Modelagem Baseada em Agentes para Políticas Públicas
aula 6: PolicySpace

Furtado, Bernardo Alves

March 8, 2019

ipea Institute for Applied Economic Research

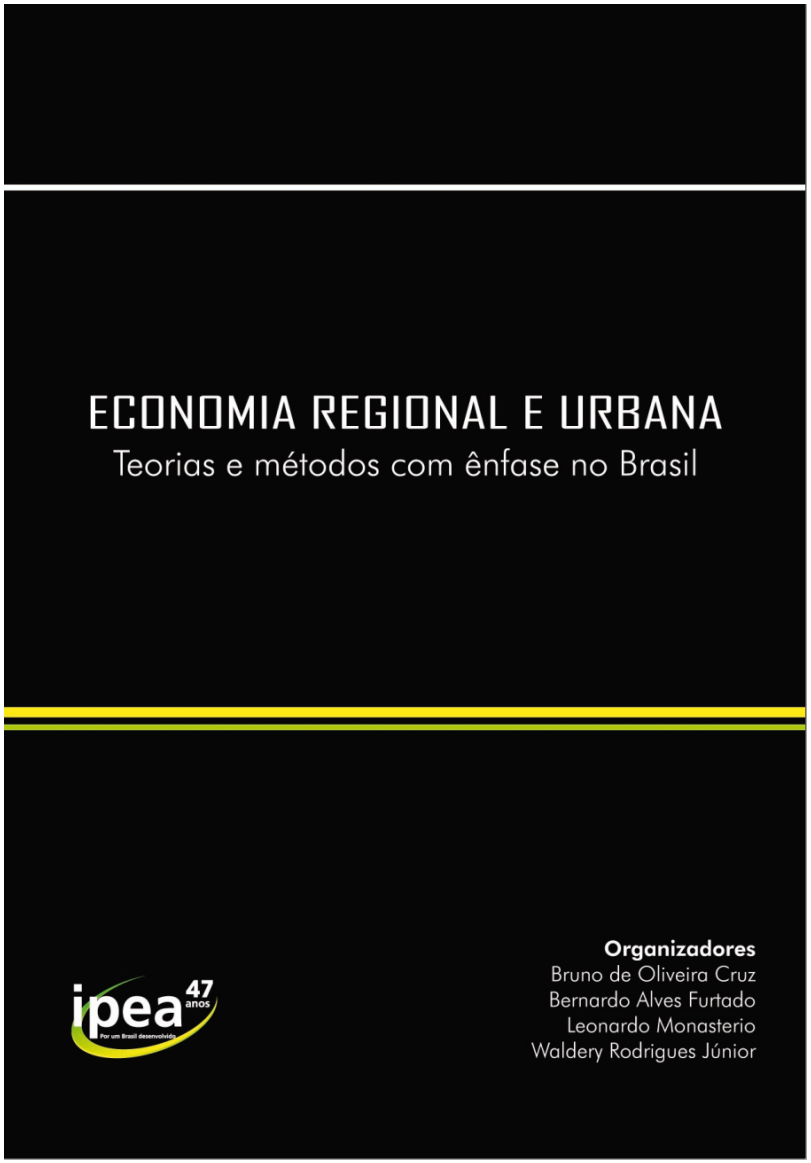
Overview

PolicySpace
- Preamble
- The model

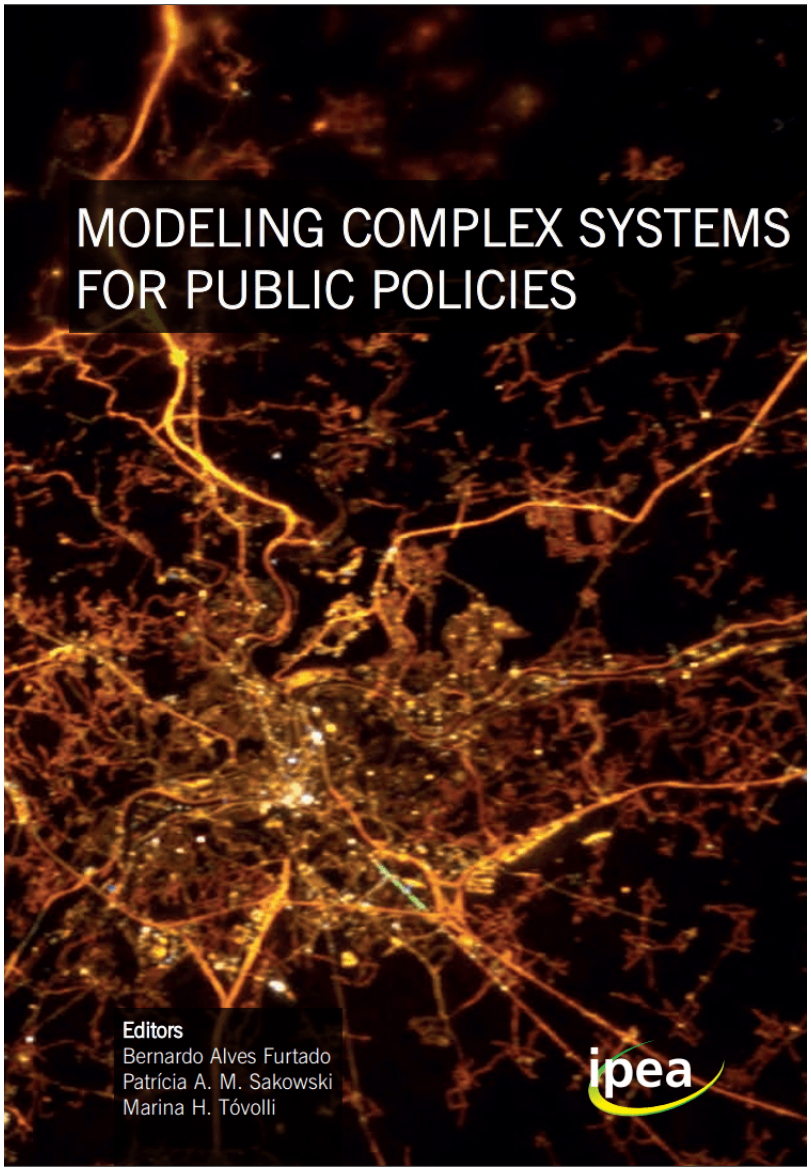
Validation
- Validation

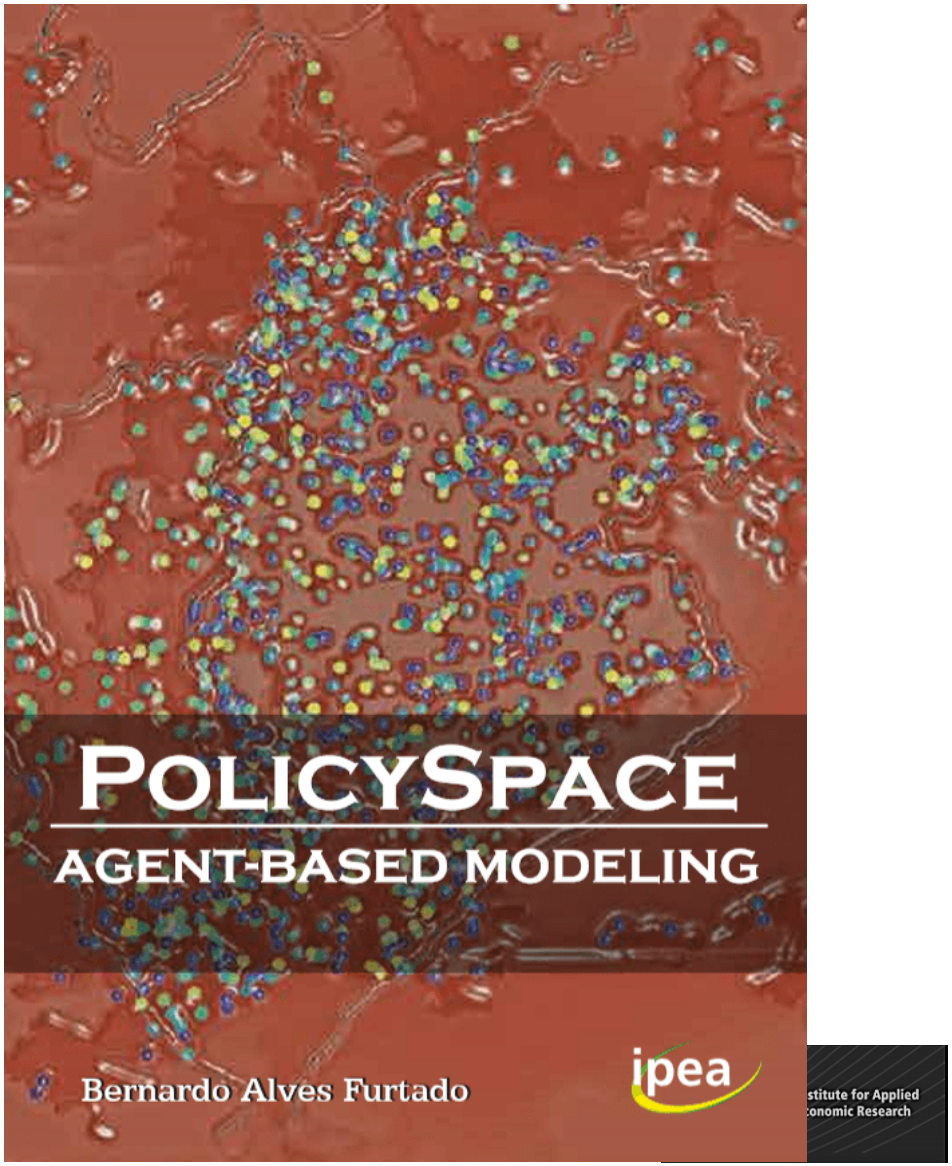
Application
- Application

Platform
- Paper factory
- Transit simulation


ECONOMIA REGIONAL E URBANA
Teorias e métodos com ênfase no Brasil
Organizadores
Bruno de Oliveira Cruz
Bernardo Alves Furtado
Leonardo Monasterio
Waldery Rodrigues Júnior
ipea
47 anos


Editores
Bernardo Alves Furtado
Cleandro Krause
Karla Christina Batista de França
Território metropolitano, políticas municipais
por soluções conjuntas de problemas urbanos no âmbito metropolitano
ipea


MODELING COMPLEX SYSTEMS
FOR PUBLIC POLICIES
Editors
Bernardo Alves Furtado
Patrícia A. M. Sakowski
Marina H. Tóvolli
ipea


POLICYSPACE
AGENT-BASED MODELING
Bernardo Alves Furtado
ipea

Molding PolicySpace

- Urban economics [1]
- Spatial heterogeneity [2]
- Functional urban regions [3]
- Heterogeneity of taxes [4, 5]
- Access to opportunities [6, 7]
- Needs unified planning [8]

In short

PolicySpace is an **open source, spatial-economic agent-based model** with three **markets** and a **tax-system** that empirically simulates 46 **metropolitan regions** in Brazil

Concept

ABM is a computer implementation of an artificial environment that contains agents that interact in time and space

Literature

Based on Lengnick [9], a family of the 'emerging practices' in Macroeconomics models [10]

Contributions

- Incorporates intra-urban space
- Mobility of families (via real estate market)
- Population dynamics
- Use of **distance** (consumption and labor markets)
- 'Bridge' among MABMs, LUTs, Activity models

Motivation

- Public policies: effects on space and time, on citizens
- Complex Systems: **agents and interactions**
- Method: agent-based modeling
  - Low cost (*in silico* experimentation)
  - What-if questions
  - Dynamic, spatial, and **modular**

ipea Institute for Applied Economic Research

Research question

Would alternative municipalities' taxes configurations increase citizens' quality of life?

ODD protocol: entities, states, scales

- Citizens (workers), mobile
- Families (collective of citizens), mobile
- Residences
- Firms
- Municipalities - government bodies
- 2000-2020
- Markets: labor, goods, real estate [1]

[1] I thank collaborators Isaque Eberhardt and Francis Tseng

ODD: data initialization

- Generating (loading) agents: region, pop., vacancy, members per family
- Agents in a region, into families, into residences
- Firms
- Official data
  - shapefiles
  - gender, age, firms by tracts
  - qualification, municipal HDI, taxes by municipalities
  - mortality, fertility by states

ODD: processes and temporal execution I

1. Production: number of employees and qualification
2. Demographics: birthday, mortality, fertility
3. Goods market: families' consumption
   - Savings: not consumed portion
   - Criteria: prices or distance
4. Firms: decisions on
   - wages (revenues)
   - prices (stocks)
   - hiring/firing (profits)
5. Labor market
   - Firms paying higher wages, choose first
   - Criteria: qualification or distance

ODD: processes and temporal execution II

6. Real estate market
   - Percentage of families
   - House vacancies
   - Prices: demand: family savings x supply: hedonically calculated
7. Taxes on properties
8. Municipality invest taxes on Quality of Life Index
9. Data output (a lot of data!)

Parameters

- Offer flexibility and analysis to the model
- Attributes of agents (productivity)
- Rules
  - Distance
  - Wage (unemployment)

ODD sub-models: taxes

Tests two True-False parameters on how to distribute taxes:

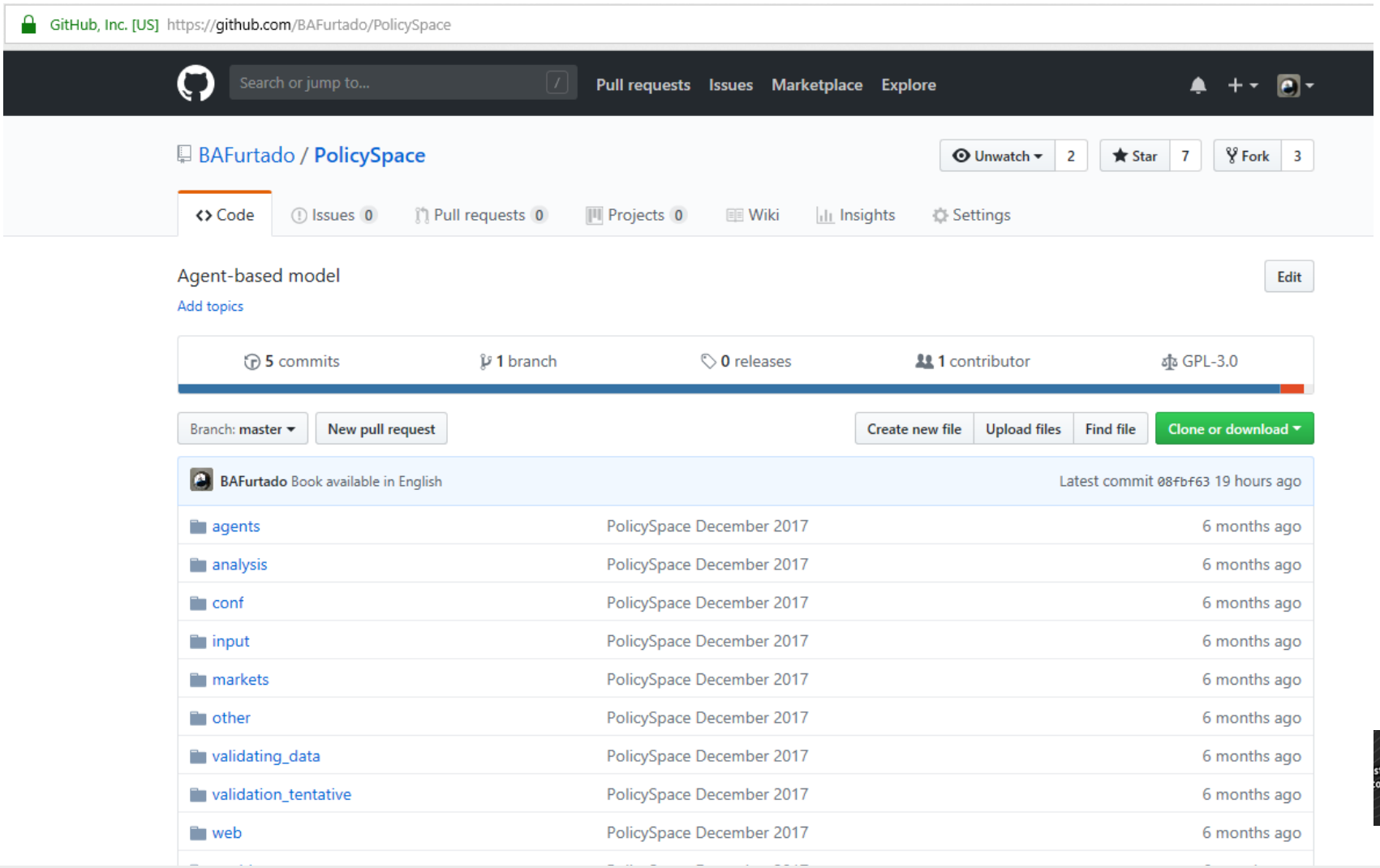
1. **'municipalities as a single region for tax purposes'**
2. presence of progressive tax called MPF

Automated running

python main.py [options]

- Numerous times: *-n 4*
- Numerous processors: *-c 12*
- Sensitivity analysis: *sensitivity ALPHA:0:1:7*
- Numerous metropolitan regions: *acps*
- Numerous tax schemes: *distributions*
- Browser interface: *web*

Available on GitHub



Validation

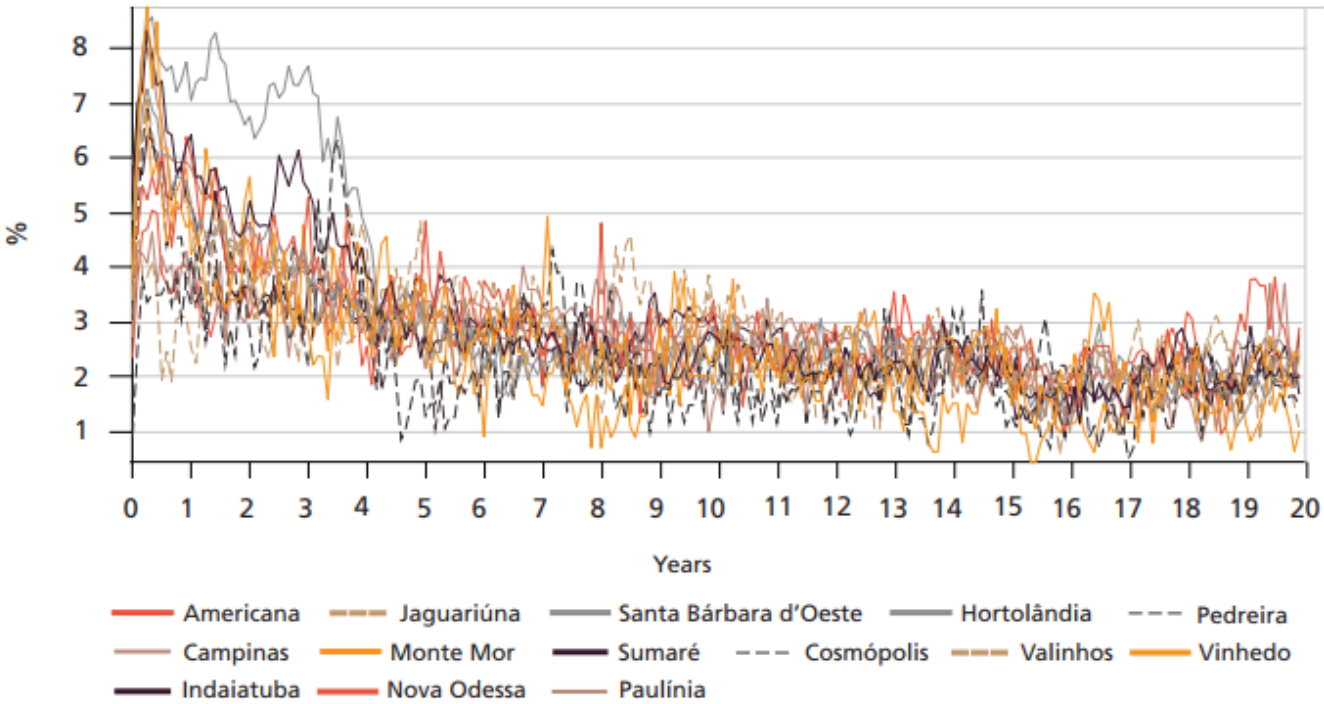
We validate the model in a five-step process:

1. macroeconomics indicators
2. sensitivity analysis
3. taxes reproducibility globally
4. taxes distribution set of regions
5. structural sensitivity

Validation I: jobs

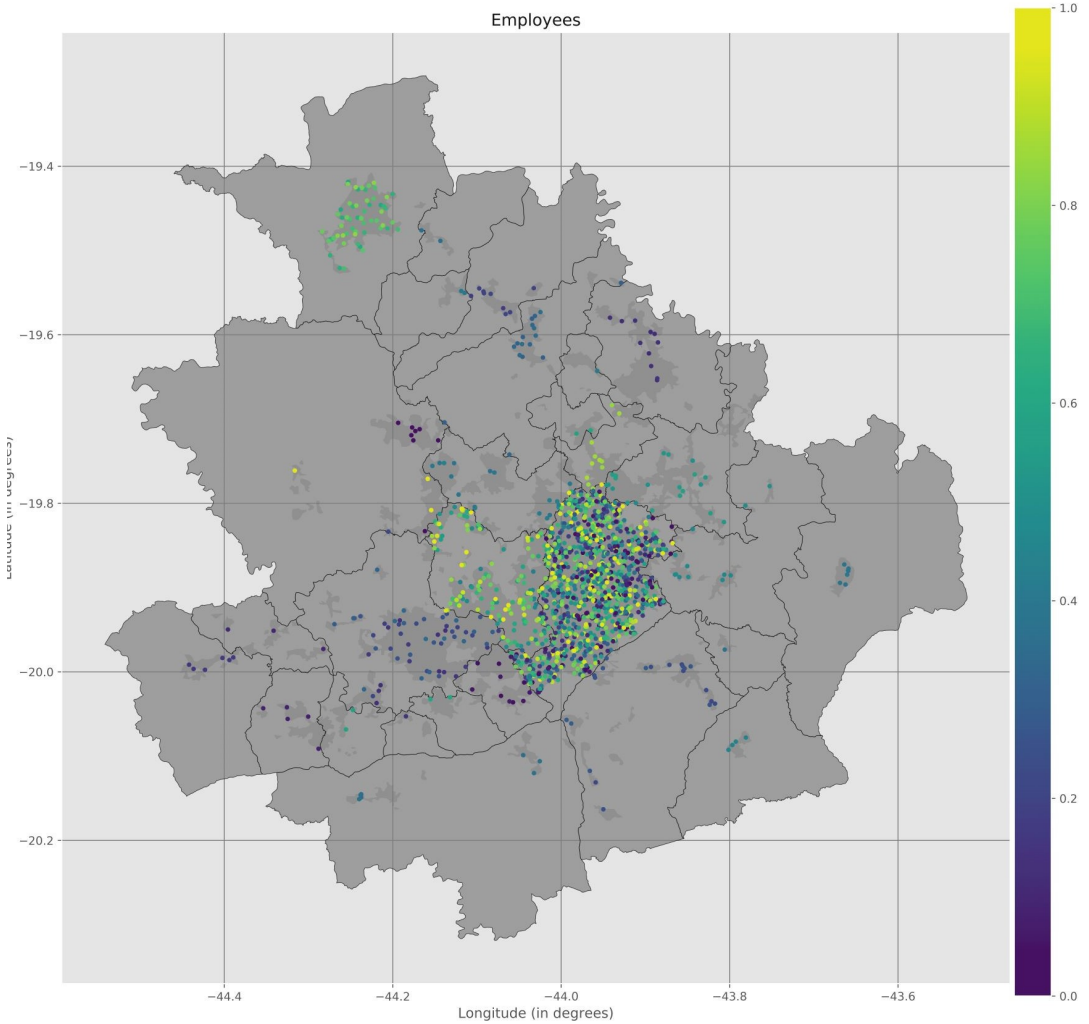
GRAPH 6

Campinas: unemployment by municipality



Author's elaboration.
Note: Data for 2% of the population and default configuration.

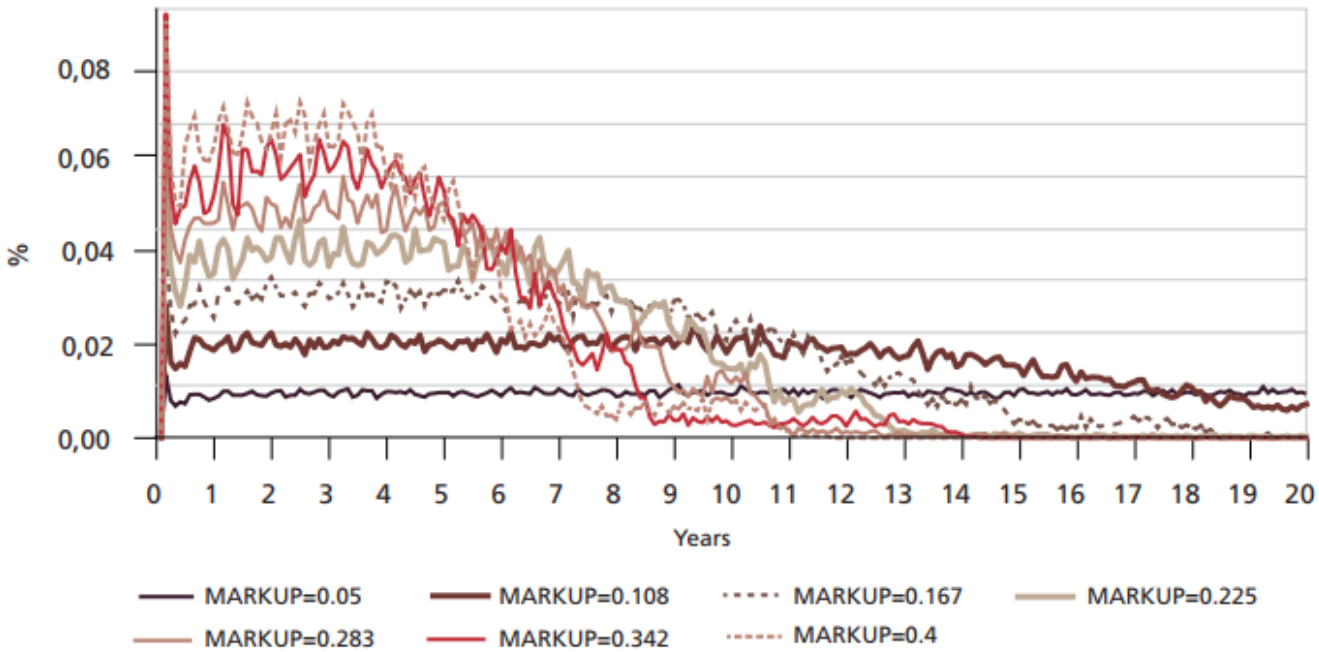
Validation I: jobs



Validation II: sensitivity markup - inflation

GRAPH 3

Brasília: sensitivity analysis with parameter *markup* – monthly inflation estimates



Author's elaboration.
Note: Data for 1% of the population and default configuration.

Validation III: taxes

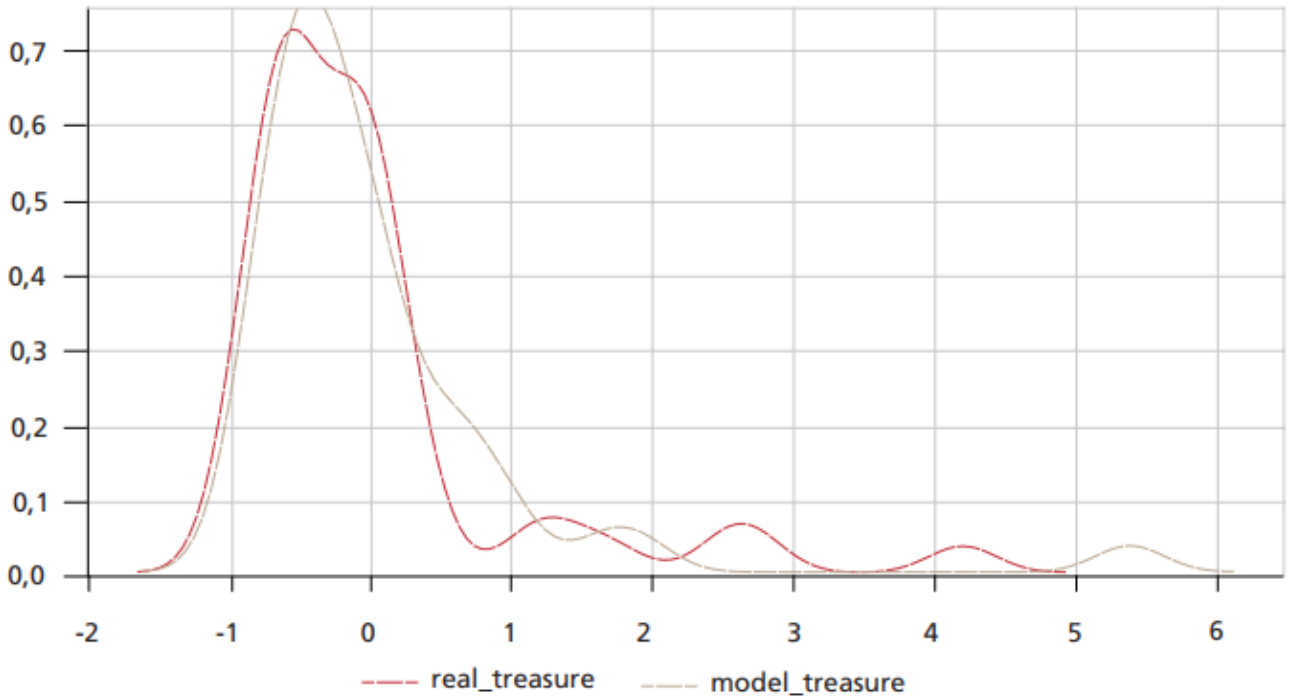
Taxes/GDP	**Literature [11]**	**Simulated**	**Treasure**
Labor	0.0024	0.0105	
Firm	0.0065	0.0173	
Consumption	0.0093	0.0334	
Property	0.0007	0.0056	0.0044
Transaction	0.0008	0.0012	0.0012
Total collected	**0.0207**	**0.0679**	**0.0869**
FPM		0. 0534	0.0184
Taxes/total			
Labor	0.1178	0.1522	
Firm	0.3181	0.2595	
Consumption	0.4498	0.4819	
Property	0.0356	0.0885	0.0919
Transaction	0.0399	0.0179	0.0119
FPM		0.4303	0.412

Validation IV: Total tax

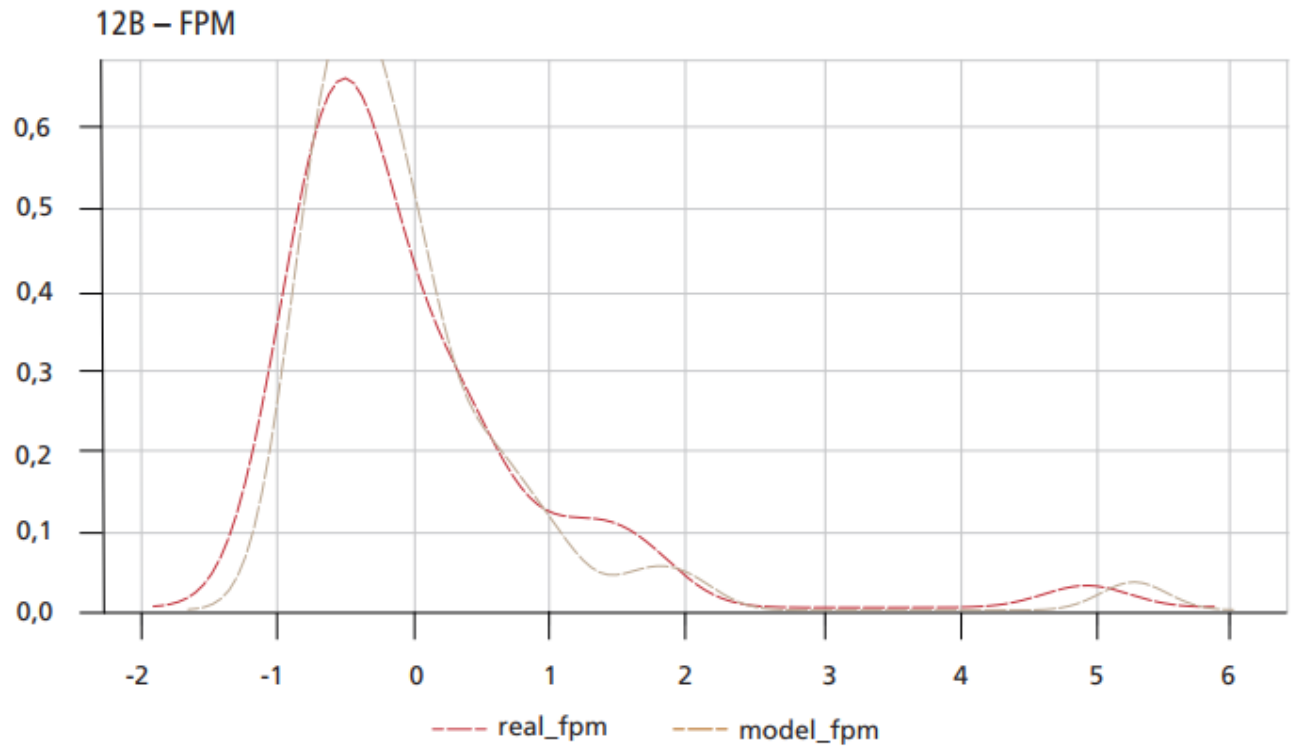
GRAPH 12

Comparison between observed and simulated values for all ACPs

12A – Total collected tax



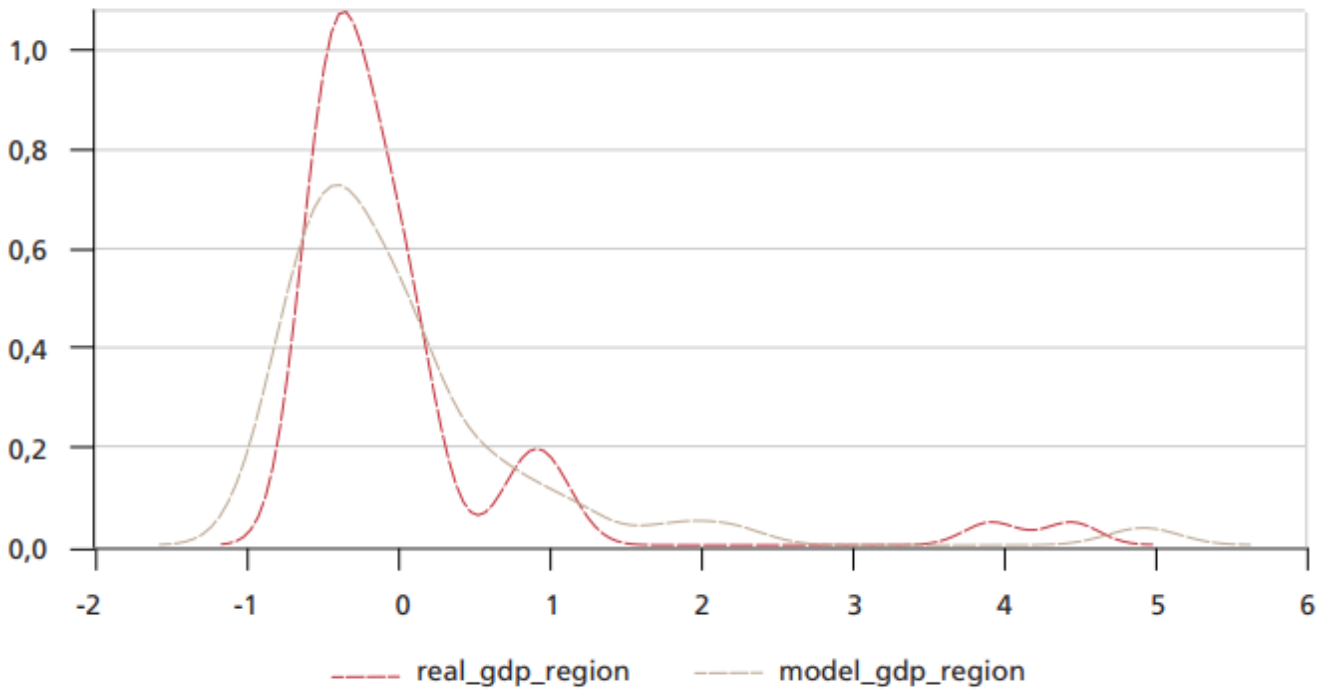
Validation IV: FPM



Validation IV: GDP

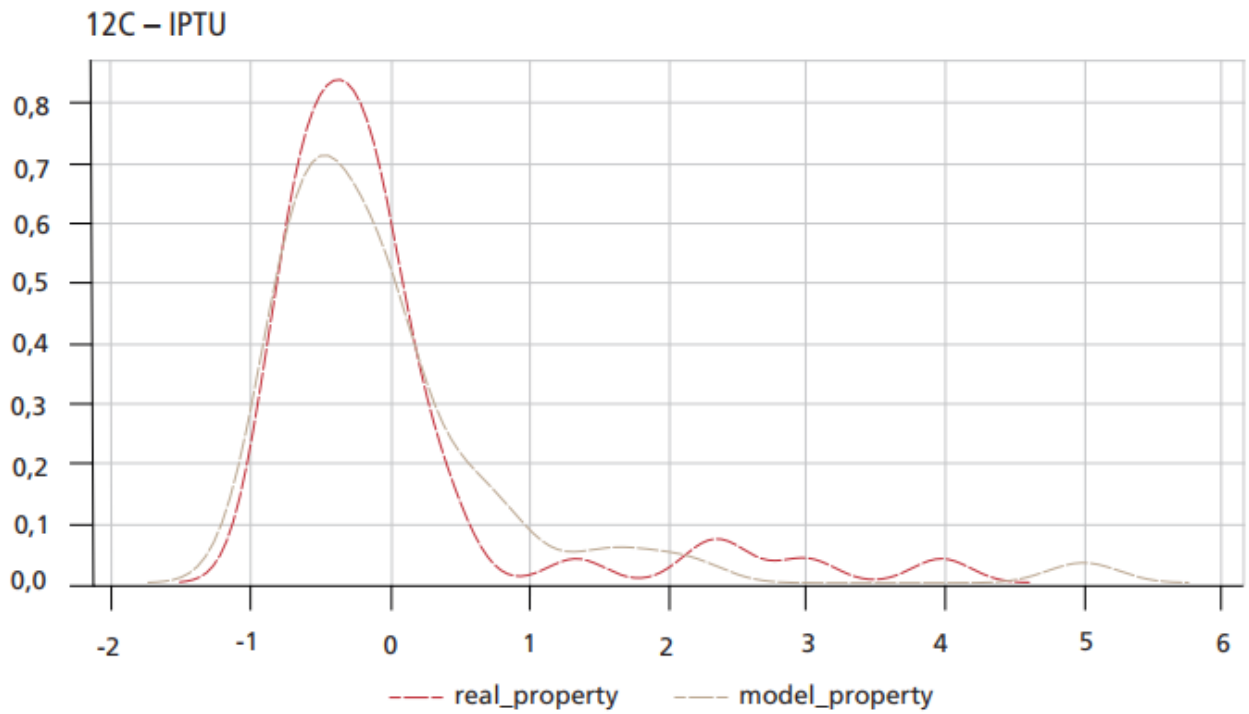
GRAPH 11

Comparison between observed and simulated GDP for all ACPs

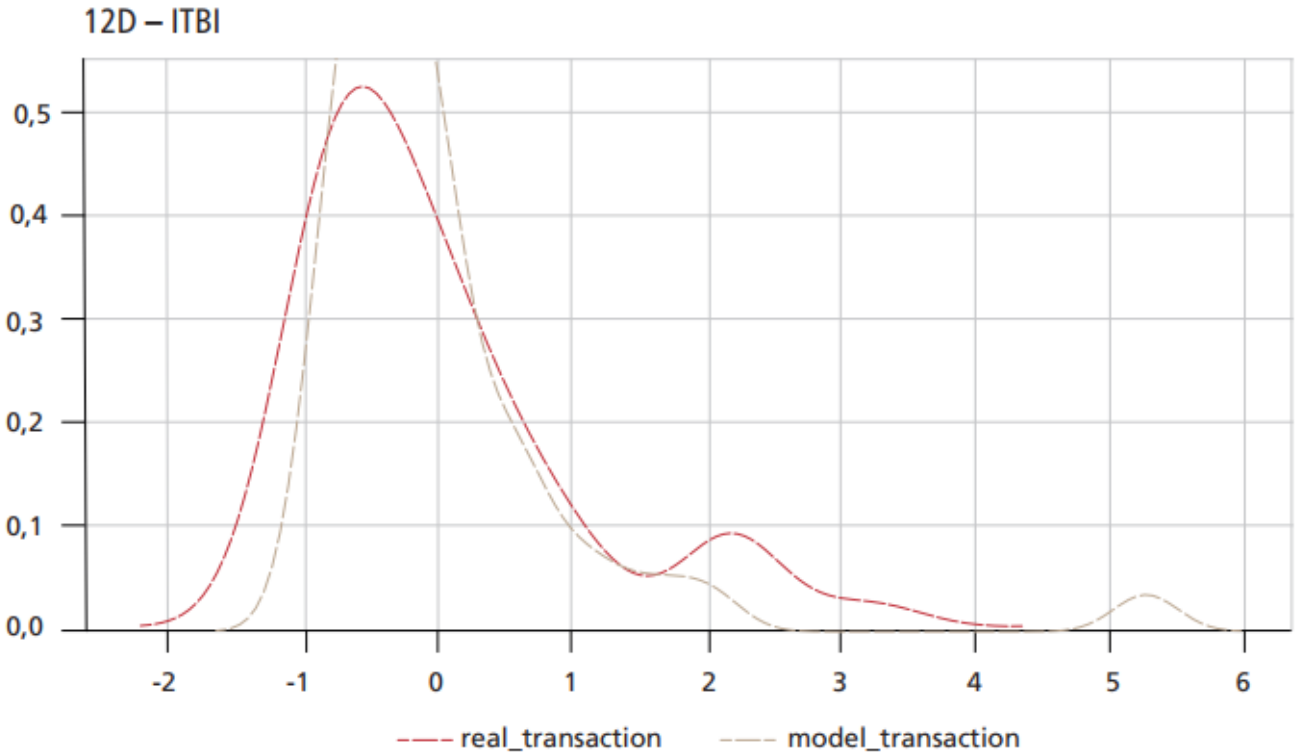


Author's elaboration.

Validation IV: Property tax



Validation IV: Transactions tax

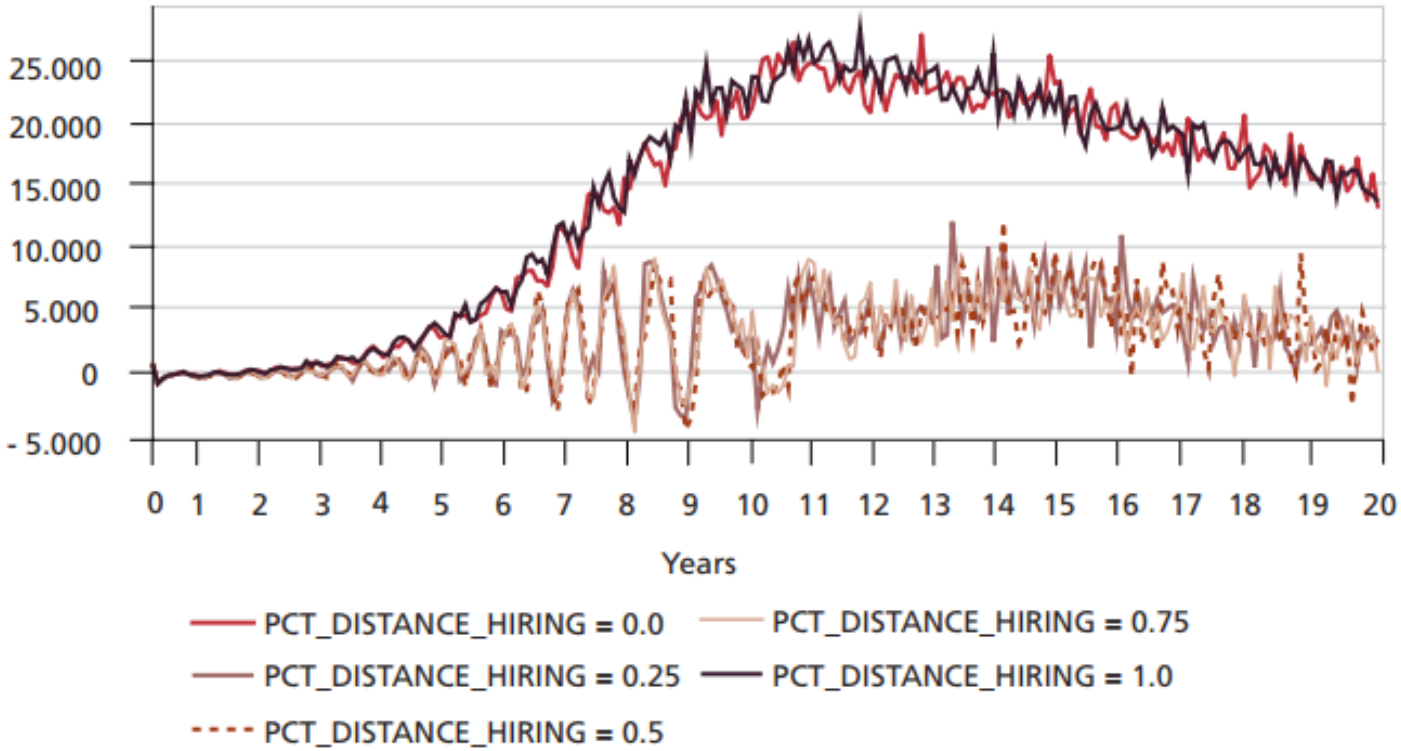


Author's elaboration.

Validation V: rules

GRAPH 1

Sensitivity analysis of the hiring rule by distance criterion 'for firms' profit

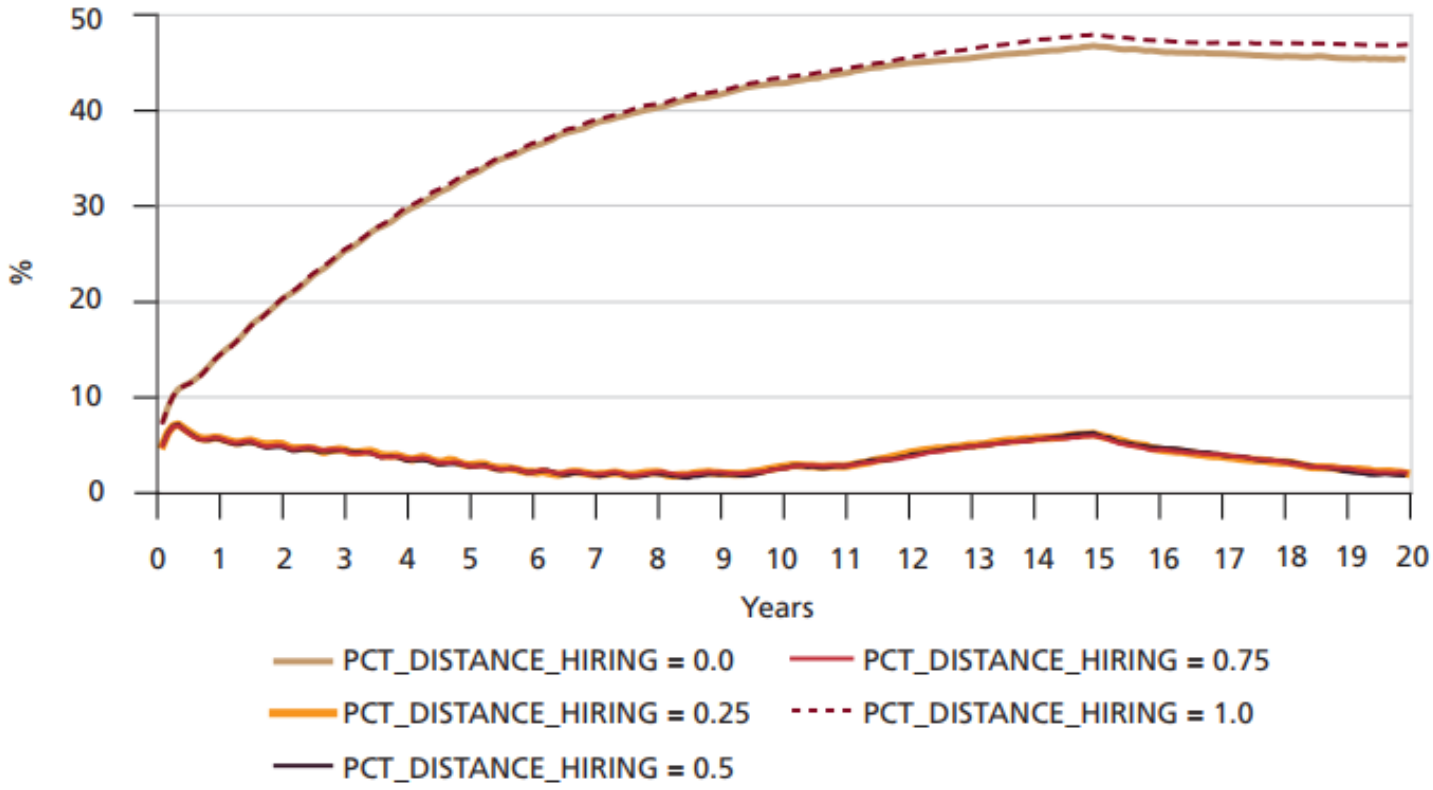


Author's elaboration.
Note: Results for Belo Horizonte, with 2% of the population, average of three simulations.

Validation V: rules

GRAPH 2

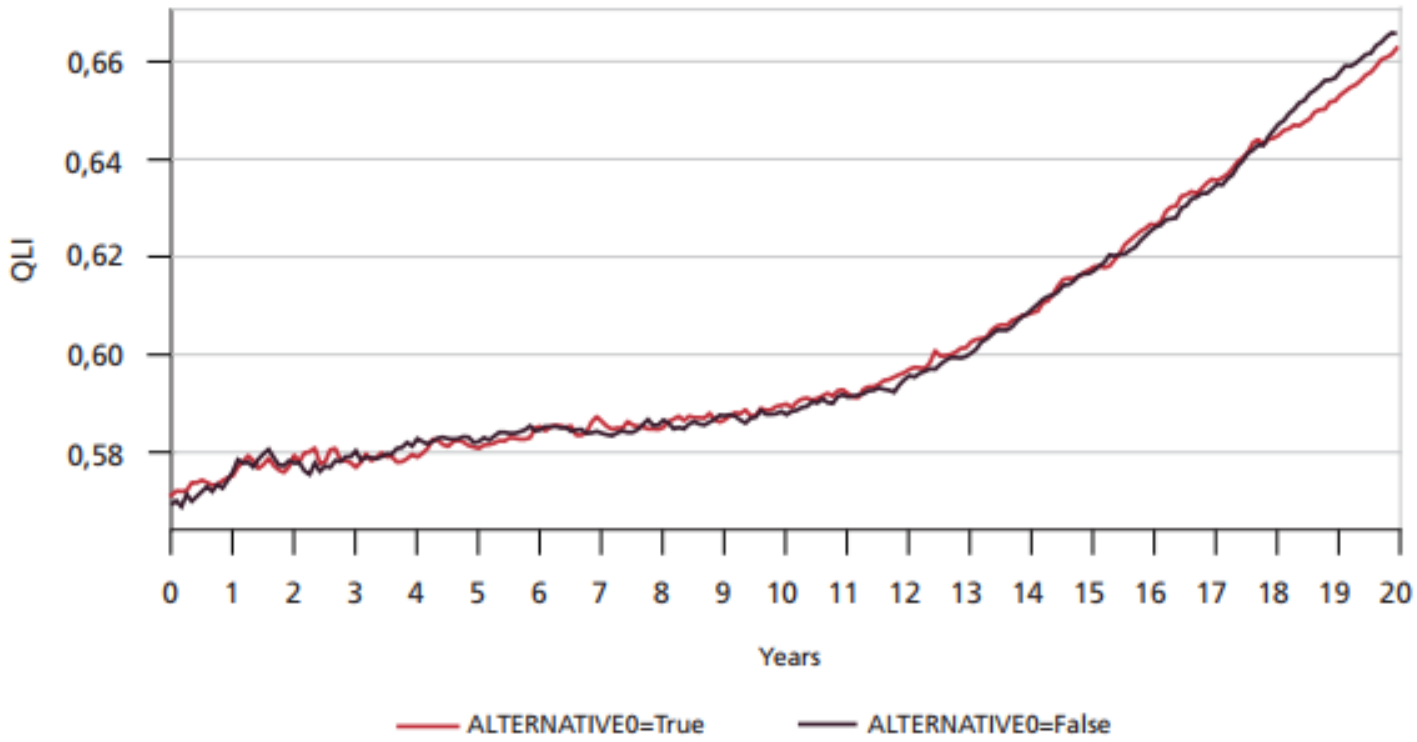
Sensitivity analysis of the hiring rule by distance criterion for unemployment



Author's elaboration.
Note: Results for Belo Horizonte, with 2% of the population, average of three simulations.

GRAPH 3

Distributive rule alternative, municipalities together or apart with MPF rule

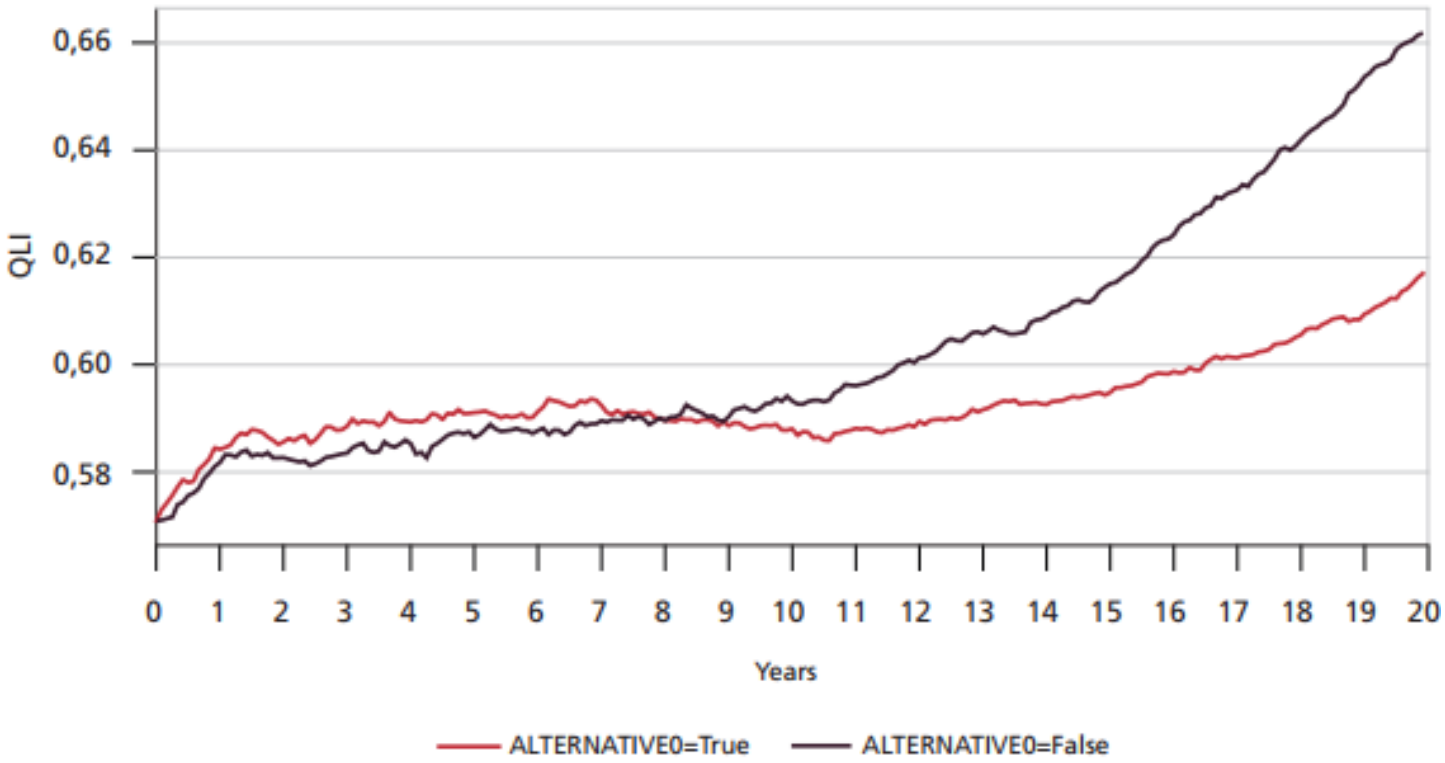


Author's elaboration.

Notes: 1. This simulation follows the default setting in which MFP=TRUE.
2. Results for Brasília with 1% of the population, average of five simulations.

GRAPH 1

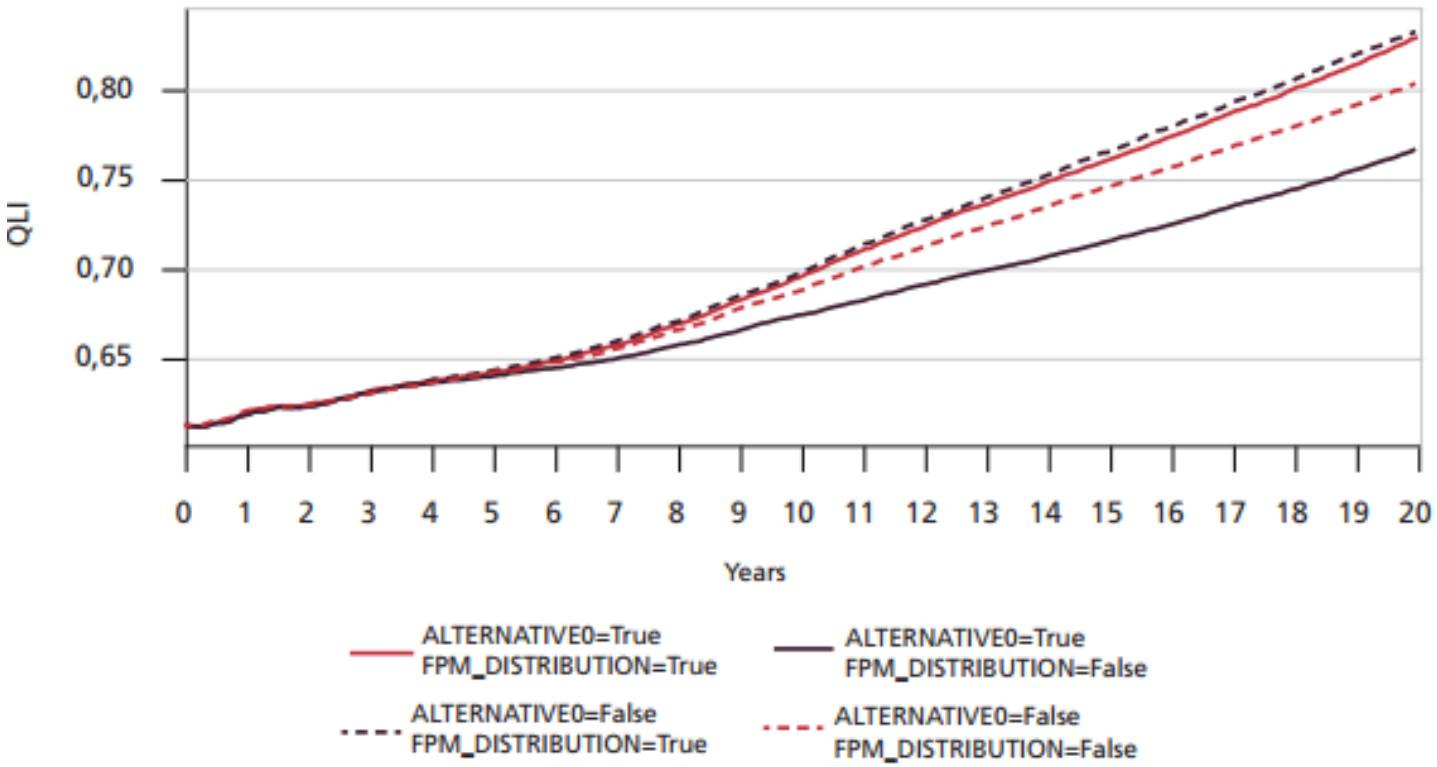
Distributive rule alternative, municipalities together or apart without MPF rule



Author's elaboration.

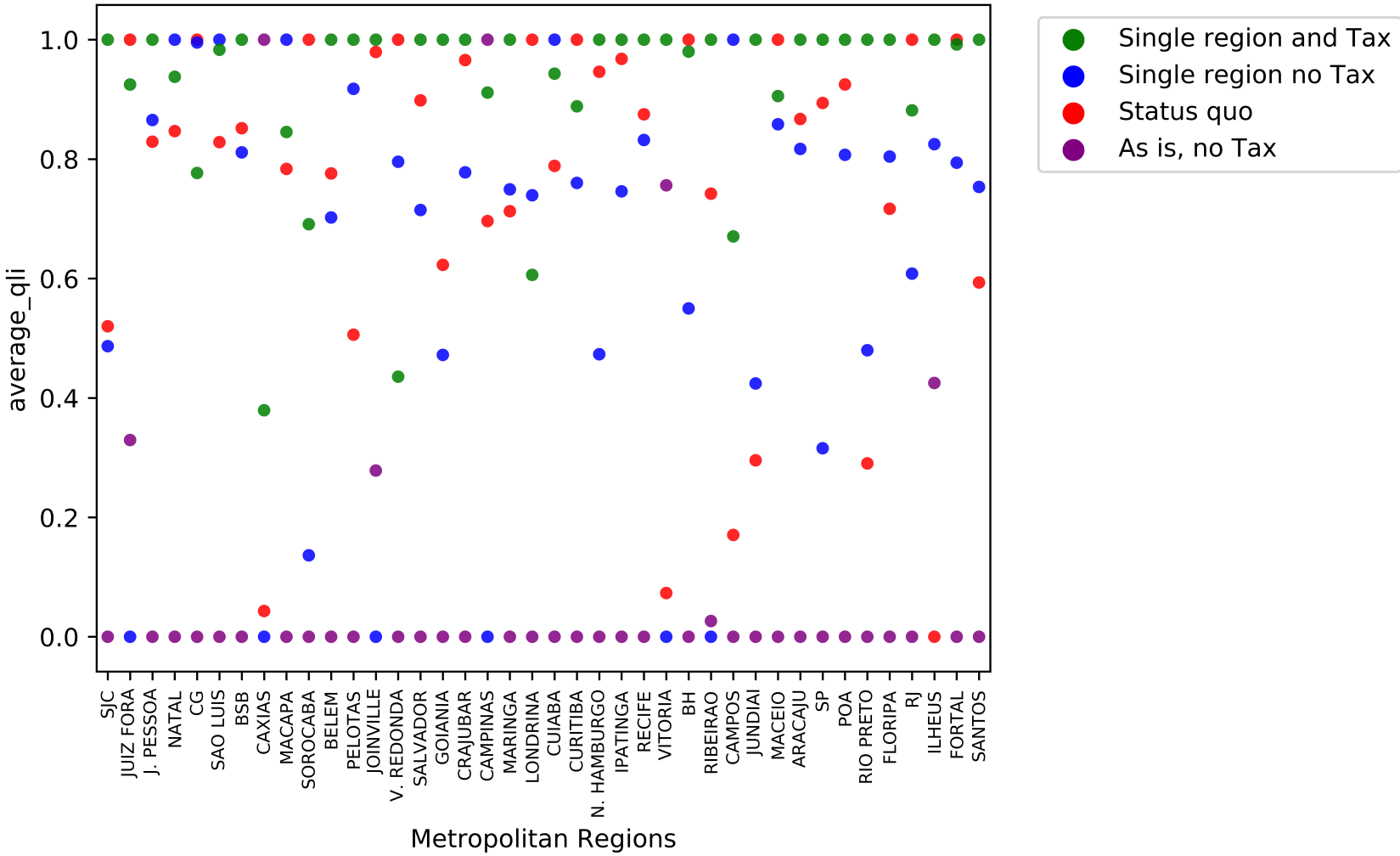
Notes: 1. The average QLI is always weighted by the population. For this simulation MFP=FALSE.
2. Results for Brasília with 1% of the population, average of four simulations.

GRAPH 4
Distributive rule alternatives



Author's elaboration.
Note: Results for Rio de Janeiro with 2% of the population, average of ten simulations.

ipea Institute for Applied Economic Research


Single region and Tax
Single region no Tax
Status quo
As is, no Tax
average_qli
1.0
0.8
0.6
0.4
0.2
0.0
SJC
JUIZ FORA
J. PESSOA
NATAL
CG
SAO LUIS
BSB
CAXIAS
MACAPA
SOROCABA
BELEM
PELOTAS
JOINVILLE
V. REDONDA
SALVADOR
GOIANIA
CRAJUBAR
CAMPINAS
MARINGA
LONDRINA
CUIABA
CURITIBA
N. HAMBURGO
IPATINGA
RECIFE
VITORIA
BH
RIBEIRAO
CAMPOS
JUNDIAI
MACEIO
ARACAJU
SP
POA
RIO PRETO
FLORIPA
RJ
ILHEUS
FORTAL
SANTOS
Metropolitan Regions

OLS Regressions

	Simul.1	Simul.2	Real.1	Real.2
ALTERNATIVE0[T.True]	−0.01***	−0.01*	−0.01***	−0.01
	(0.00)	(0.01)	(0.00)	(0.01)
FPM_DISTRIBUTION[T.True]	0.02***	0.02**	0.02***	0.02*
	(0.00)	(0.01)	(0.00)	(0.01)
	...	...	...	...
Log-likelihood	506.85	266.99	260.65	129.08
R-squared Adj	0.98	0.60	0.98	0.52
AIC	−931.69	−517.97	−477.31	−246.16
BIC	−806.65	−493.57	−424.90	−231.87
No. observations	156	156	80	80

- Data exploration
- Demographic analysis
- Social mobility and inequality
- Detailed tax analysis
- Specificities of real estate market
- Firms
  - Decision-making rules
  - Product innovation
  - Sectors
- Qualification investment

Machine learning

- Attempt to map from parameters to model outputs
- ... and back
  - 693 *conf.json* 693 set of outputs
  - Targets: highest GDP and lowest GINI
  - Calibration

Transit simulation

[1] B. A. Furtado, *Modeling social heterogeneity, neighborhoods and local influences on urban real estate prices: spatial dynamic analyses in the Belo Horizonte metropolitan area, Brazil*. Netherlands Geographical Studies ISSN 0169-4839, Utrecht, The Netherlands: Faculteit Geowetenschappen Universiteit Utrecht, 2009.

[2] B. A. Furtado, C. Krause, and K. C. França, *Território metropolitano, políticas municipais: por soluções conjuntas de problemas urbanos no âmbito metropolitano*. Brasília, DF: Ipea, 2013.

[3] R. Ahrend, E. Farchy, I. Kaplanis, and A. C. Lembcke, "What makes cities more productive? Evidence on the role of urban governance from five OECD countries," *OECD Regional Development Working Papers*, vol. 2014, no. 5, p. 33, 2014.

[4] B. A. Furtado, L. Mation, and L. Monasterio, "Fatos estilizados das finanças públicas municipais metropolitanas brasileiras entre 2000-2010," in *Território metropolitano, políticas municipais*, pp. 291–312, Brasília: Bernardo Alves Furtado; Cleandro Krause; Karla França, 2013.

[5] C. E. Gasparini and R. B. Miranda, "Transferências, equidade e eficiência municipal no Brasil," *Planejamento e Políticas Públicas*, Oct. 2011.

[6] O. L. C. d. F. Firkowski, "Metrópoles e regiões metropolitanas no Brasil: conciliação ou divórcio," in *Território metropolitano, políticas municipais*, pp. 21–52, Brasília: Bernardo Alves Furtado, Cleandro Krause, Karla França, 2013.

[7] A. L. Rodrigues, "Ingovernabilidade metropolitana e segregação espacial: receita para a explosão da violência," in *Território metropolitano, políticas municipais*, pp. 53–82, Brasília: Bernardo Alves Furtado, Cleandro Krause, Karla França, 2013.

[8] L. d. O. Royer, "Municípios "autárquicos" e região metropolitana: a questão habitacional e os limites administrativos.," in *Território metropolitano, políticas municipais*, pp. 157–194, Brasilia: IPEA, 2013.

[9] M. Lengnick, "Agent-based macroeconomics: A baseline model," *Journal of Economic Behavior & Organization*, vol. 86, pp. 102–120, 2013.

[10] H. Dawid and D. D. Gatti, "Agent-Based Macroeconomics," in *Handbook on Computational Economics*, vol. IV, Elsevier, 2018.

[11] J. R. R. Afonso, J. Morais Soares, and K. P. d. Castro, "Avaliação da estrutura e do desempenho do sistema tributário brasileiro: Livro branco da tributação Brasileira," tech. rep., Inter-American Development Bank, 2013.

Thank you! Questions? Collaborations?

- bernardo.furtado@ipea.gov.br
- researchgate.net/profile/Bernardo_Furtado
- GitHub/BAFurtado/PolicySpace
- https://sites.google.com/view/bernardo-alves-furtado/home