provide qualitative insights (general equilibrium effects).

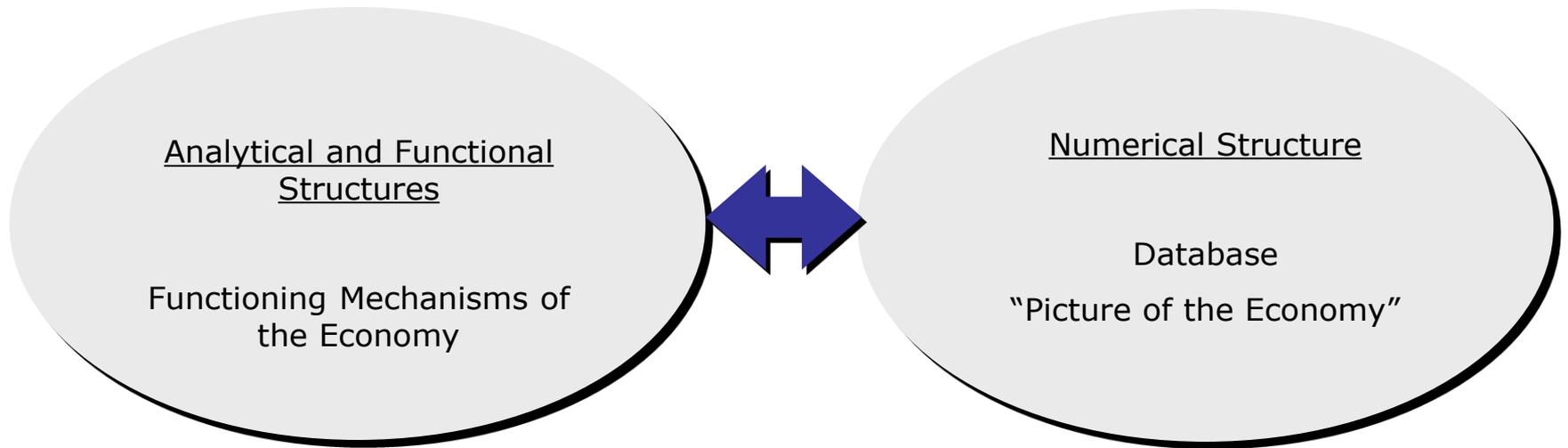
Before looking for “shortcuts”, one needs a conceptual roadmap to understand the costs and benefits of simplification.

Lack of skills is indeed a constraint in many cases; but many middle-income countries, and some low-income countries, have the capacity to implement complex models.

Lack of adequate data: also a problem. But do you wait until the data have improved sufficiently, or do you start with existing data, no matter how imperfect, and improve the database gradually?

# CGE models – Definition

---



# Productivity and the size of cities (Alonso, 1971)

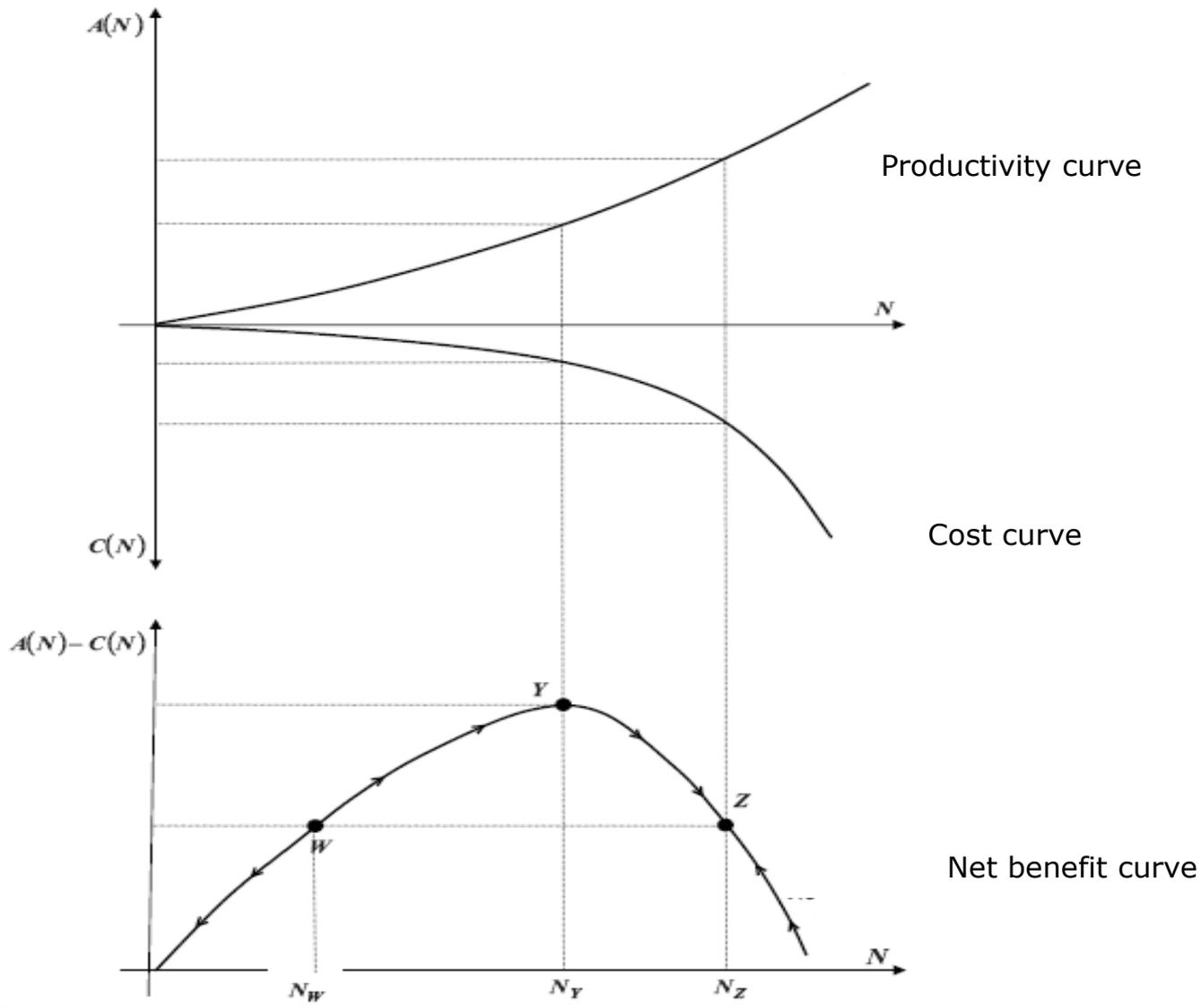
---

Productivity gains are directly associated with long term growth

Agglomerations produce benefits and costs:

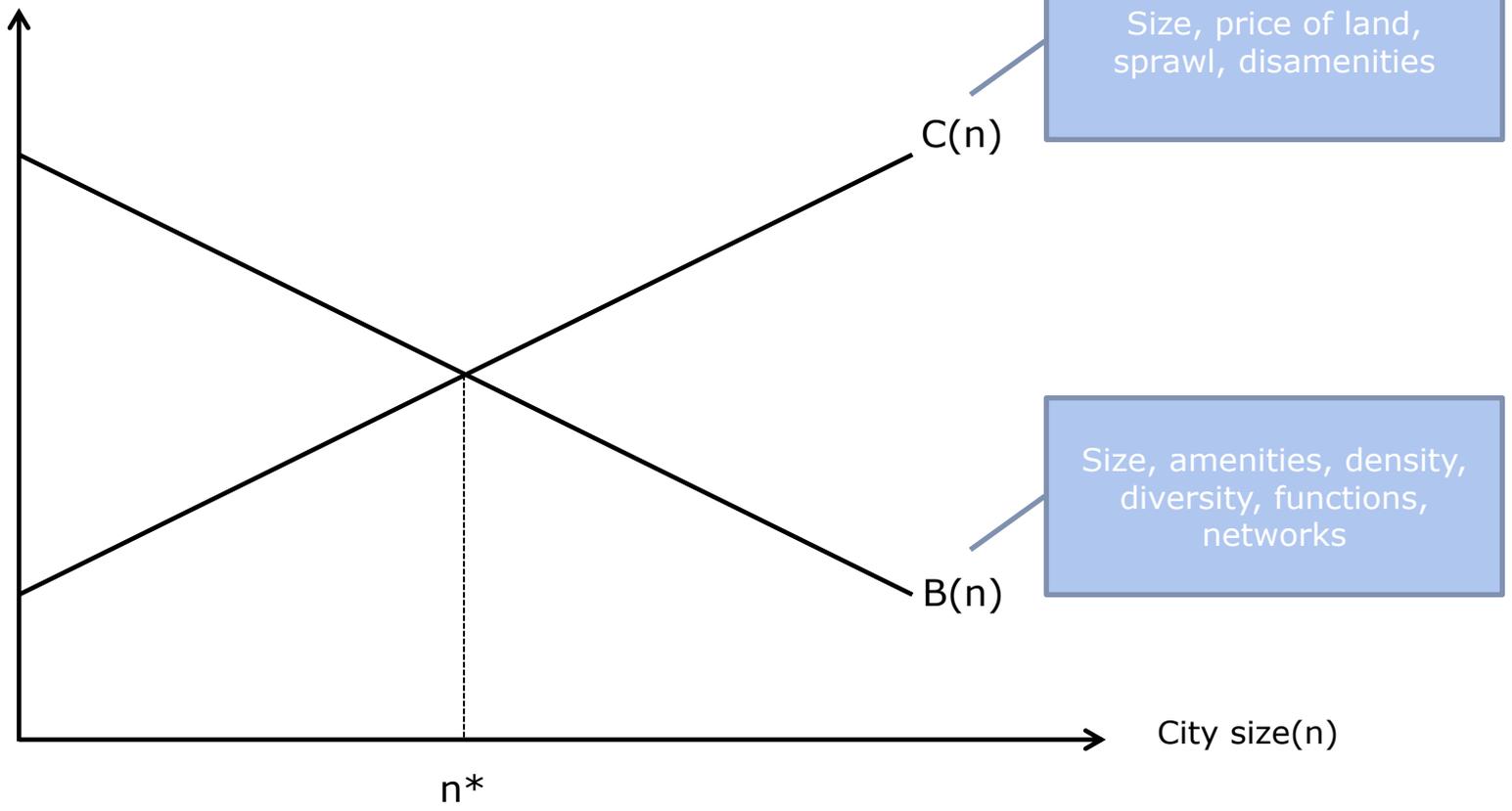
- Benefits and costs increase with the size of the city
- Optimal size of city:
  - Maximum net benefit

# Productivity and the size of cities



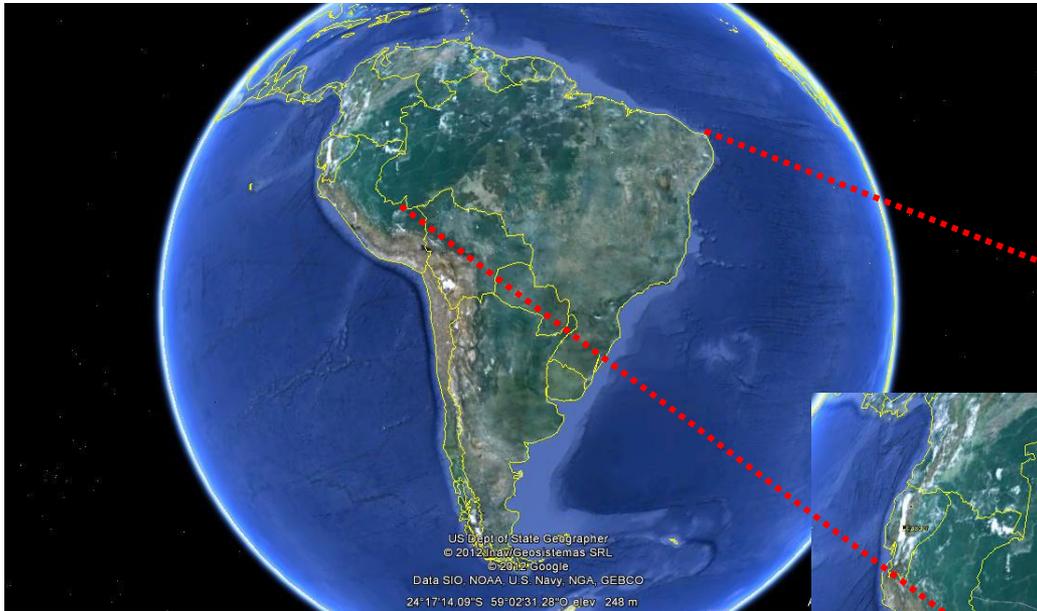
# Productivity and size of cities

Marginal costs and benefits

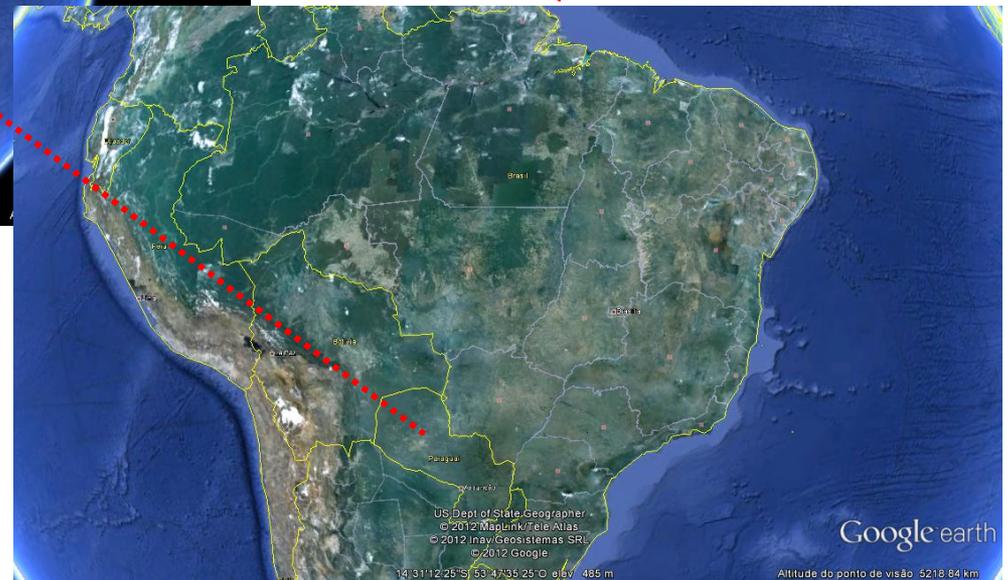


# The City of São Paulo

## South America

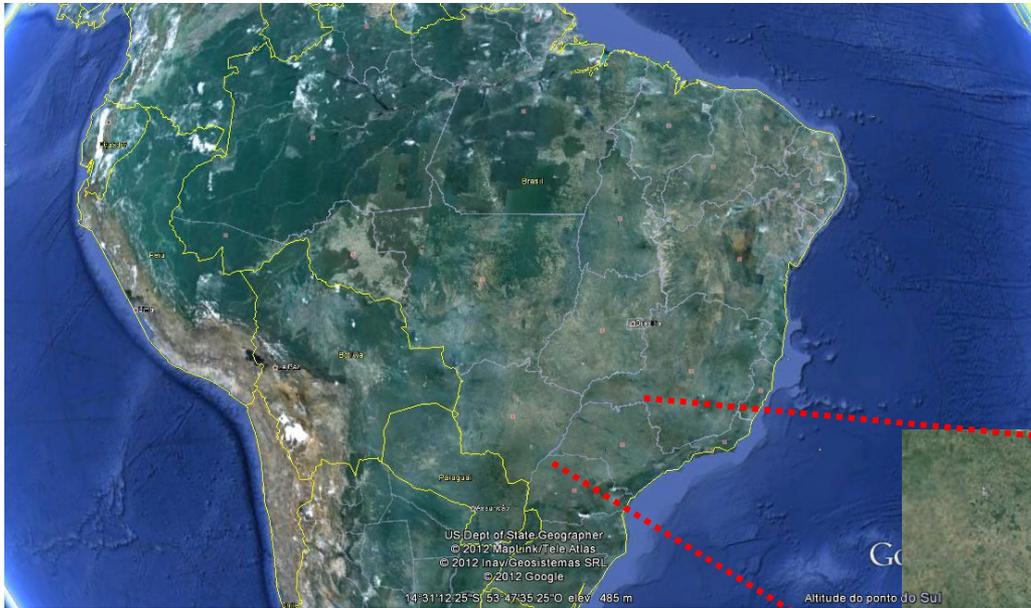


**Brazil**

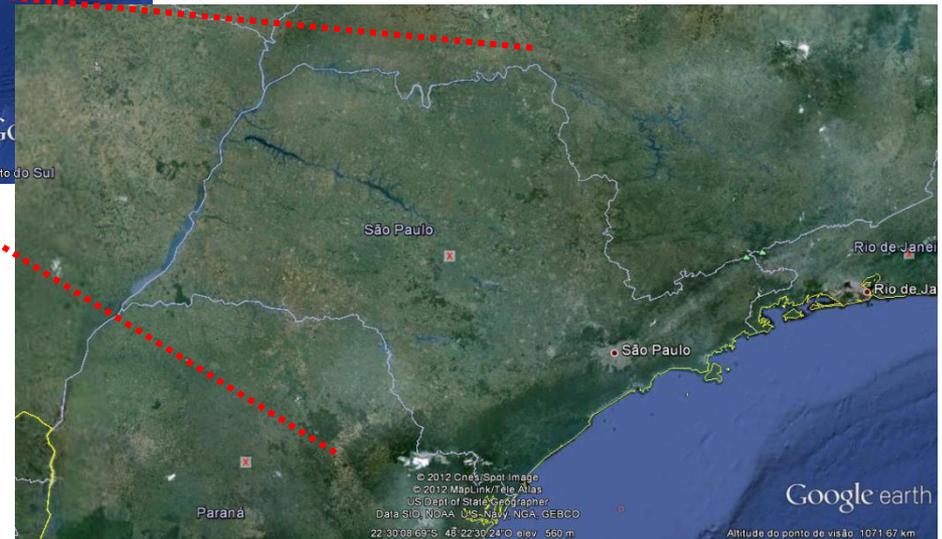


# The City of São Paulo

## Brazil

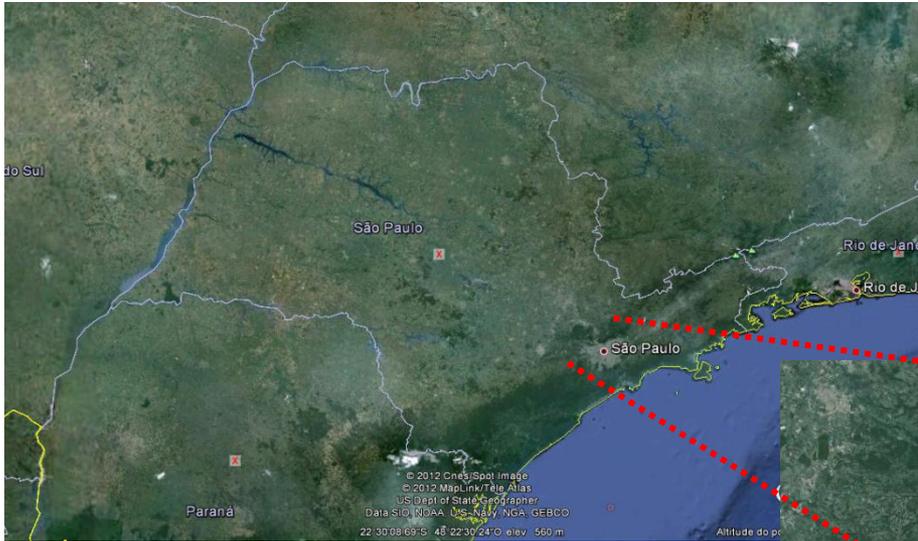


## The state of São Paulo

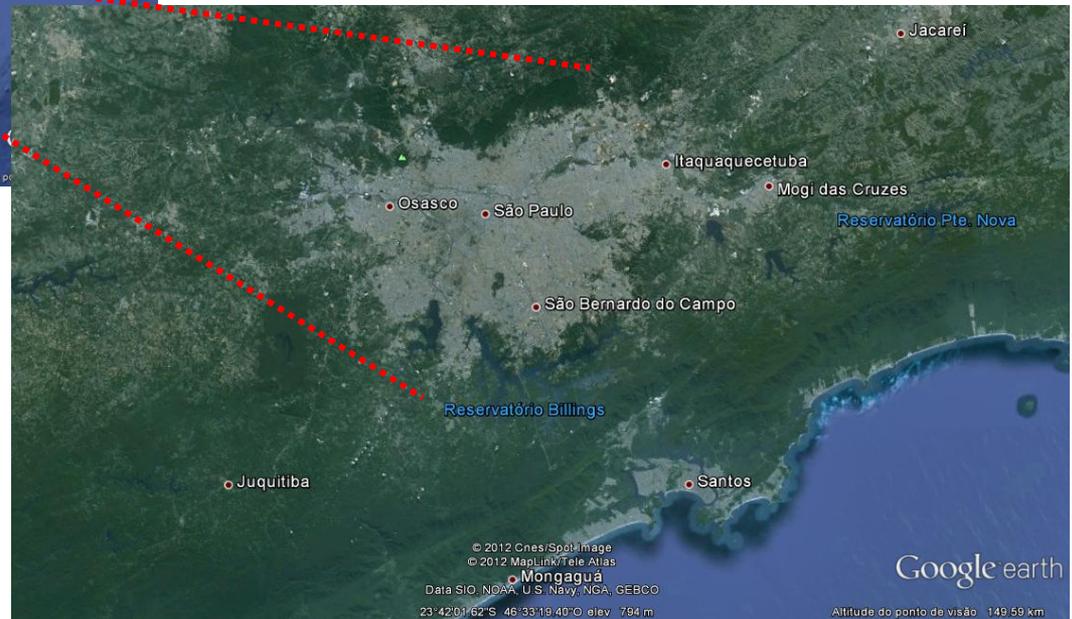


# The City of São Paulo

## The state of São Paulo

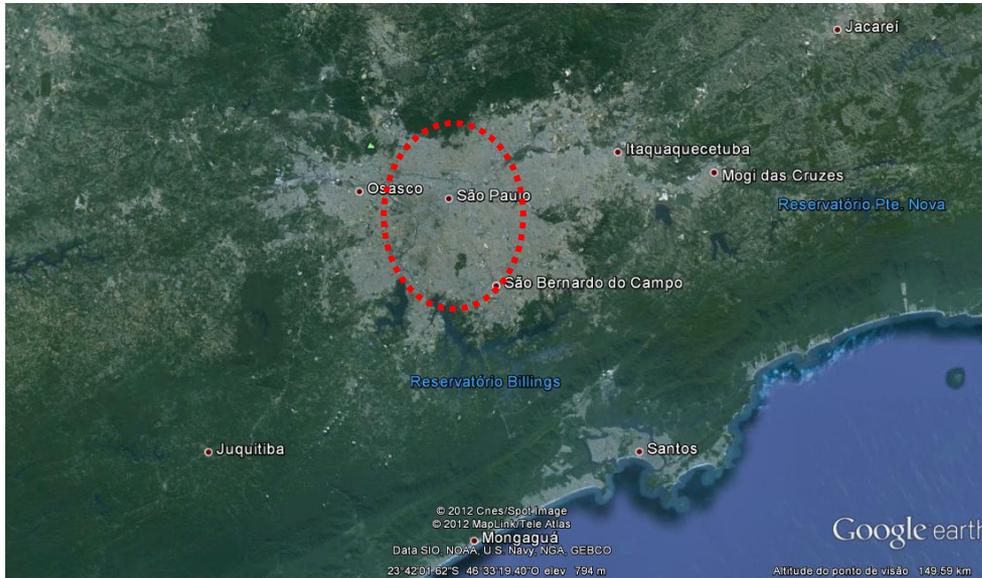


## São Paulo Metropolitan Region

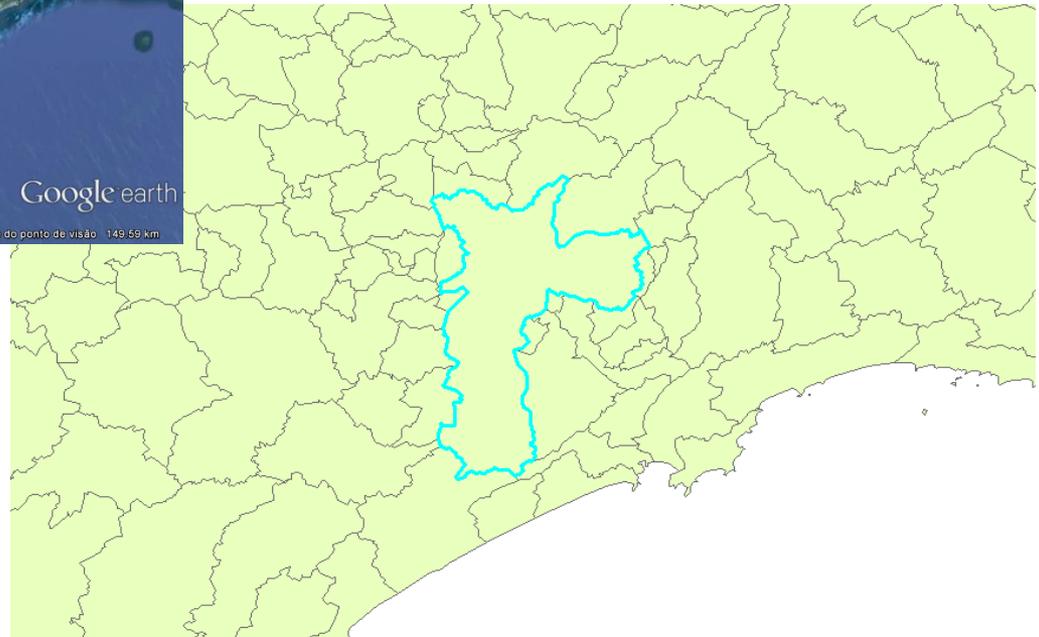


# The City of São Paulo

## São Paulo Metropolitan Region



## The city of São Paulo



# São Paulo Metropolitan Region is the financial and economic center of Brazil

Largest urban agglomeration in the country

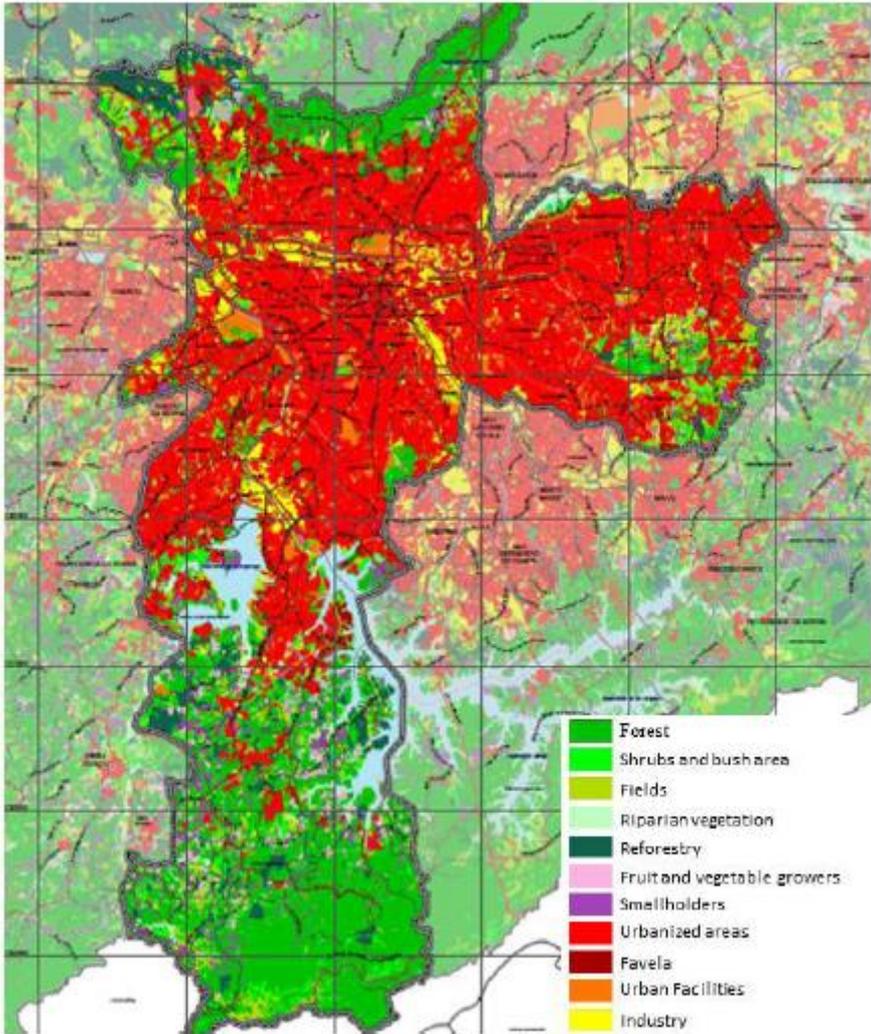
- ✓ 10.3 % of national population (2010)
- ✓ 18.9 % of Brazilian GDP (2009)

The city of São Paulo is the core of the metropolitan area

- ✓ 5.9 % of national population (2010)
- ✓ 12.0 % of Brazilian GDP (2009)

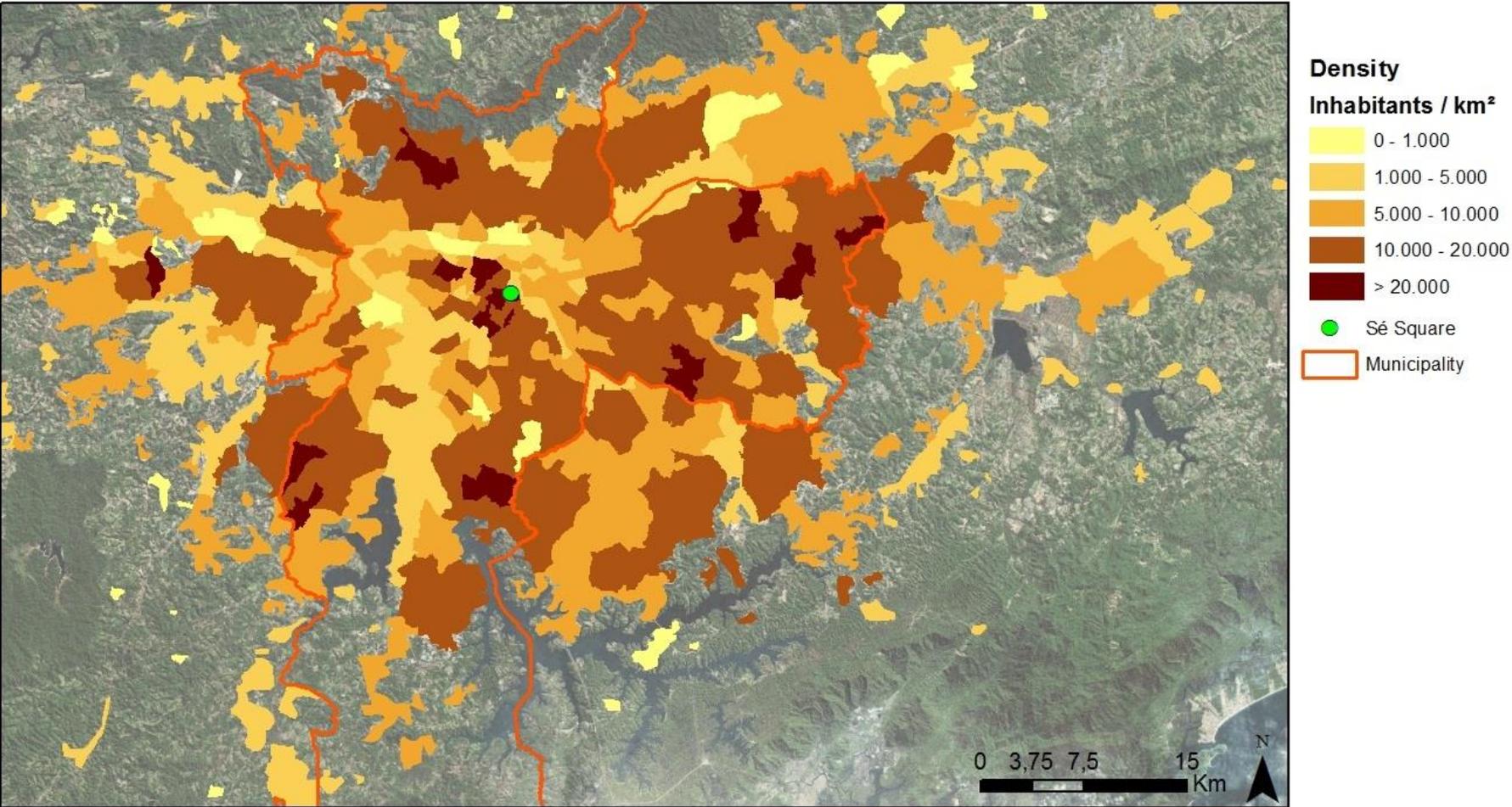
	<i>Area (000 km<sup>2</sup>)</i>	<i>Population (000 000)</i>	<i>GDP (USD billion)</i>	<i>Per capita GDP (USD)</i>	<i>HDI 2000</i>
<i>São Paulo</i>	1.5	11.3	194	17,221	0.841
<i>SPMR</i>	7.9	19.7	306	15,558	0.813
<i>Brazil</i>	8,514.9	190.8	1,619	8,486	0.665
<i>New Jersey</i>	22.6	8.9	487	54,719	-

# Land use

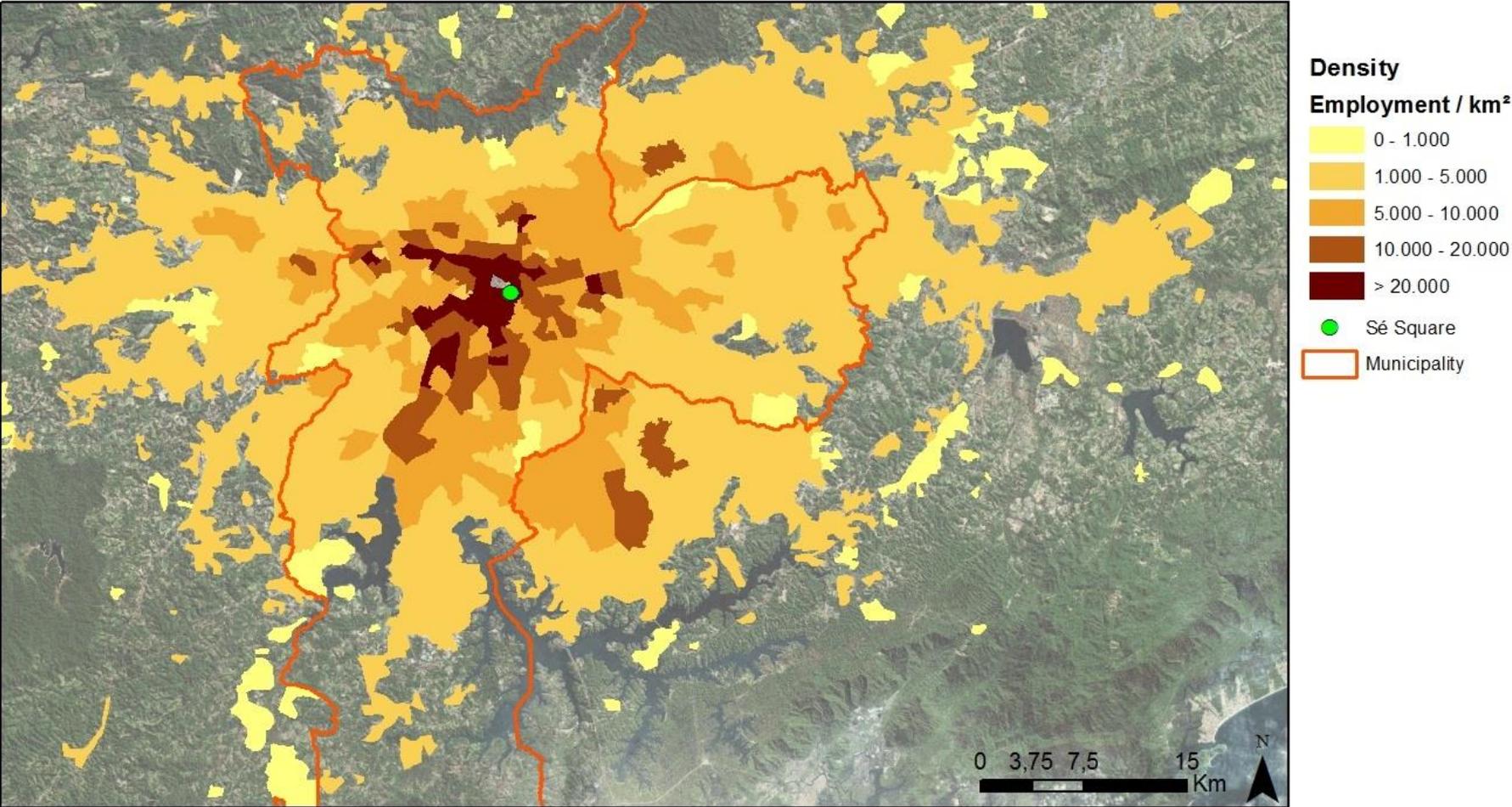


Source: EMPLASA

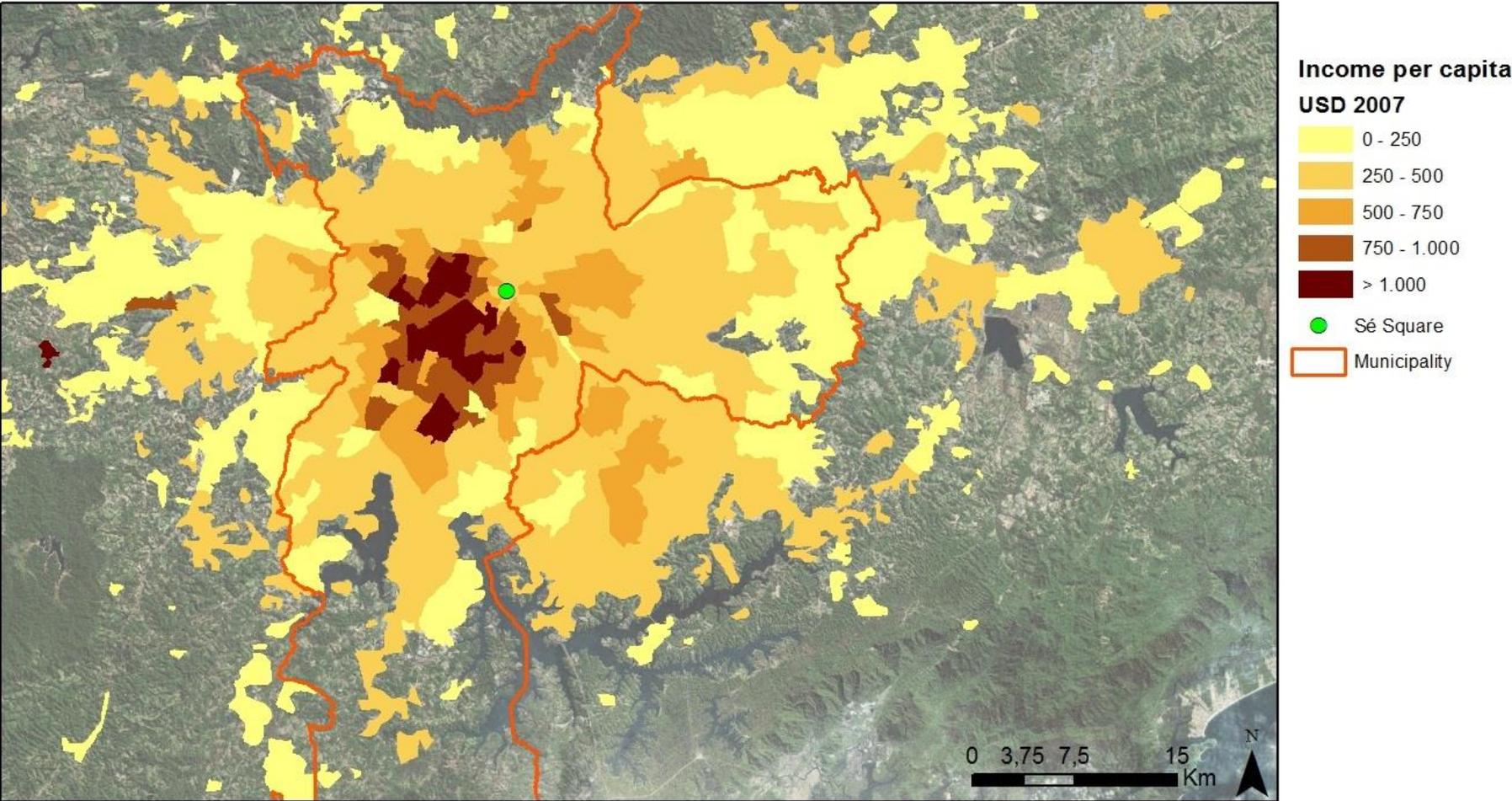
# Where people live



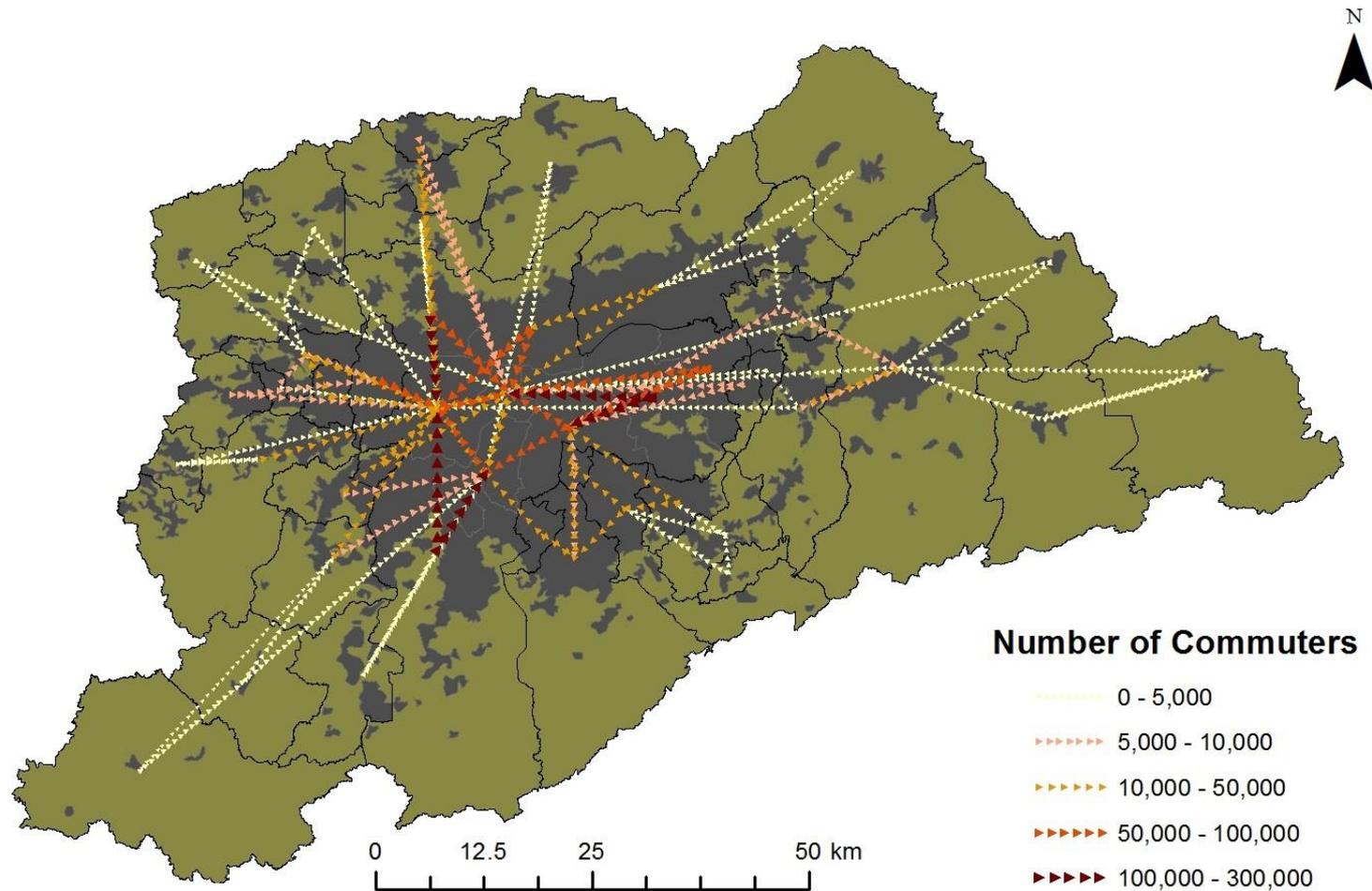
# Where people work



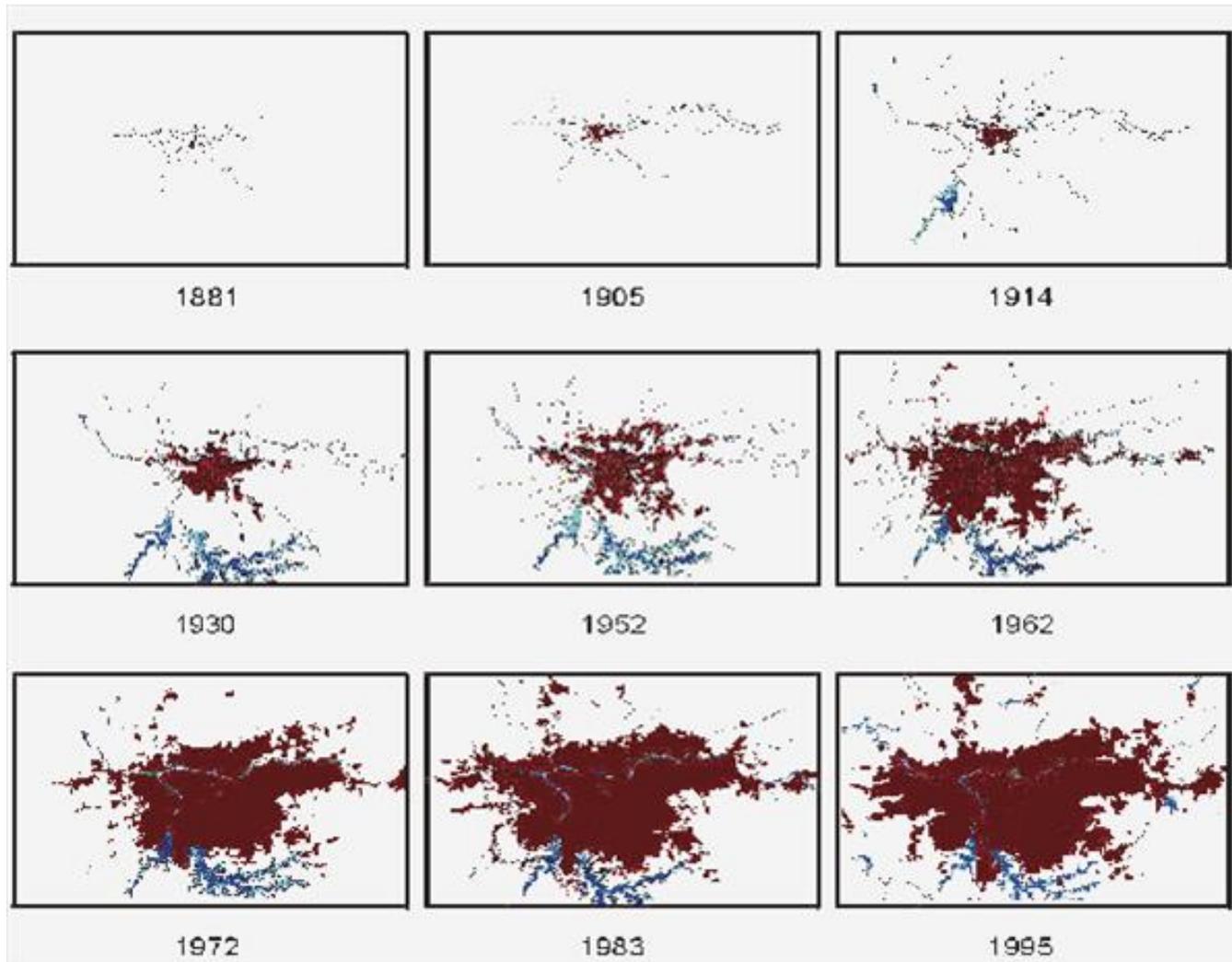
# Where the money is



The city of São Paulo receives daily an inflow of almost one million commuters (15.4% of workers in the city)

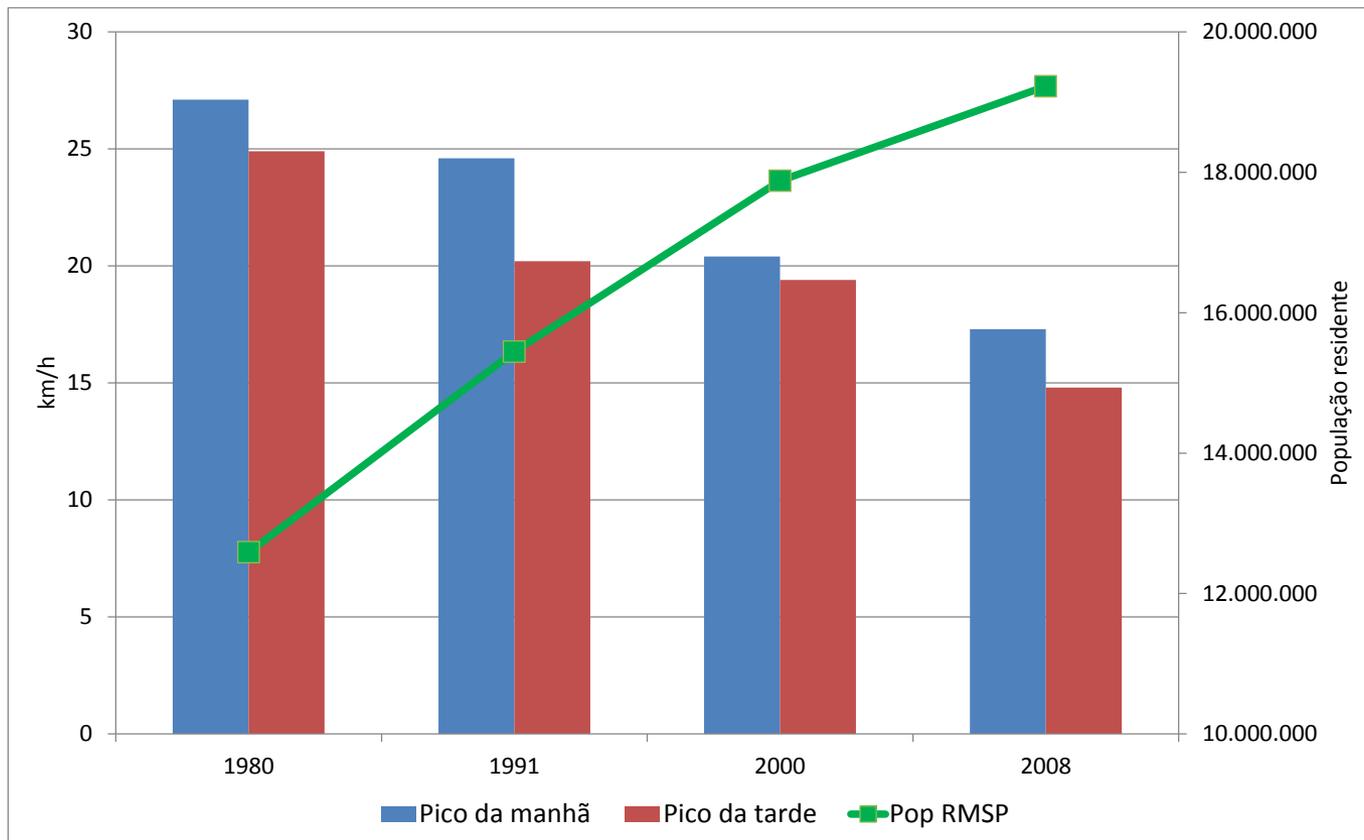


# The rapid process of urban expansion around São Paulo's CBD...



... was not followed by the implementation of adequate public transport infrastructure

**Average speed by motorized vehicles in the City of São Paulo during peak hours (in km/h) versus Population in SPMR**



# São Paulo has undergone a process of deindustrialization since the early 1970s

---

It has transformed from dominance of manufacturing to modern services production

- 44% (1970) to 17% (2003) of manufacturing jobs

It has become more competitive and at the same time more complementary to other regions as a result of hollowing out and fragmentation

- SP hinterland – 14% (1970) to 27% (2003)

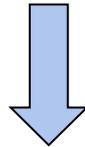
Exchange of self-contained to interdependence

Exploitation of scale economies/cheap transport/love for variety/greater exchange

Integrated analytical approach: need to understand internal organization of cities and systems of cities

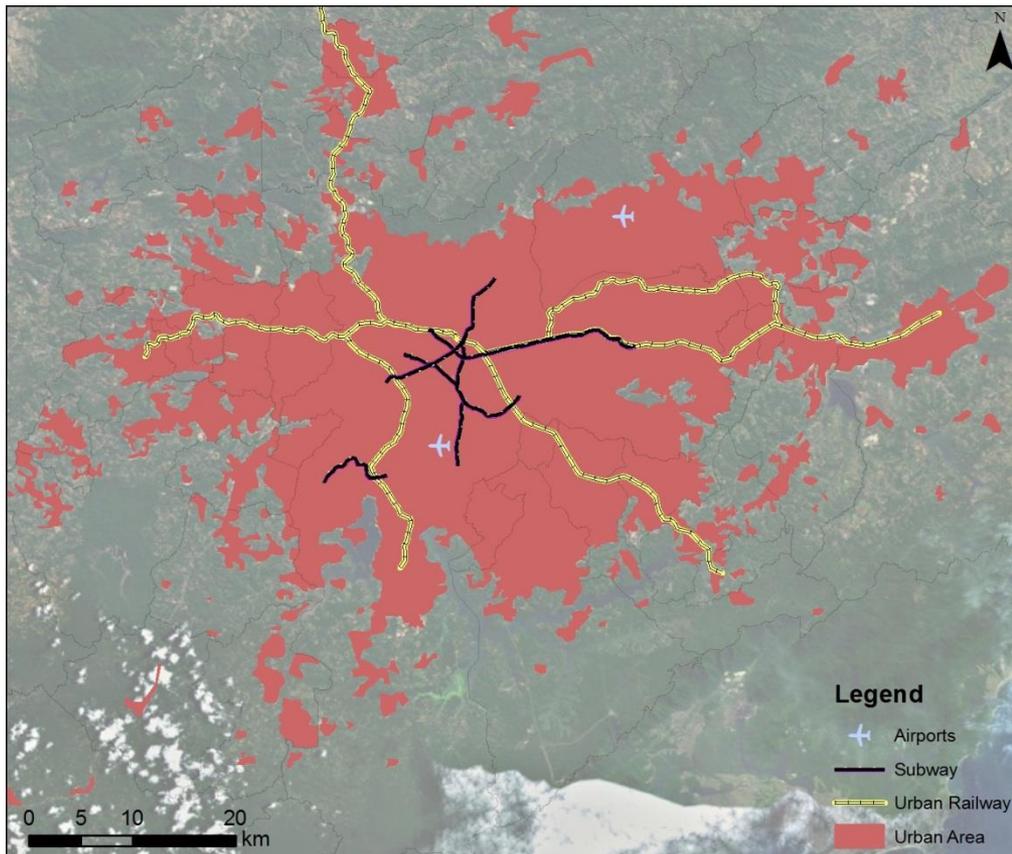
---

What if the government decided to build an inter-municipal bus corridor in the São Paulo Metropolitan Area?



What if the São Paulo subway system did not exist? ("*tau question*")

# The Subway and Railway Systems



Main **rapid-transit system** in the city of São Paulo and the largest in Brazil

**74.3 kilometers** (46.2 miles), distributed into five underground lines with 64 stations

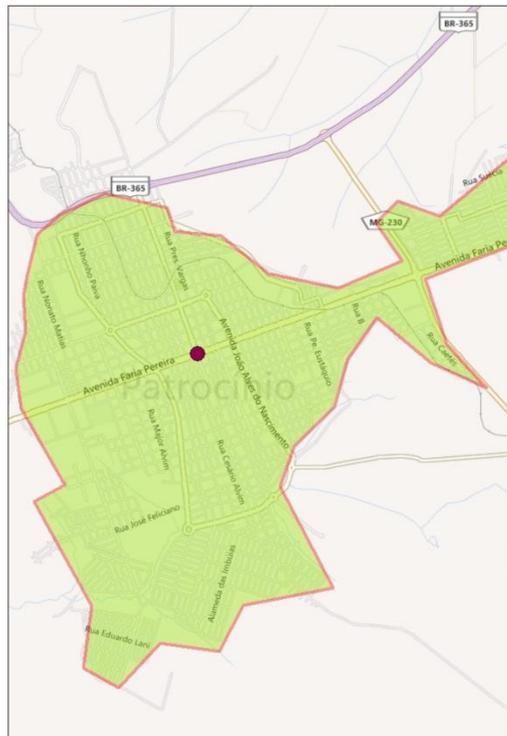
The subway system carries **4,000,000 passengers a day**

It plays an important role in passenger mobility in the SPMR, as the system is **interlinked** with the Sao Paulo Metropolitan Trains Company (CPTM) and **with other modal transportation terminals** in the city of São Paulo

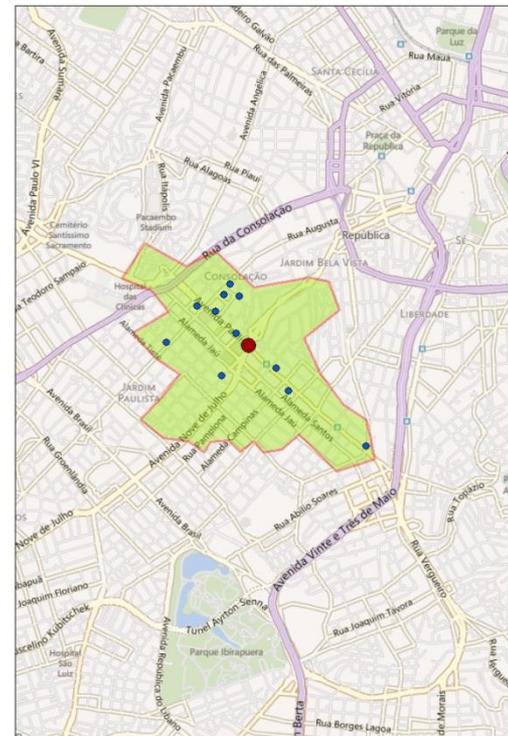
# Mobility X Accessibility

*"Mobility measures the ability to move from one place to another"*

*"Accessibility is defined as the potential of opportunities for interaction."*  
(Hansen, 1959)



Patrocínio - MG



São Paulo - SP

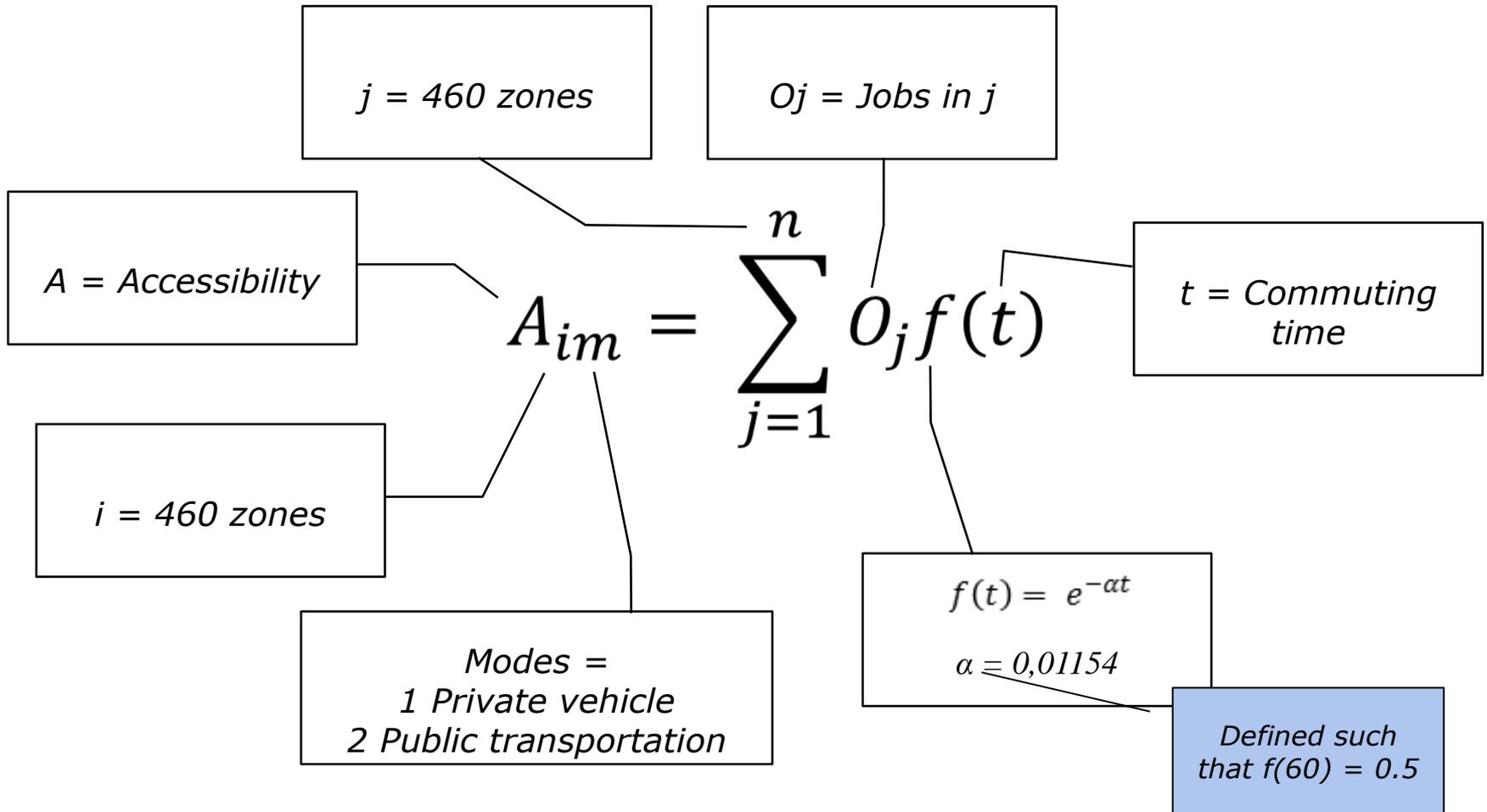
# Mobility X Accessibility

---

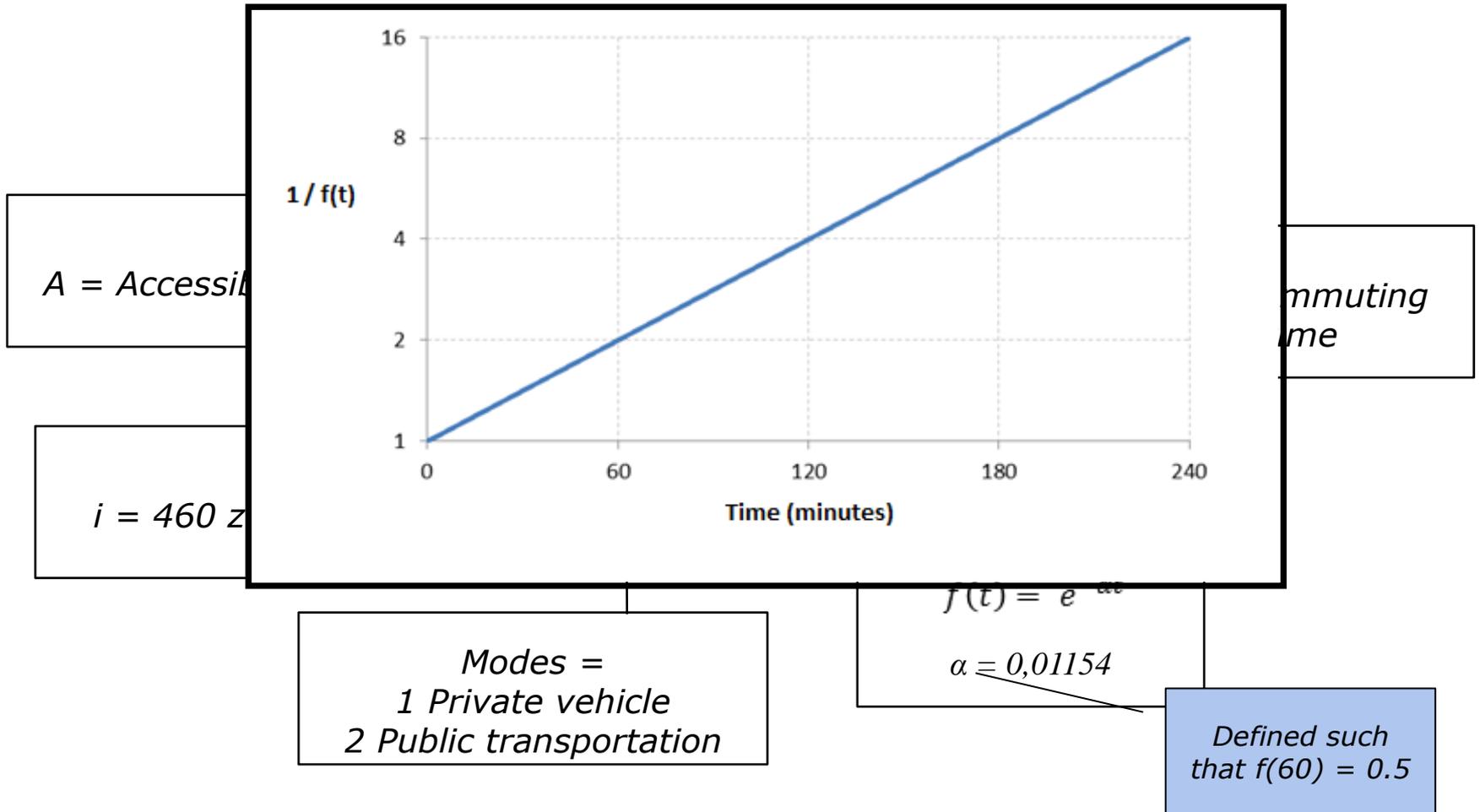
High levels of mobility can, but do not necessarily, reflect high levels of accessibility...



# Hansen's formulation

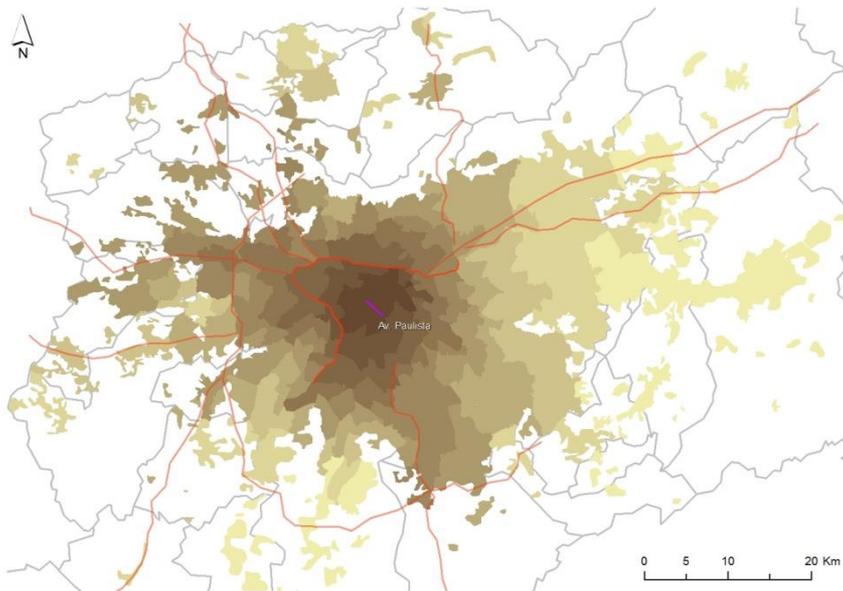


# Hansen's formulation

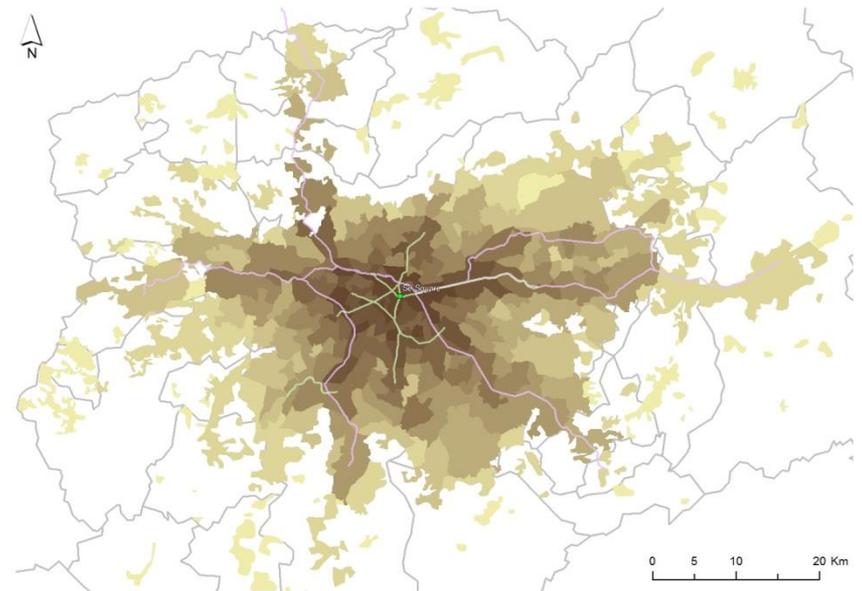


# Accessibility to jobs in SPMR

## Accessibility by private vehicle



## Accessibility by public transportation



# Semi-iterative modeling integration through *soft links*

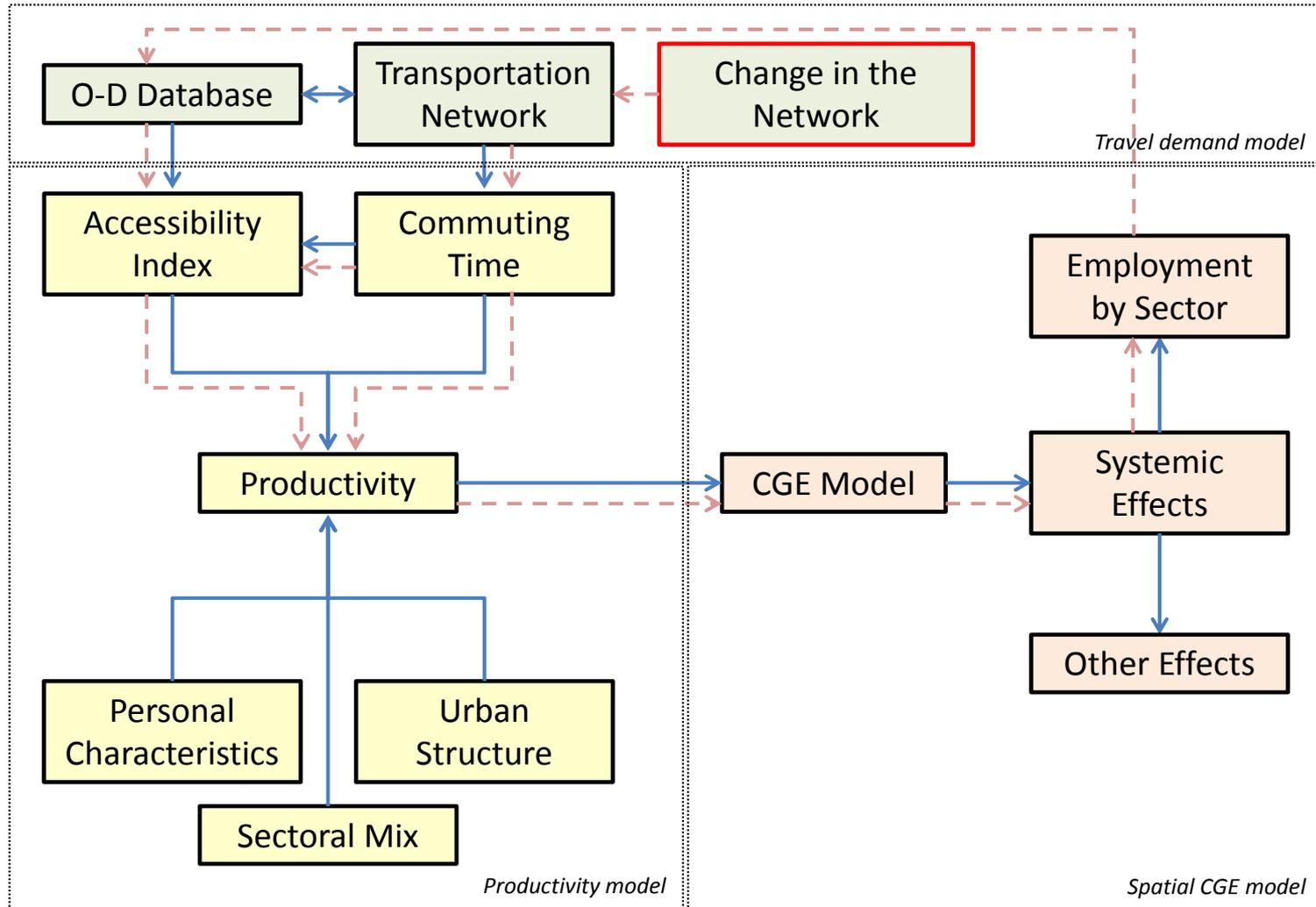
---

**Strategy:** to extract the initial causality path and to estimate the initial reactions econometrically and then to feed the results back into a spatial computable general equilibrium (SCGE) model to capture the system-wide impacts

**Soft links:** models are treated separately – they are linked so that the output of one is used as the input to other(s) through soft links

**Semi-iterative approach:** feedbacks until convergence is reached

# The integrated modeling framework



- Calibration stage
- - -> Simulation stage

# General features of the spatial computable general equilibrium (SCGE) model

---

Model based on simultaneous optimization of the behavior of individual consumers and firms, subject to resource constraints

Fully specified interregional input-output system (trade flows)

Focus on SPMR

- 39 municipalities + rest of the State of Sao Paulo + rest of Brazil

56 sectors, 110 commodities

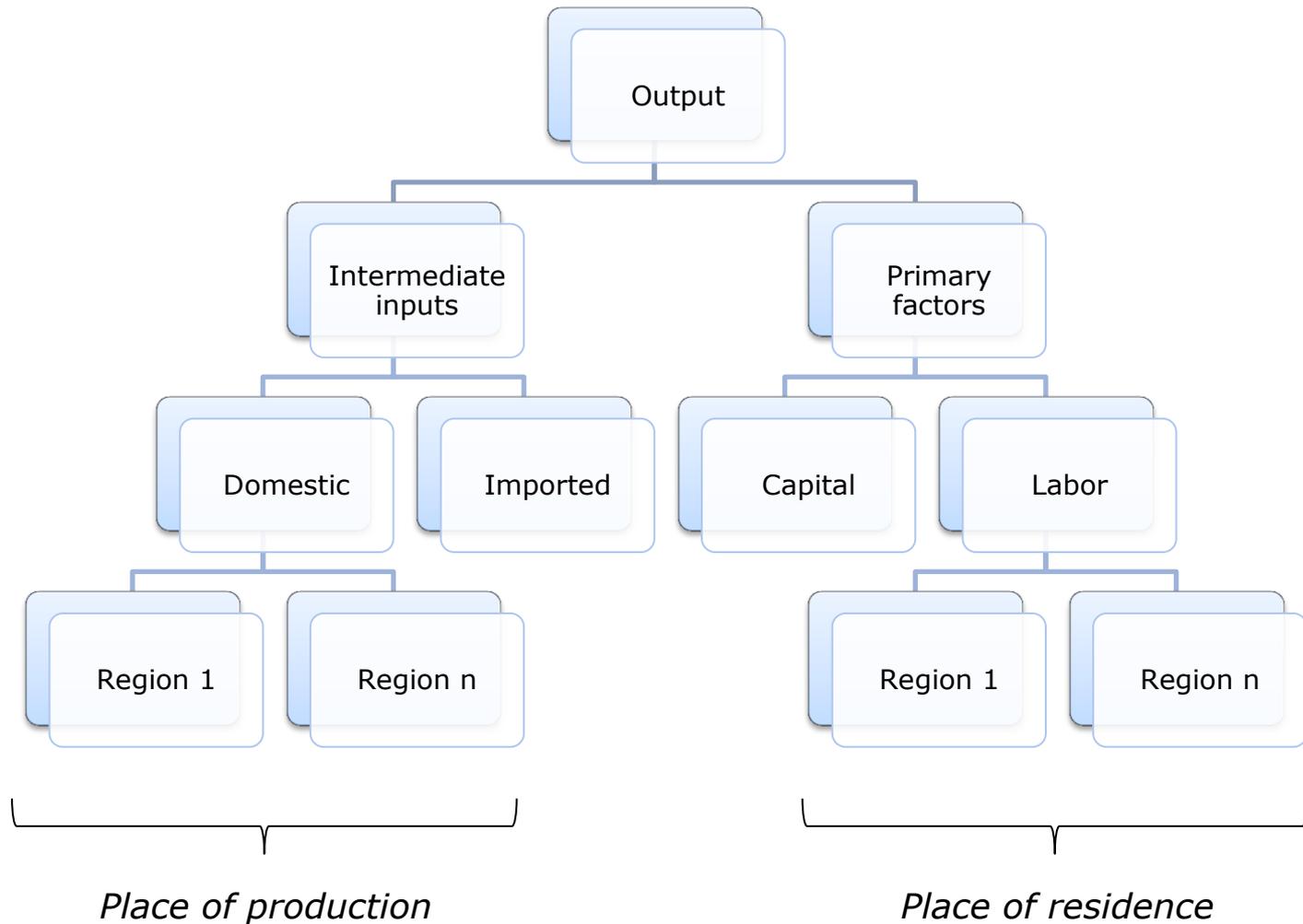
Basic database at the municipality level (2008)

*Mapping labor payments from place of work to place of residence*

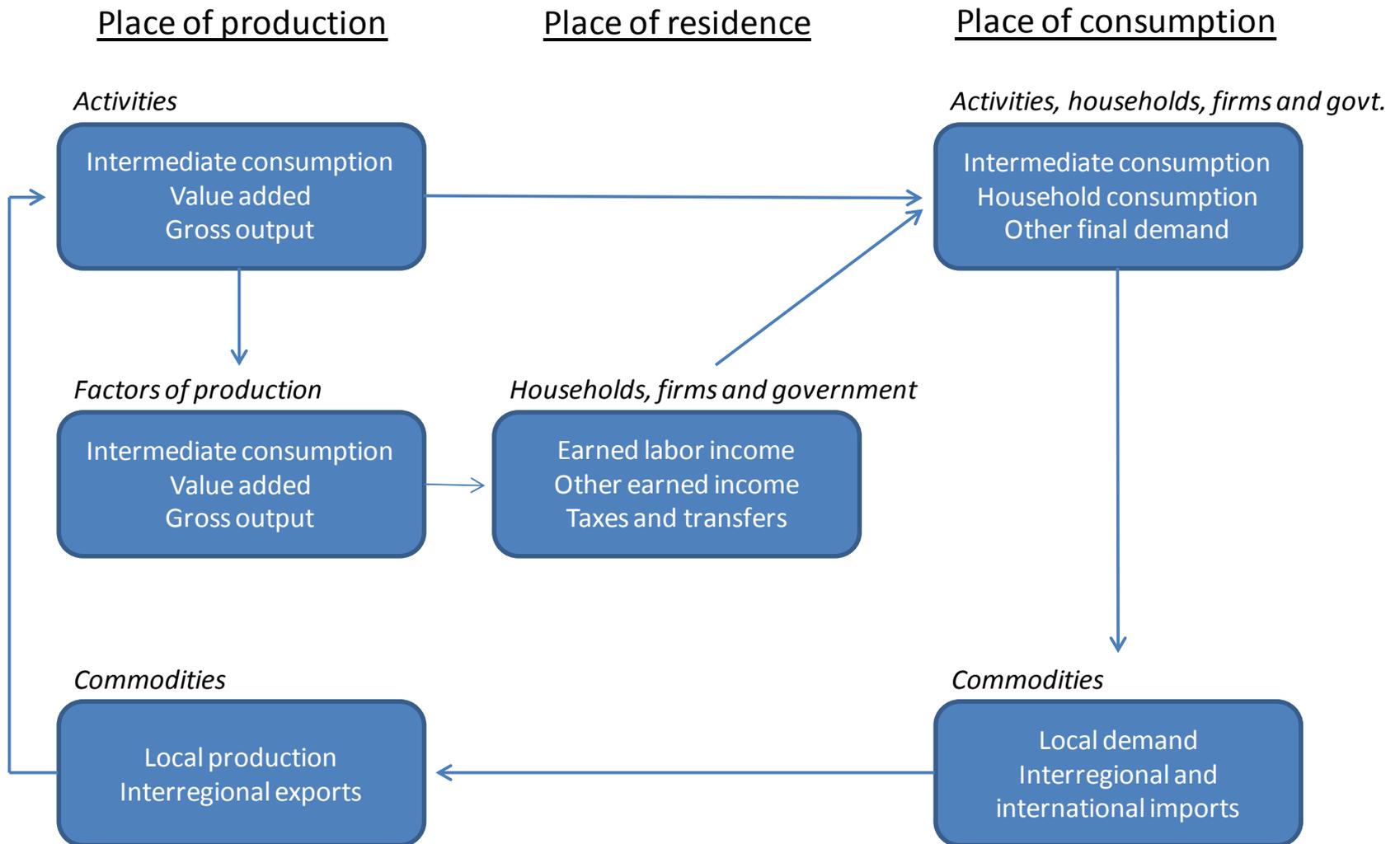
*Different patterns of household consumption by place of residence*

Reference: Haddad and Hewings (2005)

# Production function of sector $j$ in municipality $r$ (nested CES)



# Input-output relations embedded in the SCGE model



# Main questions

---

What if the underground did not exist?

What would be the difference in terms of workers' productivity?

And in terms of value added (GRP/GDP) for the city and for other regions of the country?

To which degree the improvements in productivity are embodied or disembodied in a specific type of public capital?

Mixed short-run/long-run closure (endogenous capital stocks but fixed housing stocks and residential locations).

# Simulations

---

## ***Simulation 1 – “Extraction”***

- Removal of the subway system

Goal: assess the disembodied effects associated with the very existence of the subway system

## ***Simulation 2 (“control”) – “BRT”***

- The rail network is hypothetically replaced by a BRT system; the speed decreased, on average, from 32 km/h to 21 km/h (the observed speed in some of the existing bus corridors in SPMR), and the interval between vehicles increased from 2 min to 4 min

Goal: assess the specific benefits that are derived from a subway system (embodied effects – difference between extraction and BRT)

# Commuting time and productivity

---

Workers with longer daily commuting are less productive

- Theoretical support (Zenou and Smith, 1995; Zenou, 2002; Brueckner and Zenou, 2003; Ross and Zenou, 2008; Zenou, 2008)
- On-the-job effort is negatively related to commuting time
- Excessive commuting time may induce workers to arrive late or leave early; it also increases the frequency of absenteeism, reducing workers' productivity
- Empirical support (Van Ommeren and Gutiérrez-i-Puigarnau, 2009; Porsse et al., 2012)

# Accessibility to jobs and productivity

---

Workers with higher accessibility to jobs are more productive

- Theoretical support (“matching”)
- Effective size of labor market
  - Efficiency of transport system
  - Relative location of jobs and homes
  - Helps explaining labor productivity
- How many jobs can a worker access in, say, 60 minutes?
- Empirical support

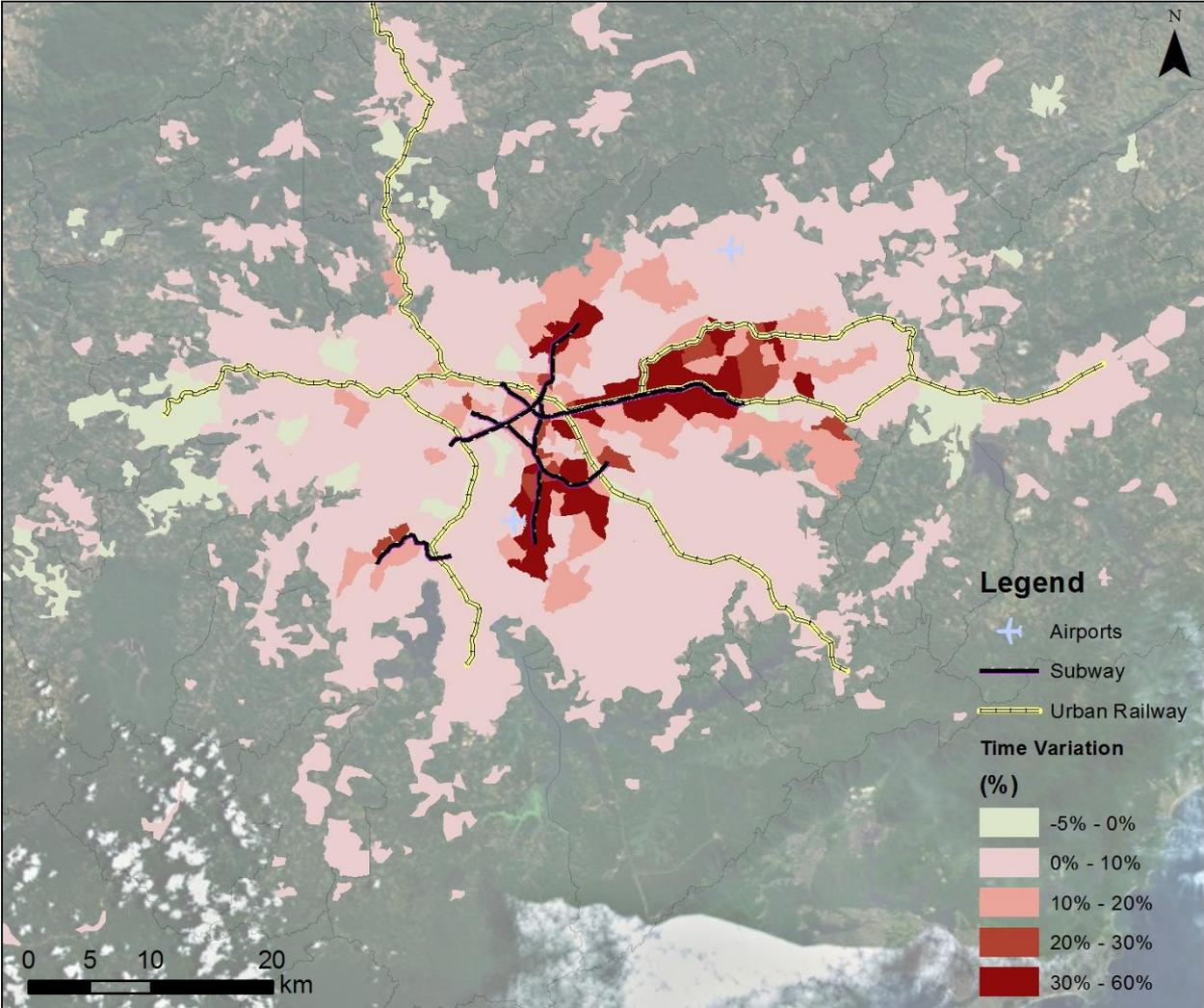
# Parameters used in the **non-behavioral** micro-simulation

*Dependent variable = WAGE*

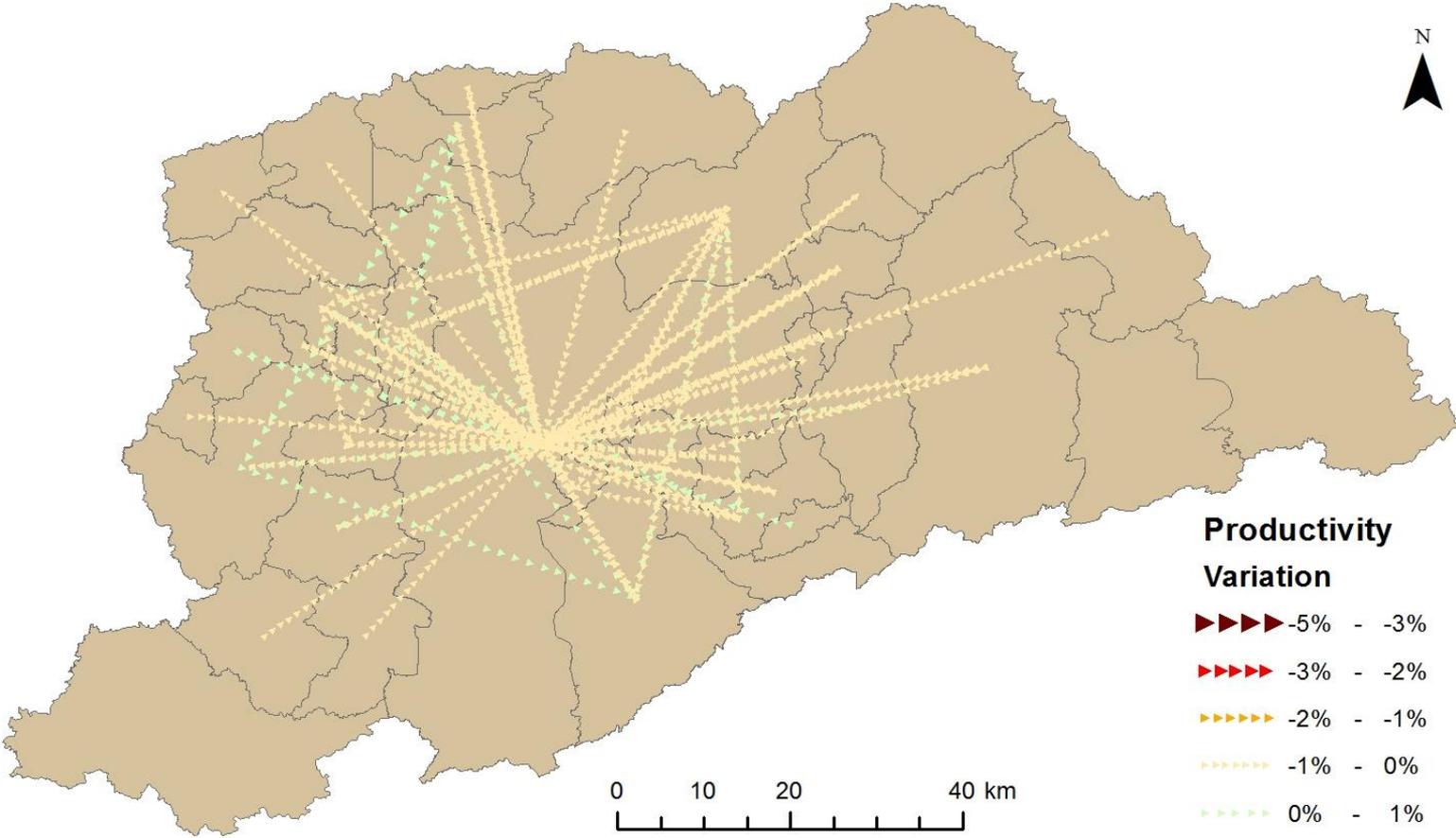
<i>Variables</i>	<i>Coefficients</i>
<b>TIME</b>	<b>-0.02714</b>
<b>ACCESS</b>	<b>0.23321</b>
C	5.77565
GENDER	-0.25140
IND	0.07823
SERV	0.02660
EDUC2	0.10212
EDUC3	0.24925
EDUC4	0.49347
EDUC5	1.13517
AGE	0.03880
AGESQ	-0.00029
PLACE OF WORK DUMMIES	YES

WAGE = wage (log); TIME = commuting time (log); ACCESS = accessibility index – public transportation (log); GENDER = dummy variable – female =1; IND = dummy variable for sectoral of activity – manufacturing = 1; SERV = dummy variable for sectoral of activity – service = 1; EDUC2 = dummy variable for schooling – elementary; EDUC3 = dummy variable for schooling – middle school; EDUC4 = dummy variable for schooling – high school; EDUC5 = dummy variable for schooling – college; AGE = age; AGESQ = square of age.

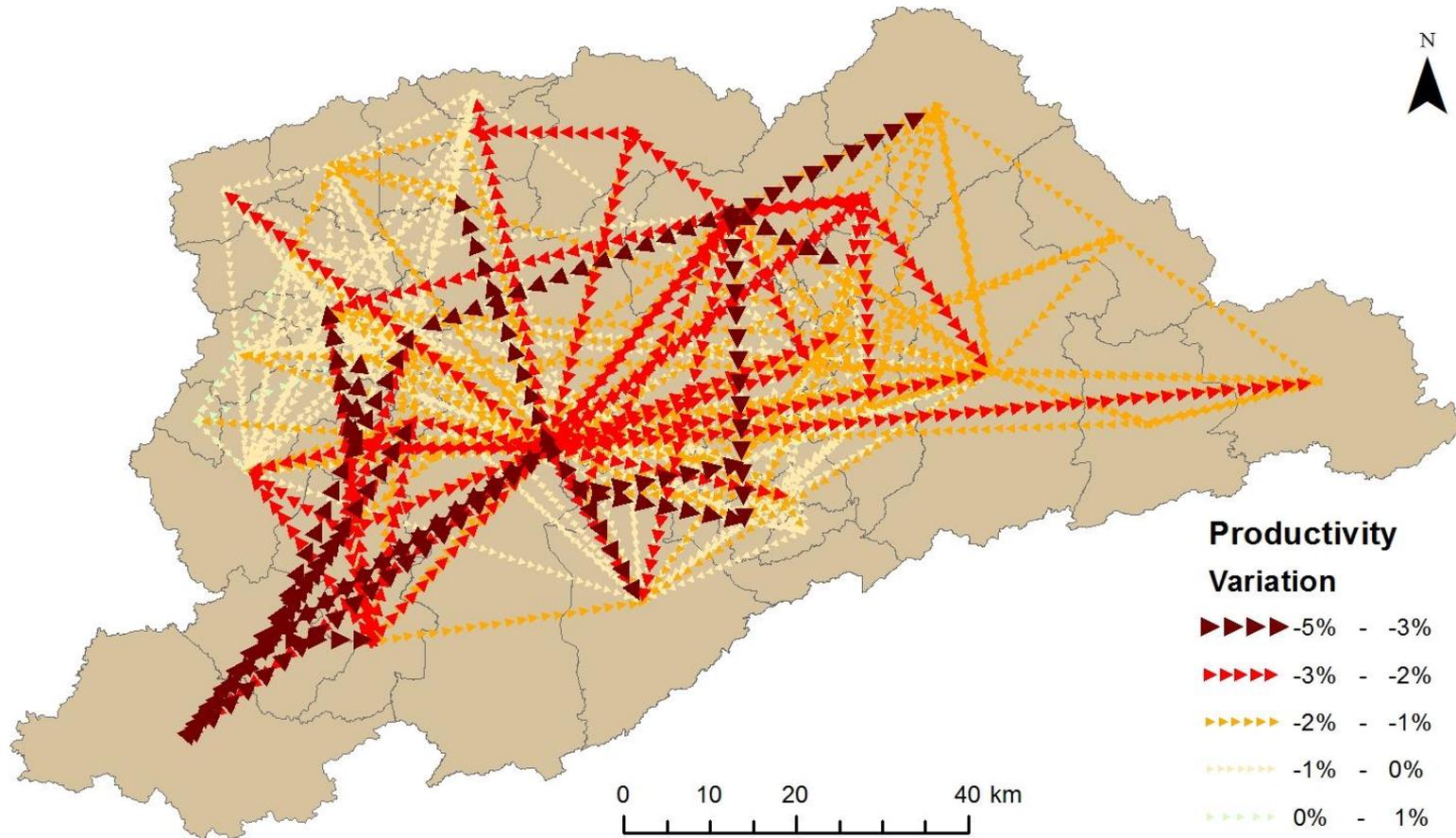
# Changes in commuting time (from the travel demand model)



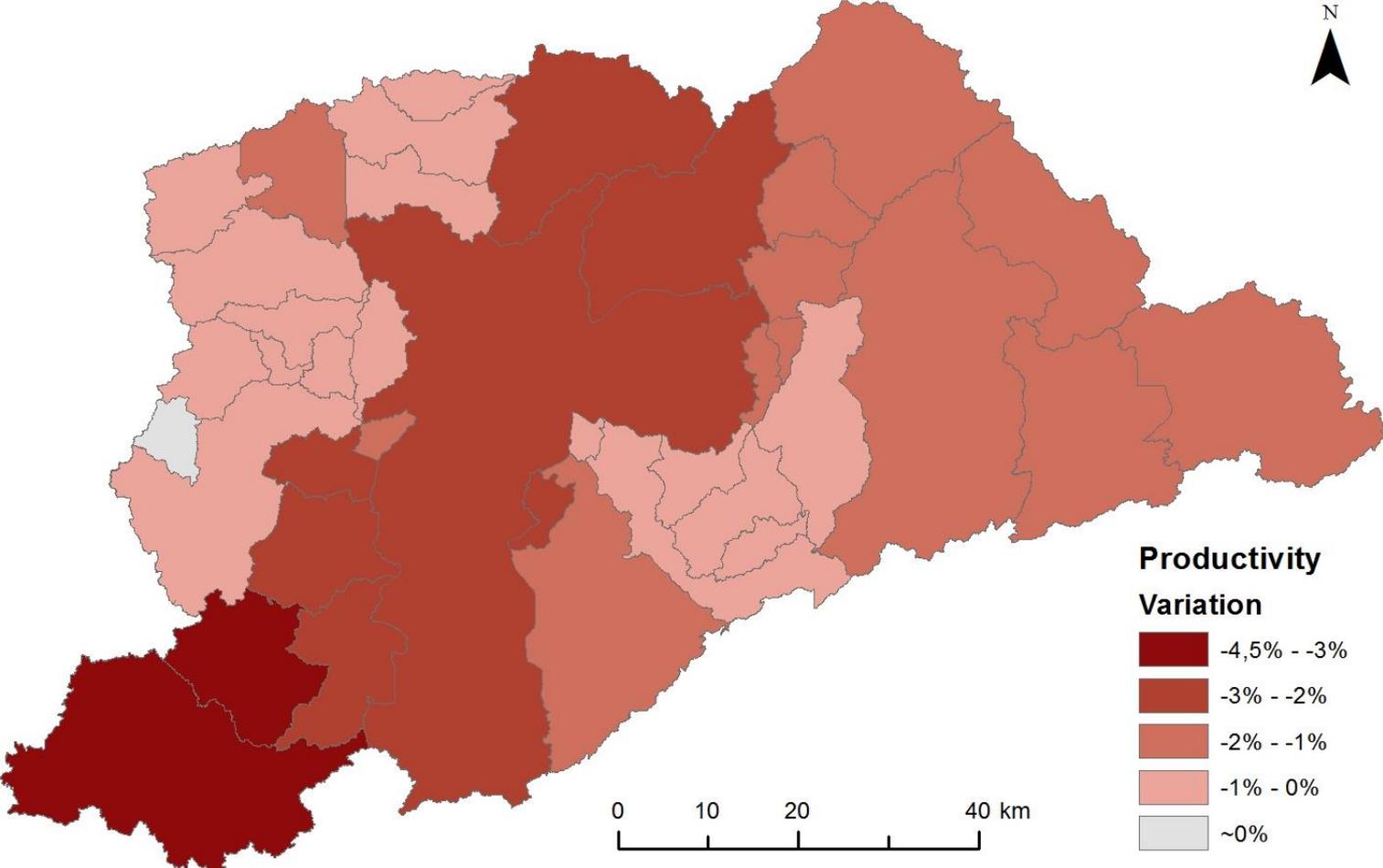
# Changes in Labor Productivity due to Changes in **Commuting Time** (by place of residence and place of work)



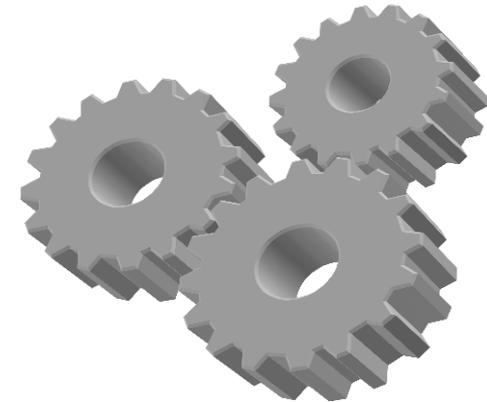
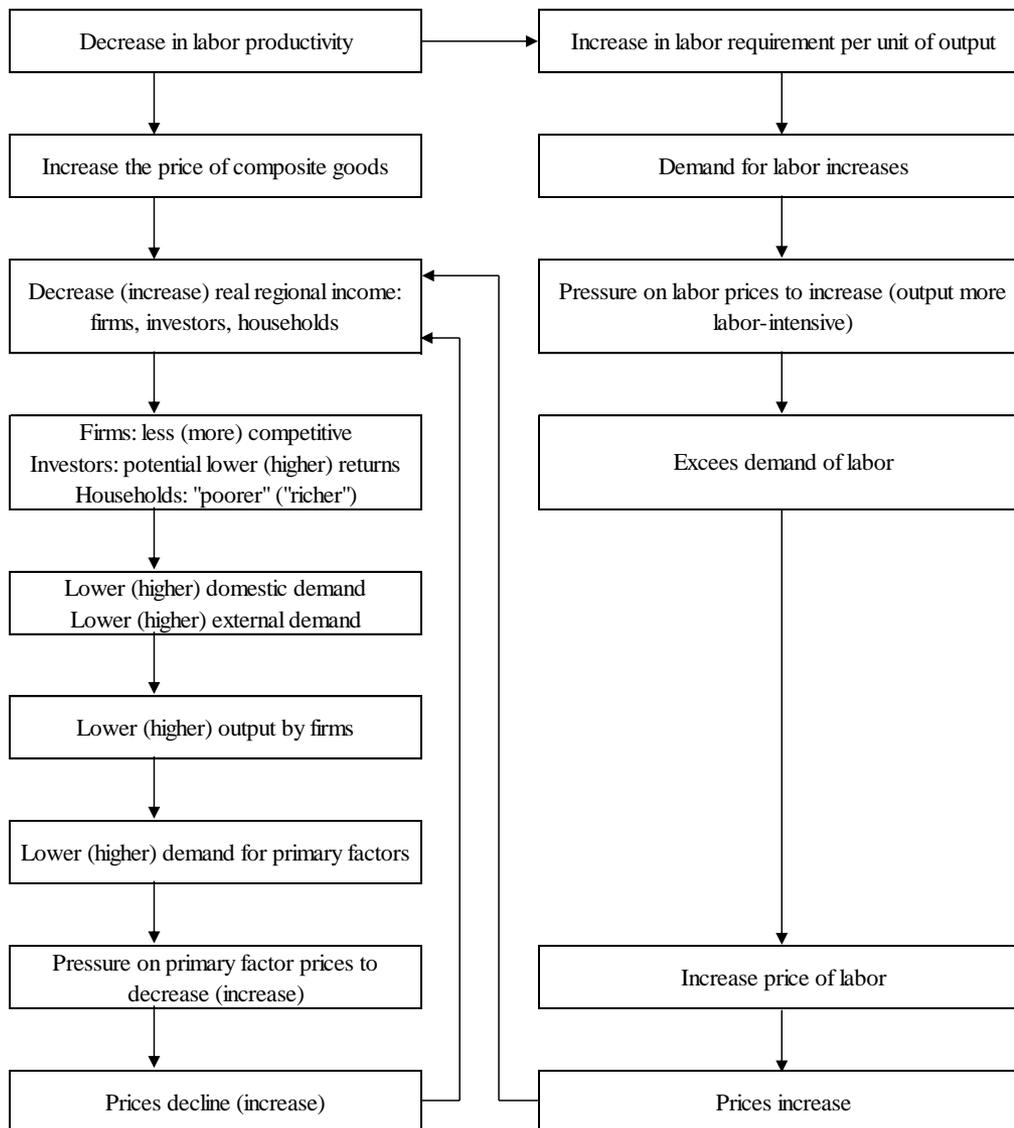
# Changes in Labor Productivity due to Changes in **Accessibility** (by place of residence and place of work)



# Overall Changes in Labor Productivity (by place of work)



# Causal relations underlying the system of equations of the SCGE model



# Macroeconomic impacts of the subway system (in percentage change)

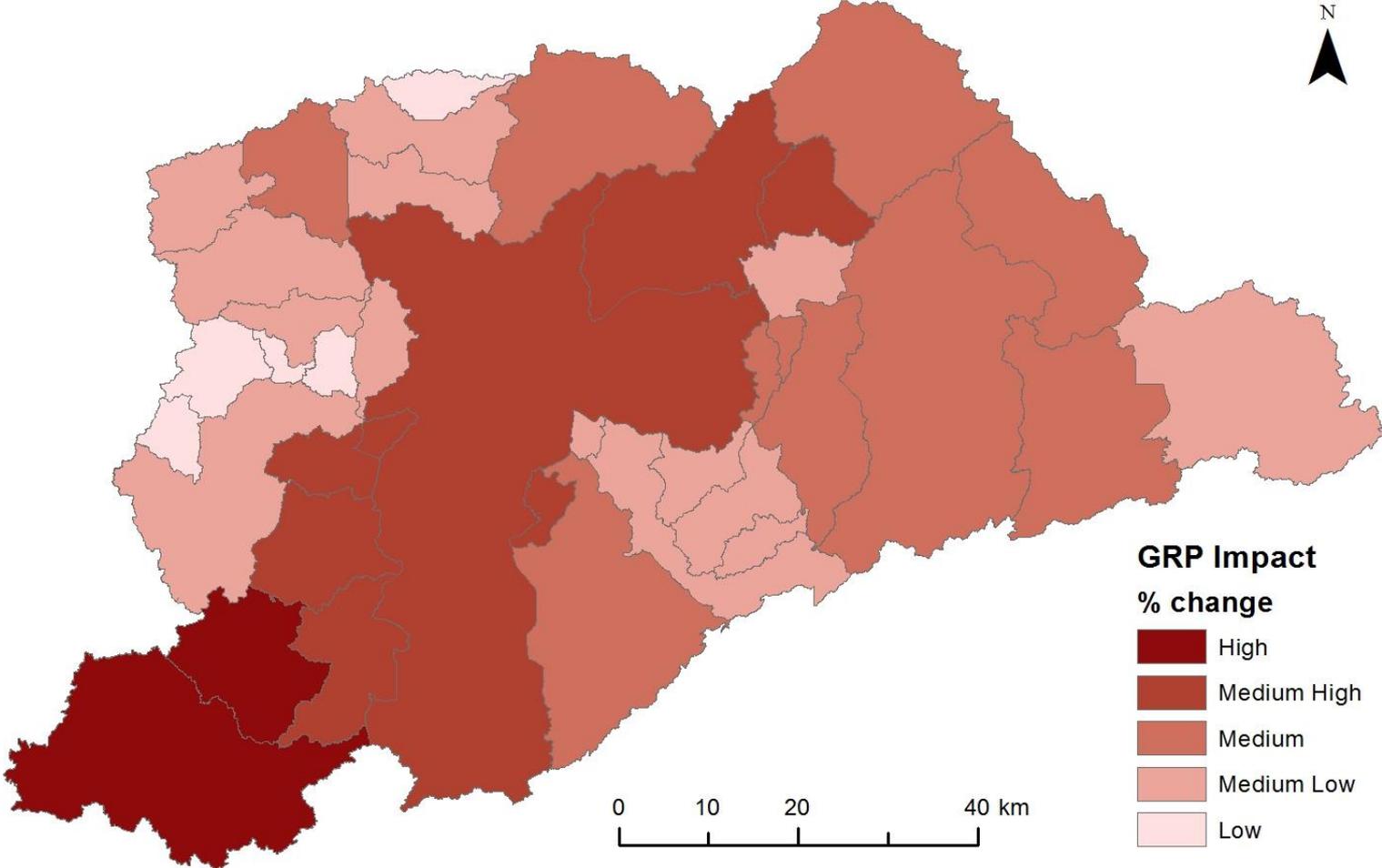
	<i>Simulation</i>		<i>Difference</i>
	<i>Extraction</i>	<i>BRT</i>	
<b><u>City of São Paulo</u></b>			
Real GRP	-1.713	-1.074	-0.638
Real household consumption	-1.663	-0.982	-0.680
Real government consumption - Regional	-1.854	-1.128	-0.726
Real government consumption - Federal	-0.520	-0.344	-0.176
Real investment	-0.338	-0.223	-0.115
Interregional export volume	-1.181	-0.766	-0.415
Interregional import volume	-0.771	-0.488	-0.284
International export volume	-2.716	-1.746	-0.970
International import volume	0.194	0.165	0.029
<b><u>Brazil</u></b>			
Real GDP	-0.634	-0.424	-0.211
Real household consumption	-0.458	-0.303	-0.155
Real investment	-0.232	-0.157	-0.074
Real government consumption - Regional	-0.599	-0.394	-0.205
Real government consumption - Federal	-0.520	-0.344	-0.176
International export volume	-1.089	-0.736	-0.353
International import volume	0.244	0.165	0.078

## Direct and total GRP/GDP impact (in BRL million)

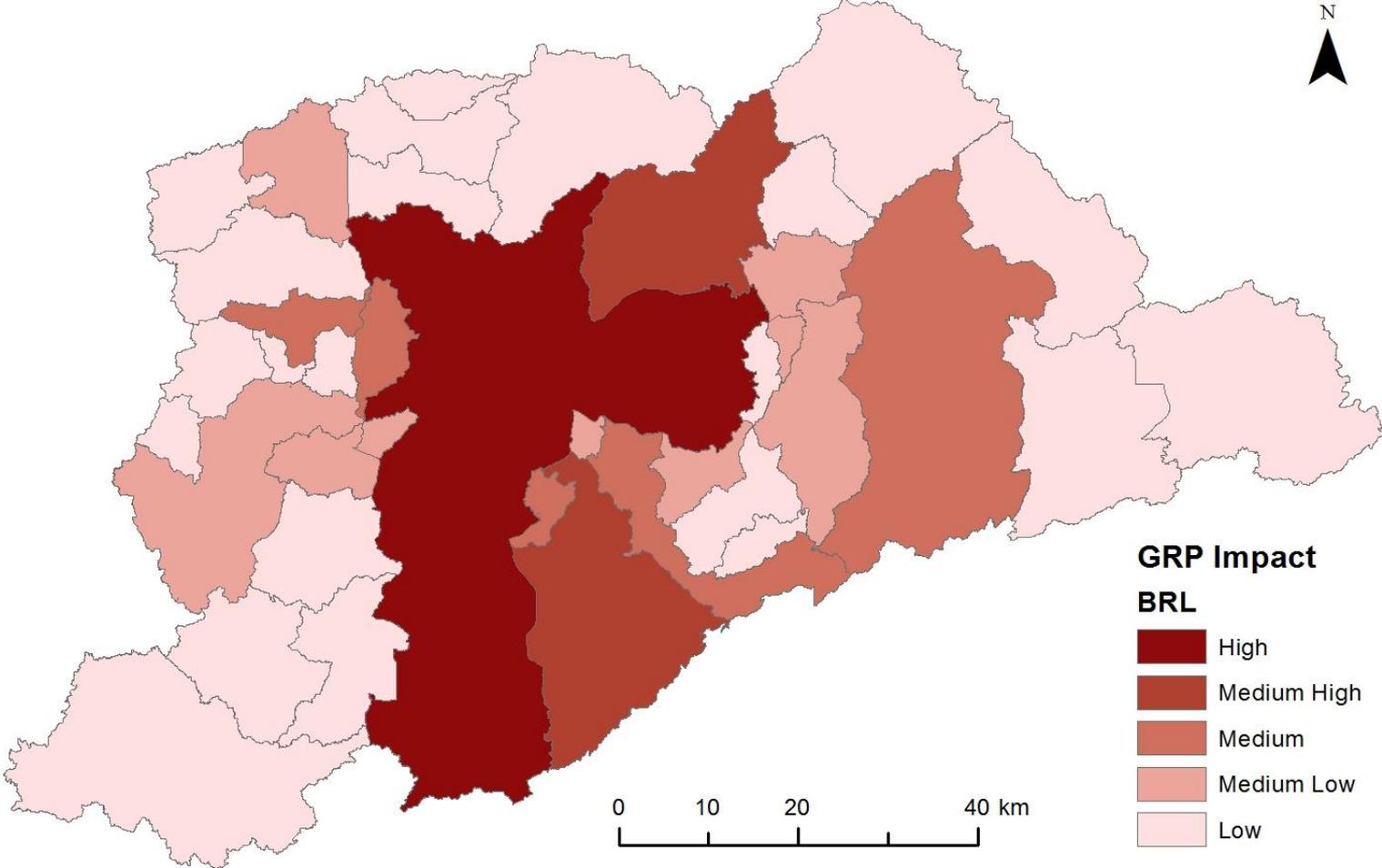
Capital costs per route-kilometer =  
BRL 400 million

	<i>Simulation</i>		<i>Difference</i>
	<i>Extraction</i>	<i>BRT</i>	
<b><u>Direct (place of work)</u></b>			
São Paulo City (SPC)	3358.0	1954.2	1403.8
Rest of SPMR (SPMR)	838.5	633.2	205.3
<b><u>Total</u></b>			
São Paulo City (SPC)	6154.7	3860.1	2294.6
Rest of SPMR (SPMR)	2172.0	1663.4	508.6
Rest of São Paulo State (RSP)	2296.8	1546.2	750.5
Rest of Brazil (RB)	8701.8	5836.0	2865.8
Brazil	19325.3	12905.7	6419.6
<b><i>Intra-city multiplier</i></b>	<b><i>1.8</i></b>	<b><i>2.0</i></b>	<b><i>1.6</i></b>
<b><i>Economy-wide multiplier</i></b>	<b><i>4.6</i></b>	<b><i>5.0</i></b>	<b><i>4.0</i></b>

# GRP gains in the RMSP municipalities "Extraction" (in % of 2008 GRP)



# GRP gains in the RMSP municipalities "Extraction" (in BRL 2008)





Savings result from the greater mobility of workers and subsequent increase in productivity

[Print](#) [Email](#)

Share: [f](#) [+](#) [t](#)

URL: [agencia.fapesp.br/17458](http://agencia.fapesp.br/17458)

## São Paulo subways help Brazil save R\$ 19.3 billion per year, calculates study

June 26, 2013

By José Tadeu Arantes

**Agência FAPESP** – In addition to facilitating the life of its people, the metro could make a major contribution to the economy. If São Paulo did not have a subway, for example, the Brazilian economy would lose R\$ 19.3 billion per year. This value corresponds to two thirds of the cost of the construction

of the entire subway system in the city. If these savings were invested in the metro system, it would be possible to double the metro system in just a year and a half.

That is the conclusion of a study entitled “The Underground Economy: Tracking the Wider Impacts of the São Paulo Subway System,” coordinated by Eduardo Amaral Haddad, full professor in the Department of Economics of the School of Economics and Accounting at the Universidade de São Paulo (FEA-USP).

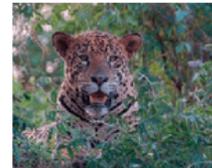
The econometric study was funded by FAPESP and the National Council of Scientific and Technological Development (CNPq) under the auspices of the National Science and Technology Institute on Climate Change ([INCT Clima](#)).

The main topics and related themes of the study were presented at a workshop that was held at

FOLLOW AGENCY FAPESP

[Newsletter](#) [Facebook](#) [Twitter](#)



### Jaguars could disappear from the Atlantic Rainforest

Brazilian researchers warn that the biome only has 250 adult animals distributed across eight isolated populations, and only 50 are reproducing.

### Brazilian researchers develop healthier beef

The meat, shown here prepared for analysis, was enriched with vitamin E, canola oil and selenium and contains less cholesterol



### Lack of rain affects Amazônia's capacity to absorb carbon

Study published in the cover of *Nature* calculates the carbon balance in the Amazon Basin from 2010 to 2011.

### Brazilian study homes in on injury prevention among high-performance athletes

New scale evaluates pain profiles and identifies which athletes are likely to put their bodies to the

# Reaching the planner

---

Methodology developed to assess the socioeconomic impacts of new bus corridors in SPMR (contract research)

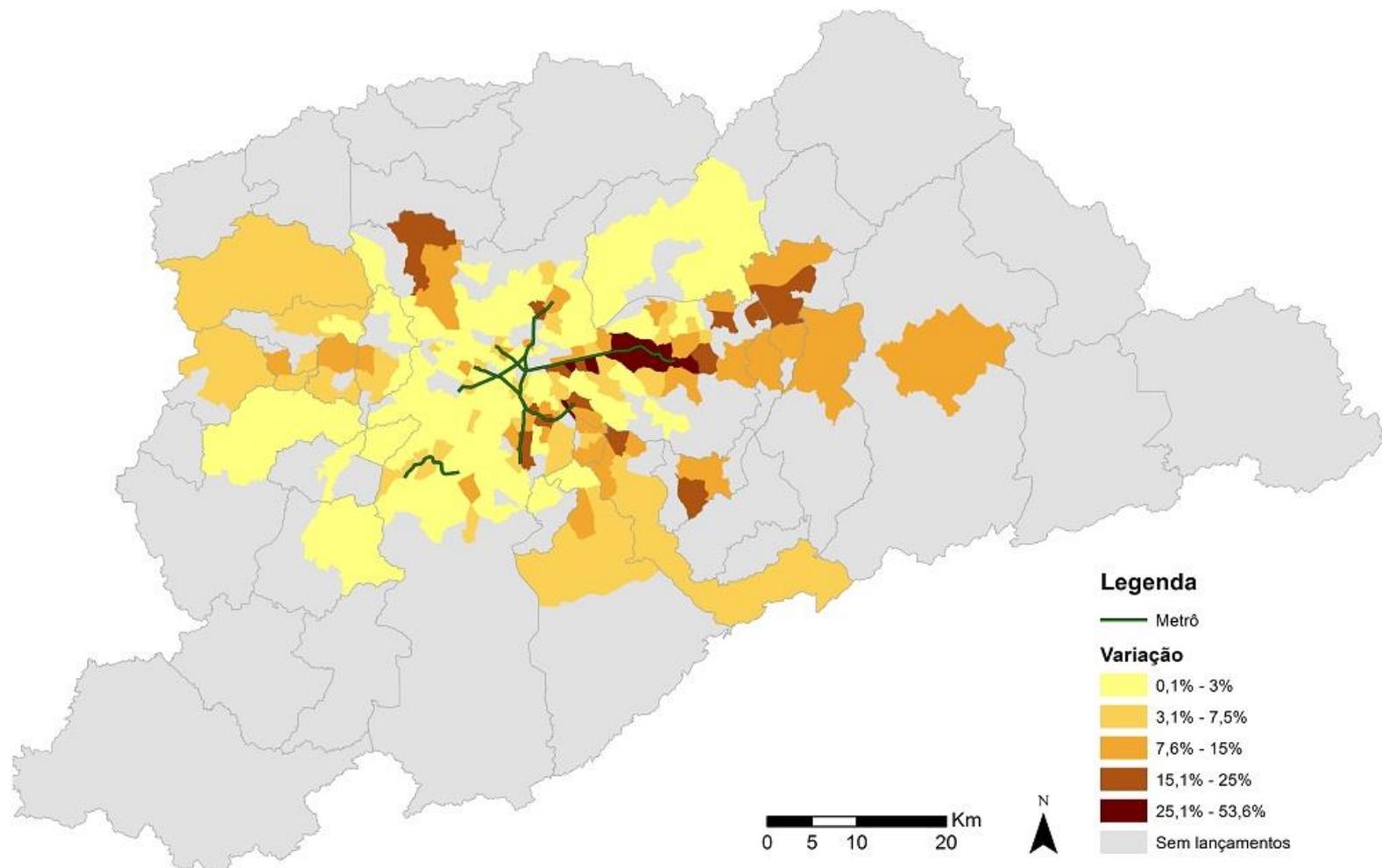
Similar project for other Metropolitan Areas, e.g. Campinas

Interest on spatial and economy-wide impacts

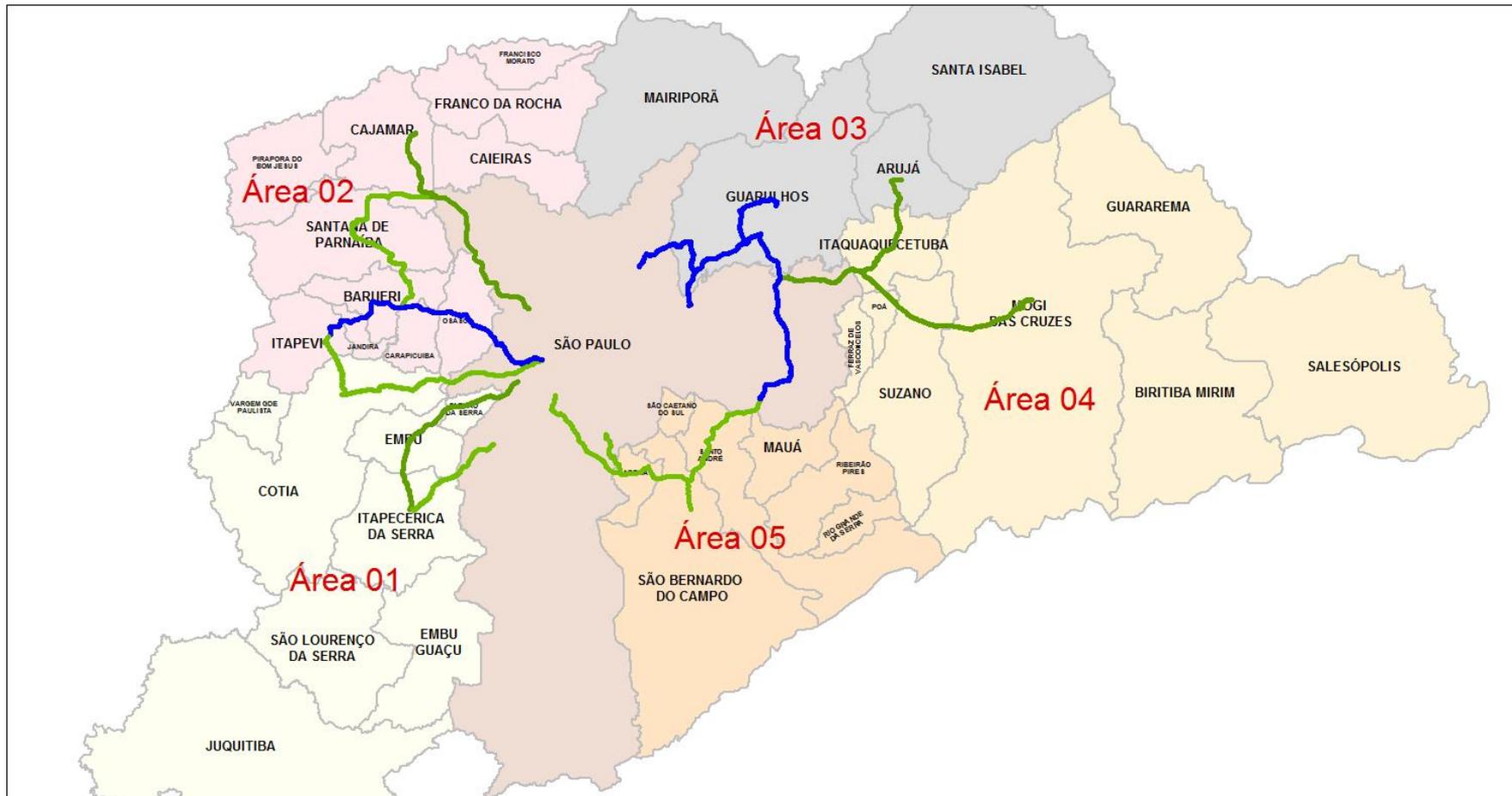
Another issue of interest – housing market (accessibility)

Other aspects – concession contracts

# Surface of changes (%) in the estimated average housing prices – with *versus* without subway



# Metropolitan bus corridors



# Key messages

---

Need to consider both internal and external interactions of the urban system

Network effects reinforce the consequences of a seemingly local phenomenon (subway runs only within the city limits!)

Economic effects are not only local – economic impacts spread through production and income linkages

Coordination problem – policy decisions are made at either the municipality, state or federal level (no metropolitan authority with decision power in Brazil)

Financing – who pays the bill?

# Impact of "good" urban management

Marginal costs and benefits

