NEREUS
Núcleo de Economia Regional e Urbana da Universidade de São Paulo
The University of São Paulo Regional and Urban Economics Lab

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POLICY CENTER FOR THE NEW SOUTH
THINK • STIMULATE • BRIDGE

Modelo de Equilibrio General en la Evaluación de Desastres

Comisión Nacional de Prevención de Riesgos y Atención de Emergencias – Desarrollo Estratégico del SNGR, San José, Costa Rica, 2-3 de junio, 2022

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What is a CGE?

Computable, based on data

It has many sectors

And perhaps many regions, primary factors and households

A big database of matrices

Many, simultaneous, equations (hard to solve)

Prices guide demands by agents

Prices determined by supply and demand

Trade focus: elastic foreign demand and supply

General features of CGE models

CGE models include equations specifying:

- market-clearing conditions for commodities and primary factors
- producers' demands for produced inputs and primary factors
- final demands (investment, household, export and government)
- the relationship of prices to supply costs and taxes
- various macroeconomic variables and price indices

Neo-classical flavor

- demand equations consistent with optimizing behavior (cost minimization, utility maximization)
- competitive markets: producers price at marginal cost

CGE simplifications

Not much dynamics (leads and lags)

An imposed structure of behavior, based on theory

Neoclassical assumptions (optimizing, competition)

Nesting (separability assumptions)

Why: time series data for huge matrices cannot be found

Theory and assumptions (partially) replace econometrics

What is a CGE model good for?

Analyzing policies that affect different sectors in different ways

The effect of a policy on different:

- Sectors
- Regions
- Factors (Labor, Land, Capital)
- Household types

Policies (tariff or subsidies) that help one sector a lot, and harm all the rest a little

What-if questions

What if productivity in agriculture increased 1%?

What if foreign demand for exports increased 5%?

What if consumer tastes shifted towards imported food?

What if CO2 emissions were taxed?

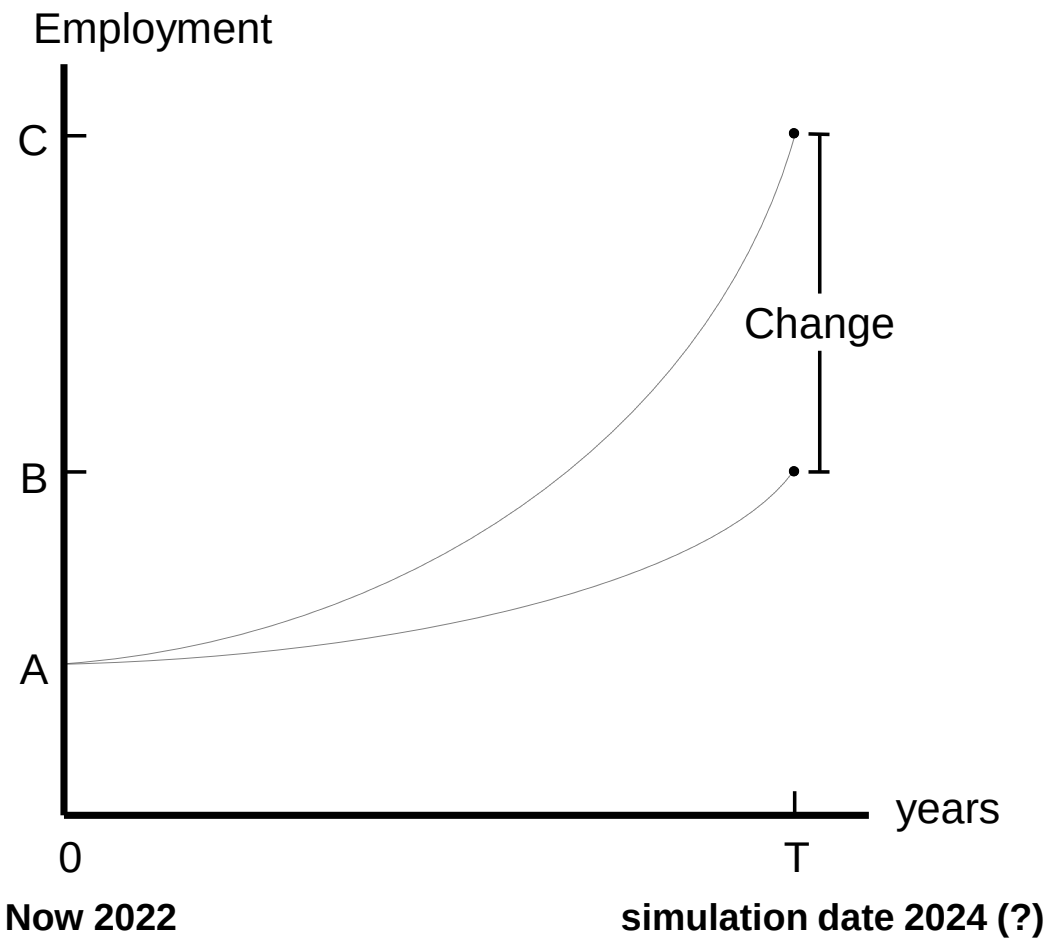
What if water became scarce?

A great number of exogenous variables (tax rates, endowments, technical coefficients)

Comparative static models: results show effect of policy shocks only, in terms of changes from initial equilibrium

Comparative-static interpretation of results

Results refer to changes at *some* future point in time



Regional modeling

Intense interest in regional results

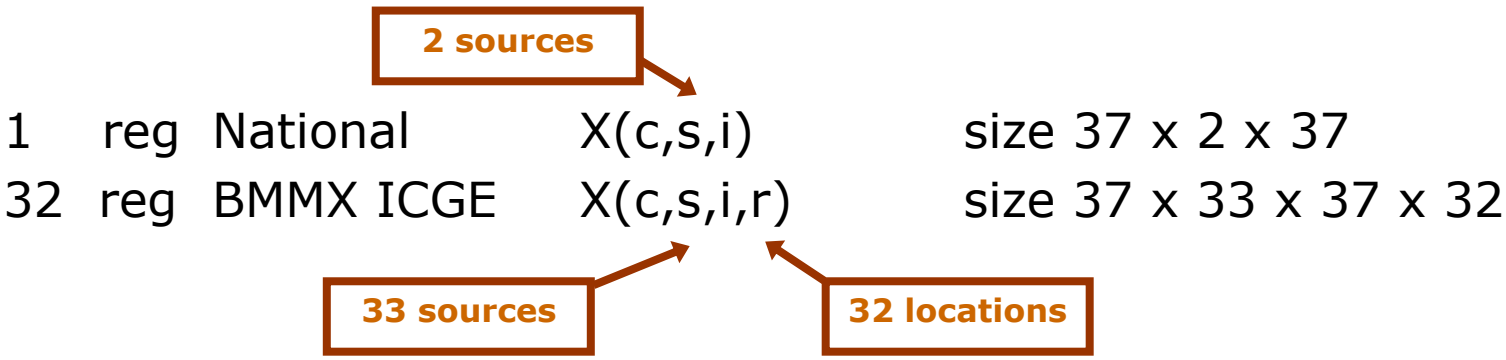
Policies which are good for nation but bad for one region may not be politically feasible

Assistance to one region may harm nation

Two approaches: **Bottom-Up** or Top-Down

The bottom-up approach

Simply add a regional subscript (or two) to each variable and data



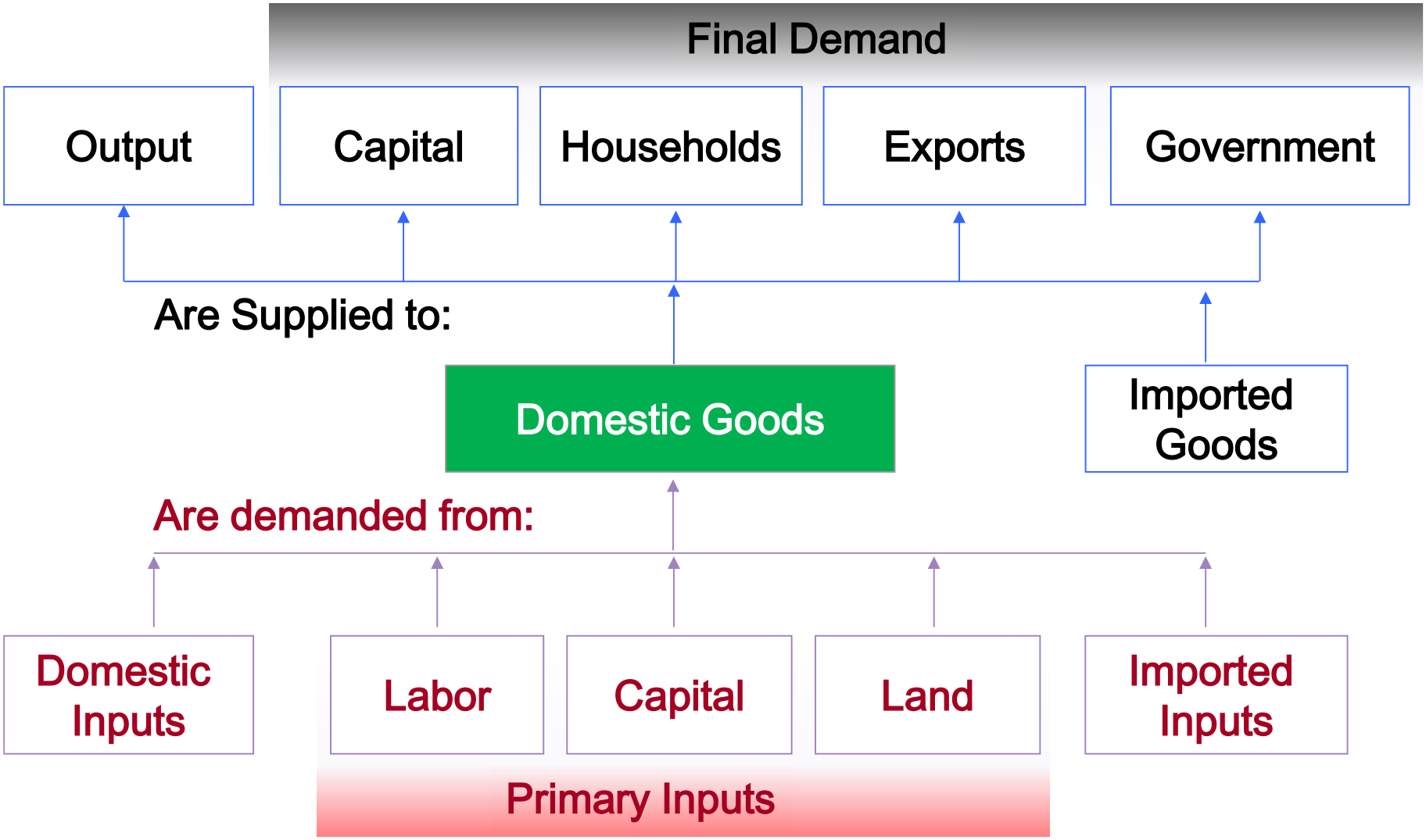
Database has grown by factor of [33/2]*32 = 528

Number of variables also 528 times bigger

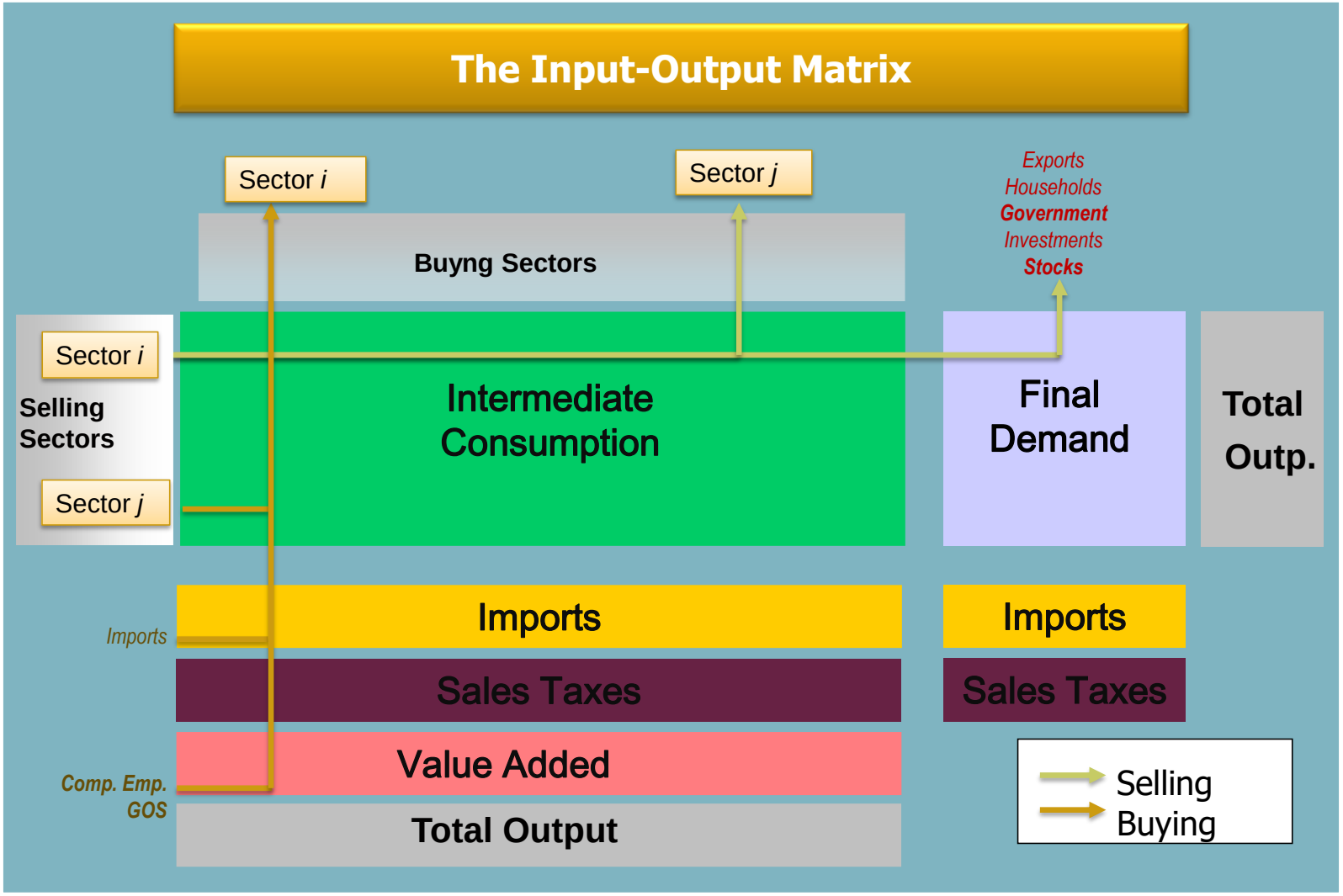
Solve time and memory needs move with SQUARE of model size

(so model needs 280,000 times as much memory and takes 280,000 times longer to solve)

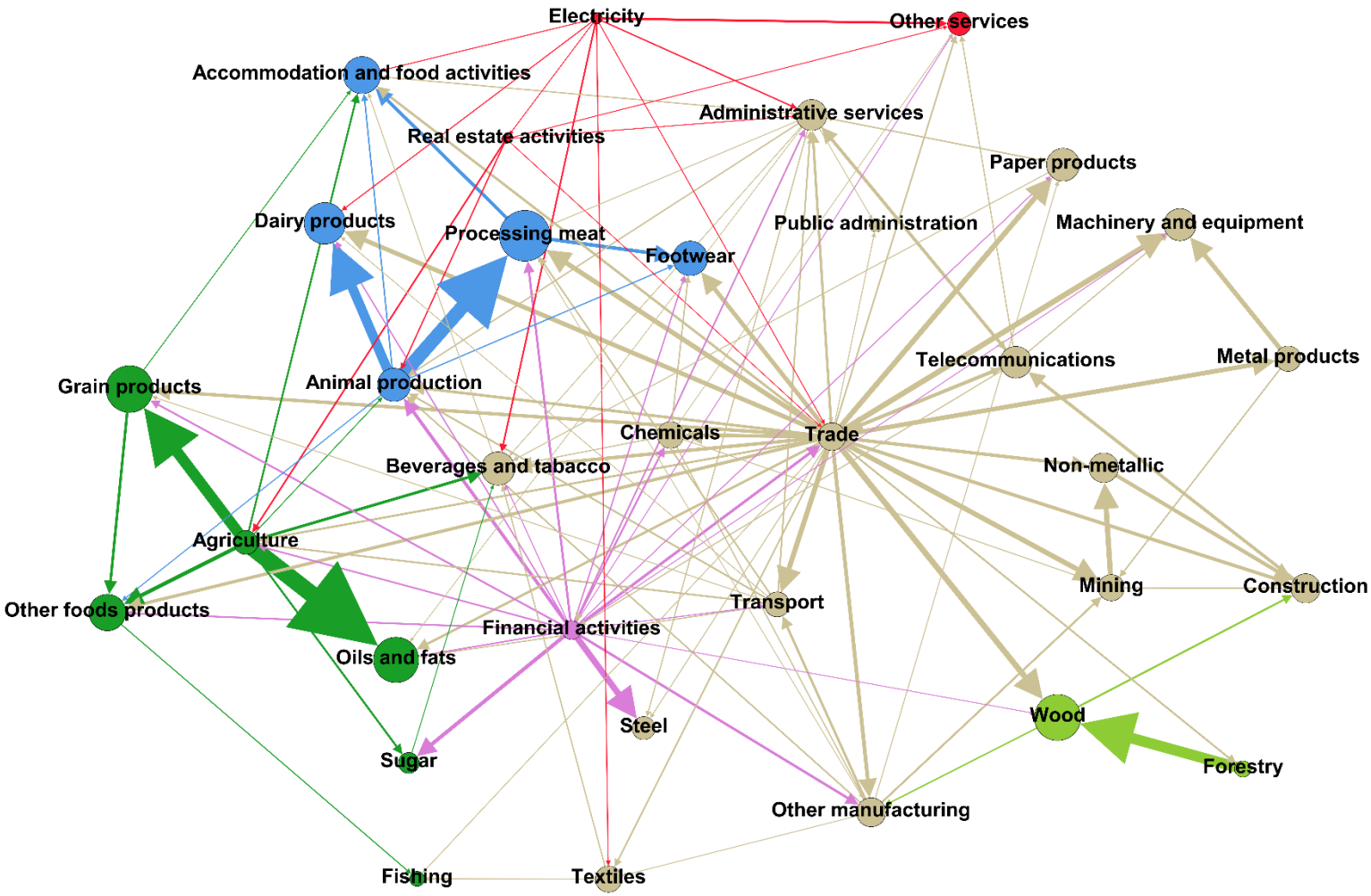
Stylized GE model: input-output flows



Input-output table



Input-output network in Paraguay

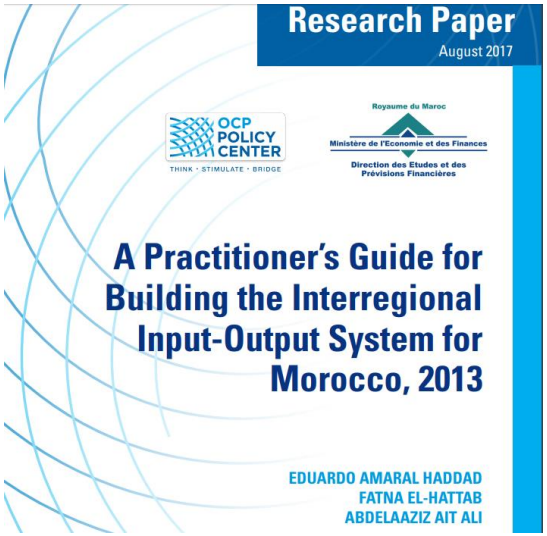


Interregional IO models

	Buying Sectors Region L	Buying Sectors Region M			
Selling sectors **Region L**	Interindustry Inputs LL	Interindustry Inputs LM	FD LL	FD LM	TO L
Selling sectors **Region M**	Interindustry Inputs ML	Interindustry Inputs MM	FD ML	FD MM	TO M
	Imports from the World	Imports from the World	M	M	M
	Sales Taxes	Sales Taxes	T	T	T
	Value Added	Value Added			
	Total Output L	Total Output M			

Interregional IO models

Examples of **international applications**: Azores, Angola, Brazil, Chile, Colombia, Egypt, Ecuador, Greece, Iraq, Lebanon, Morocco, Mexico, Paraguay, Saudi Arabia



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Vol. 11, n. 4, pp. 424-446, 2017
http://www.revistaaber.org.br

MATRIZ INTERESTADUAL DE INSUMO-PRODUTO PARA O BRASIL: UMA APLICAÇÃO DO MÉTODO HOAS*

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Interregional Input-Output Tables for Mexico, 2013

Reference: Haddad, E. A., Araújo, I. F., Ibarrarán, M. E., Boyd, R., Elizondo, A., Liedo, P., Belausteguigoitia, J. C., and Menchero, M. (2019). Interregional Input-Output System for Mexico, 2013, *TD NEREUS 07-2019*, The University of São Paulo Regional and Urban Economics Lab (NEREUS).

What should we know?

How microeconomic theory – cost-minimizing, utility-maximizing – underlies the equations

The use of nested production and utility functions

How input-output data is used in equations

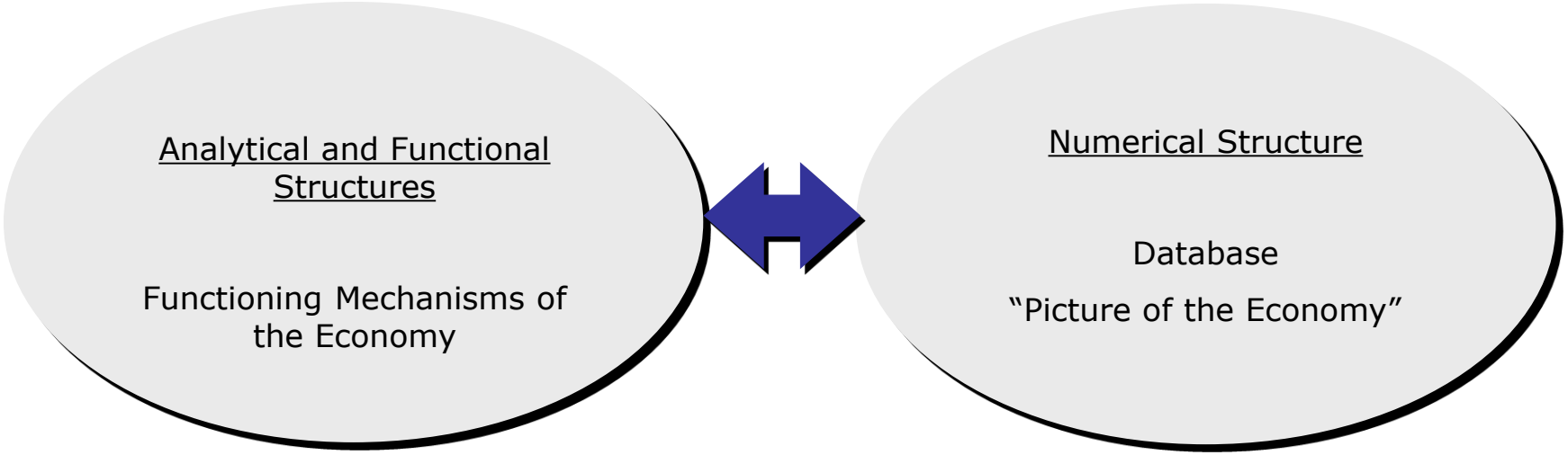
How model equations are represented in percent change form

How choice of exogenous variables makes model more flexible

[How GEMPACK is used to solve the BMMX model]

CGE models mostly similar, so skills will transfer

CGE models – Definition



Nested structures in CGE models

In each industry: Output = function of inputs:

output = F (inputs) = F (Labor, Capital, Land, dom. goods, imp. goods)

Separability assumptions simplify the production structure:

output = F (primary factor composite, composite goods)

where: primary factor composite = CES (Labor, Capital, Land)

labor = CES (Various skill grades)

composite good (i) = CES (domestic good (i), imported good (i))

All industries share common production structure

BUT: Input proportions and behavioral parameters vary

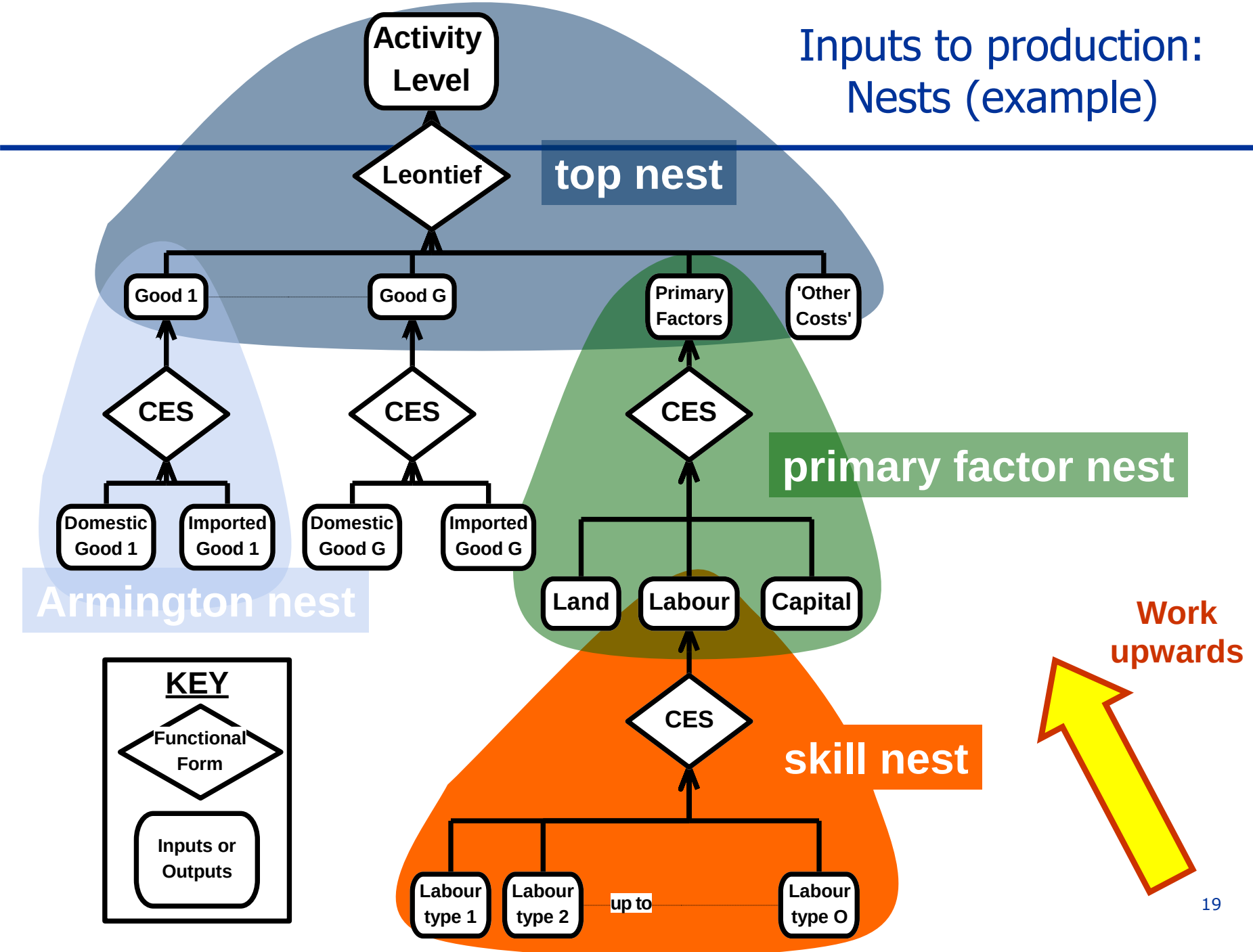
Nesting is like staged decisions:

First decide how much leather to use – based on output

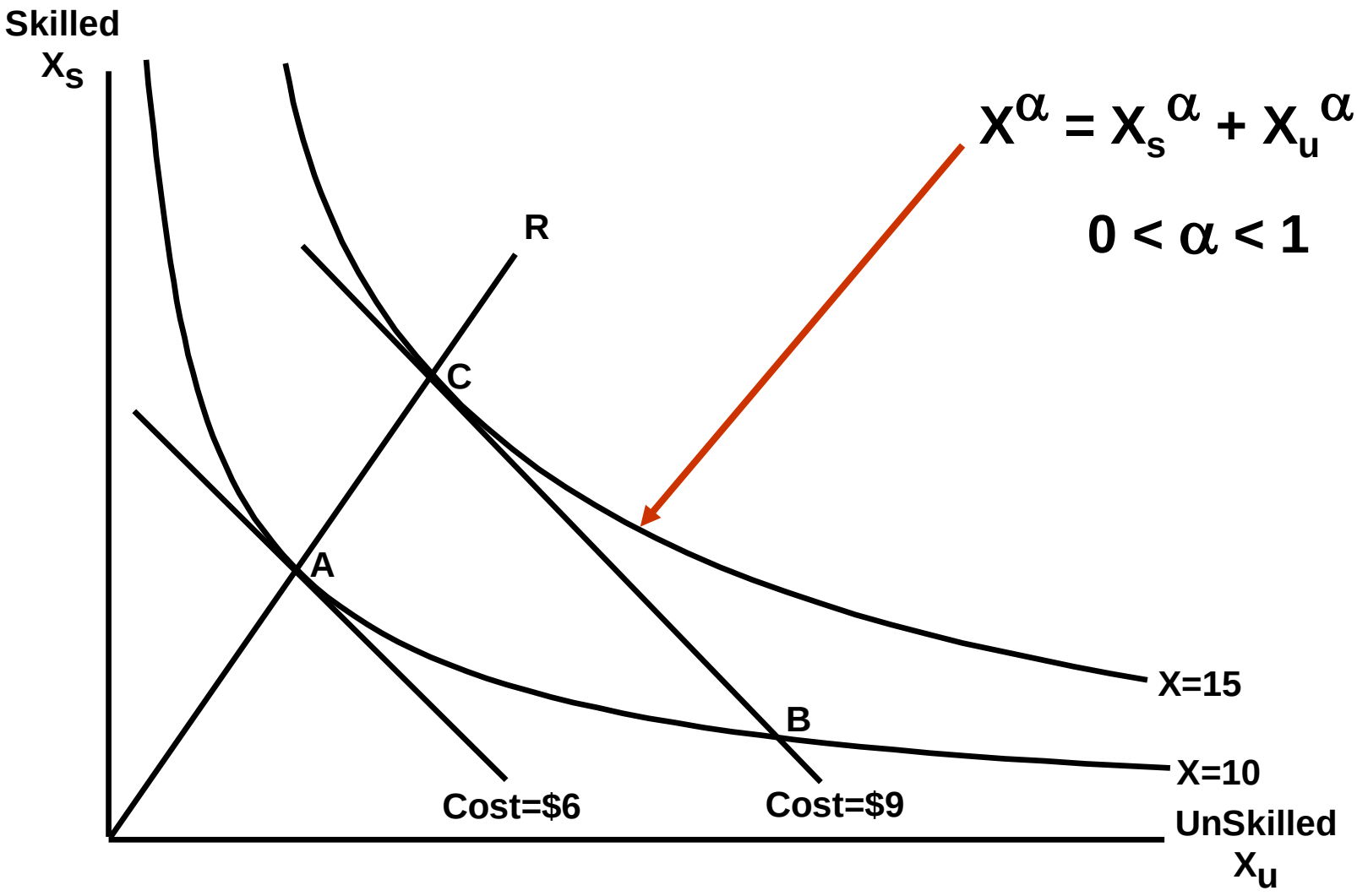
Then decide import/domestic proportions, depending on the relative prices of local and foreign leather

Each nest requires 2 or 3 equations

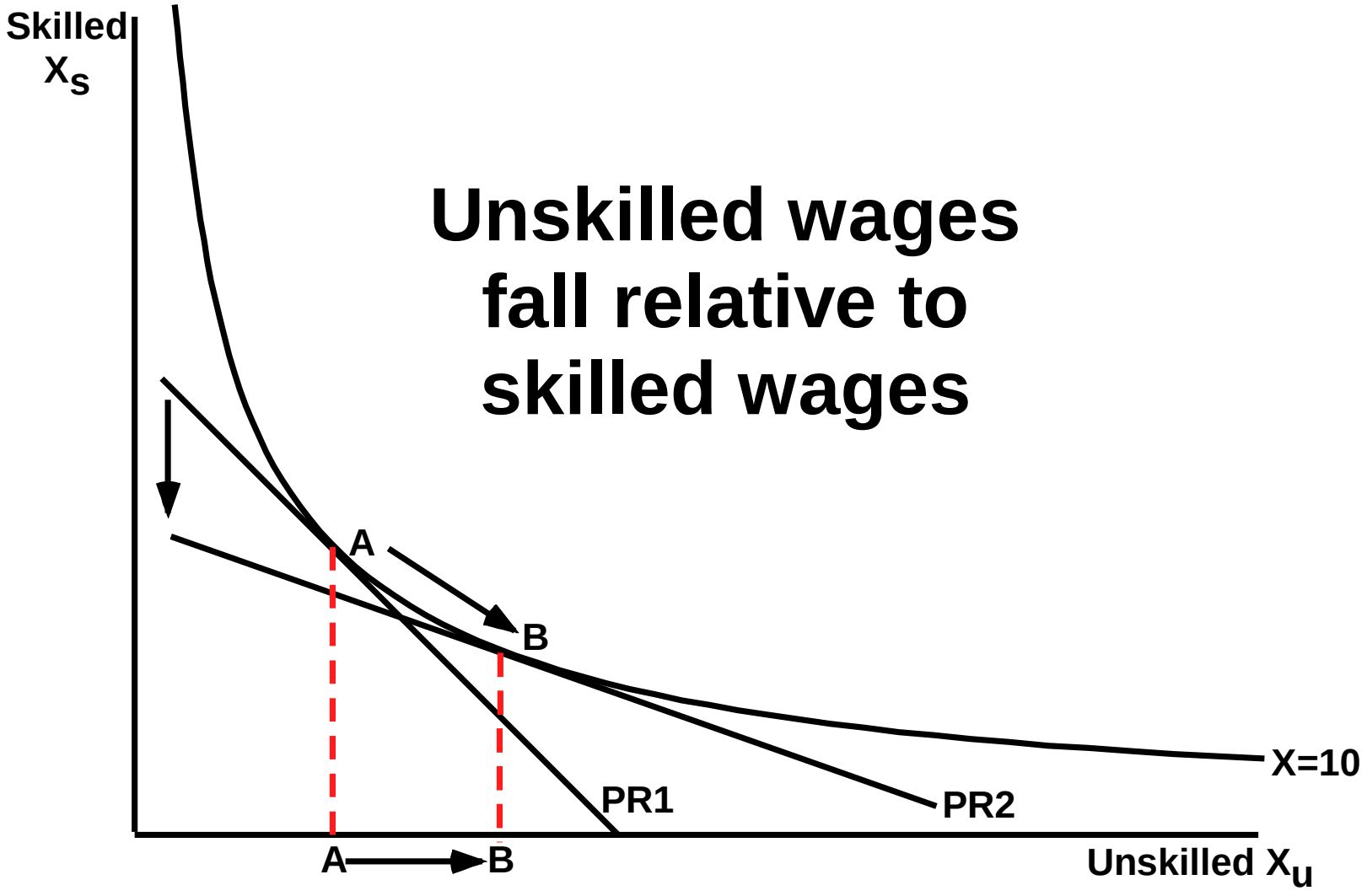
Inputs to production: Nests (example)



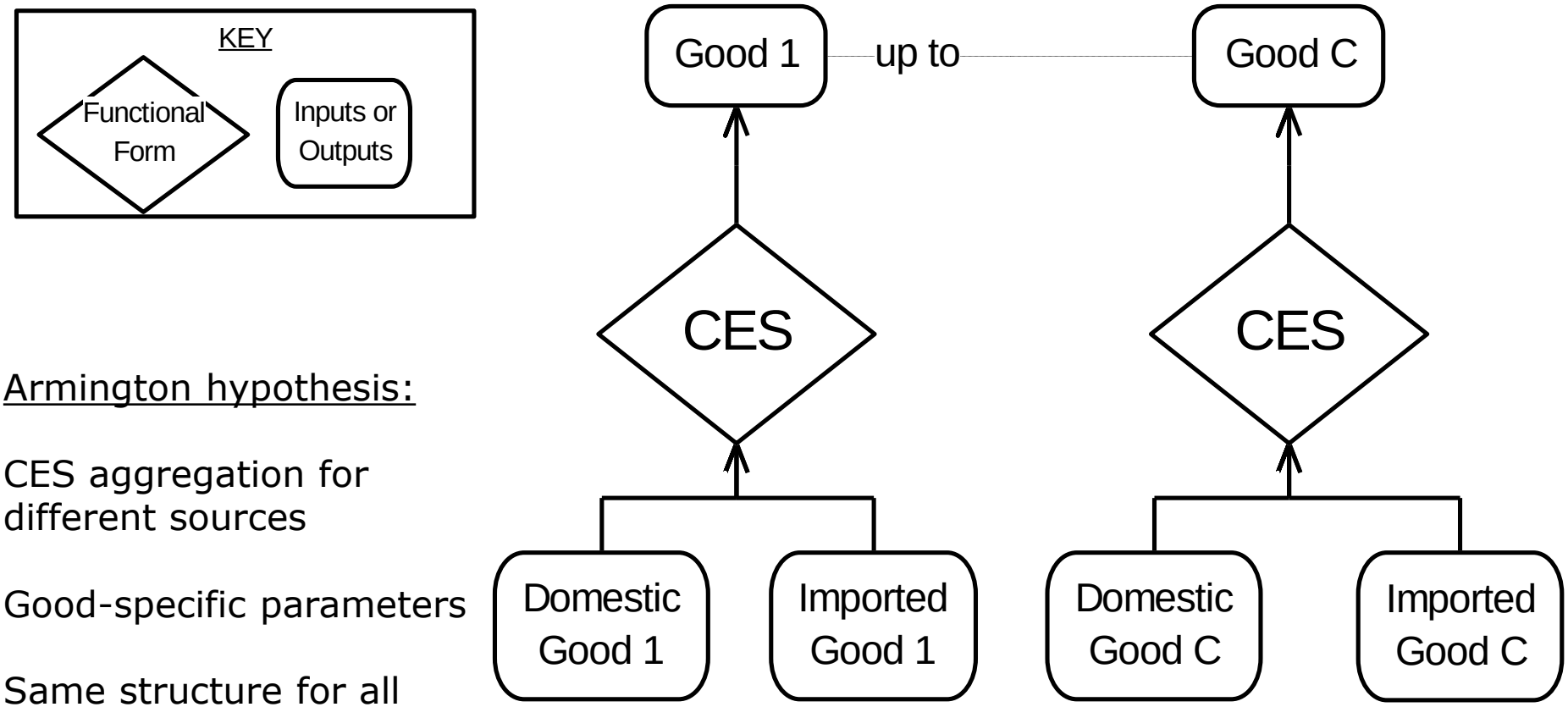
Example 1: CES skill substitution



Effect of price change



Example 2: Substitution between domestic and imported sources



Armington hypothesis:

CES aggregation for different sources

Good-specific parameters

Same structure for all users

Numerical example

$\mathbf{p = S_d p_d + S_m p_m}$	average price of manufactures dom. e imp.
$\mathbf{x_d = x - \sigma(p_d - p)}$	demand for domestic manufactures
$\mathbf{x_m = x - \sigma(p_m - p)}$	demand for imported manufactures

Let $\mathbf{p_m = -10\%; x = p_d = 0; S_m = 0.3}$ **and** $\mathbf{\sigma = 2}$

Then, cheaper imports imply:

$\mathbf{p=-0.3(-10\%) =-3\%}$	*decrease in the average price of imp. mnf.*
$\mathbf{x_d=-2[0-(-3\%)]=-6\%}$	*decrease in domestic demand*
$\mathbf{x_m=-2[-10\%-(-3\%)]=14\%}$	*increase in import volume*

Effects on domestic sales are proportional to $\mathbf{S_m}$ e $\mathbf{\sigma}$

Johansen models

Class of general equilibrium models in which a equilibrium is a vector *V*, of length *n* satisfying a system of equations

$$F(V) = 0 \qquad (1)$$

where *F* is a vector function of length *m*

We assume that *F* is differentiable and that the number of variables, *n*, exceeds the number of equations *m*

Johansen's approach is to derive from (1) a system of linear equations in which the variables are changes, percentage changes or changes in the logarithms of the components of *V*

Illustrative computations

We will assume that the system (1) consists of 2 equations and 3 variables and has the form

$$\begin{cases} V_1^2 V_3 - 1 = 0 \\ V_1 + V_2 - 2 = 0 \end{cases}$$

V_1 and V_2 (endogenous); V_3 (exogenous)

$$\begin{cases} V_1 = V_3^{-1/2} \\ V_2 = 2 - V_3^{-1/2} \end{cases}$$

Illustrative computations (cont.)

Initial solution: $V^I = (V_1^I, V_2^I, V_3^I) = (1,1,1)$

What is the effects on V_1 and V_2 of a shift in V_3 from 1 to 1.1?

$$\boxed{\begin{aligned} V_1 &= 0.9535 \\ V_2 &= 1.0465 \end{aligned}}$$

Johansen approach:

- Complexity and size of the system (1) normally rule out the possibility of deriving from it explicitly solution equations
- Solve a linearized version of (1)

Step by step

Derive from (1) a differential form

$$A(V)v = 0 \qquad (2)$$

v is usually interpreted as showing percentage changes or changes in the logarithms of the variables *V*

Johansen-style computations make use of a initial solution, V^I, with results being reported usually as percentage deviations from this initial solution

$$A(V) \rightarrow A(V^I) \quad \text{fixed matrix ("model")}$$

Step by step (cont.)

Derivation of (2) is by total differentiation of (1)

$$\begin{bmatrix} 2V_1V_3 & 0 & V_1^2 \\ 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} dV_1 \\ dV_2 \\ dV_3 \end{bmatrix} = 0$$

Se $V = V^I$,

$$A(V^I)v = 0 \qquad (3)$$

$$\begin{bmatrix} 2 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} dV_1 \\ dV_2 \\ dV_3 \end{bmatrix} = 0$$

Step by step (cont.)

On choosing variable 3 to be exogenous:

$$\begin{bmatrix} 2 & 0 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} dV_1 \\ dV_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} dV_3 = 0$$

$$A_\alpha(V^I)v_\alpha + A_\beta(V^I)v_\beta = 0 \qquad (4)$$

$$\begin{bmatrix} dV_1 \\ dV_2 \end{bmatrix} = -\begin{bmatrix} 2 & 0 \\ 1 & 1 \end{bmatrix}^{-1}\begin{bmatrix} 1 \\ 0 \end{bmatrix} dV_3$$

$$v_\alpha = -A_\alpha{}^{-1}(V^I)A_\beta(V^I)v_\beta \qquad (5)$$

$$\begin{bmatrix} dV_1 \\ dV_2 \end{bmatrix} = \begin{bmatrix} -0.5 \\ 0.5 \end{bmatrix} dV_3$$

$$v_\alpha = B(V^I)v_\beta \qquad (6)$$

Any difference?

Before: $V_3 \uparrow$ 10% $\rightarrow$ $V_1 \downarrow$ 4.65%, $V_2 \uparrow$ 4.65%

Now: $V_3 \uparrow$ 10% $\rightarrow$ $V_1 \downarrow$ 5%, $V_2 \uparrow$ 5%

Differences are due to linearization errors…

The operations give us the values of the derivatives or elasticities only for the initial values, V^I, of the variables

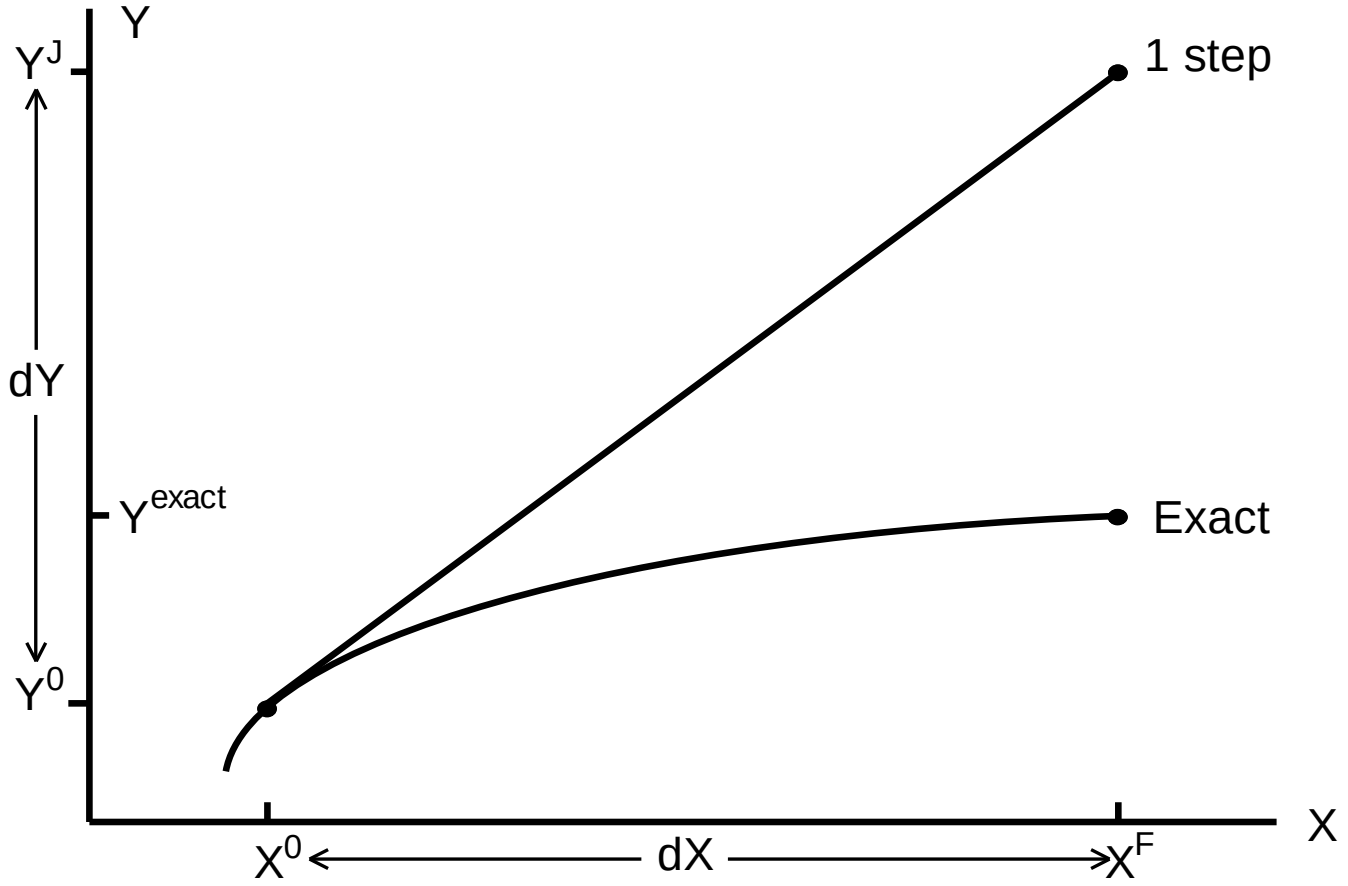
When we move away from V^I, the derivatives or elasticities will change

In percentage change form:

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = -\begin{bmatrix} 2 & 0 \\ 0.5 & 0.5 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ 0 \end{bmatrix} v_3$$

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} -0.5 \\ 0.5 \end{bmatrix} v_3$$

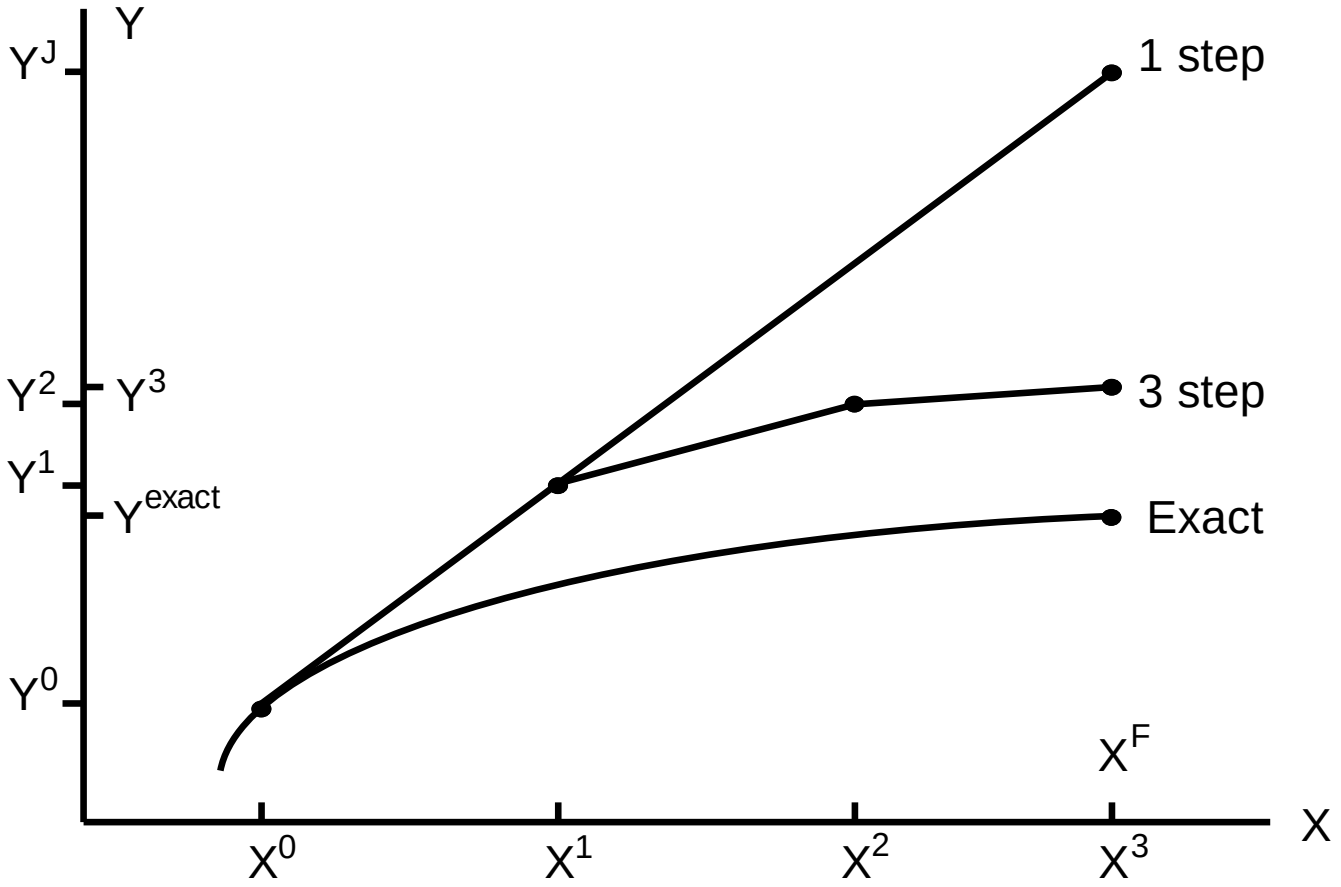
Linearization error



Y^J is *Johansen* estimate

Error is proportionately less for smaller changes

Breaking large changes in X into a number of steps



Multi-step process to reduce linearization error

Extrapolating from Johansen and Euler approximations

Method	y	Error
Johansen (1-step)	150%	50%
Euler 2-step	125%	25%
Euler 4-step	112.3%	12.3%
Euler ∞-step (exact)	100%	0

The error follows a rule (*arbitrary* polynomial approximation of continuous function)

Use results from 3 approximate solutions to estimate exact solution + error bound

Summary

1. We start with the model's equations represented in their levels form

2. The equations are linearized: take total differential of each equation

3. Total differential expressions converted to (mostly) % change form

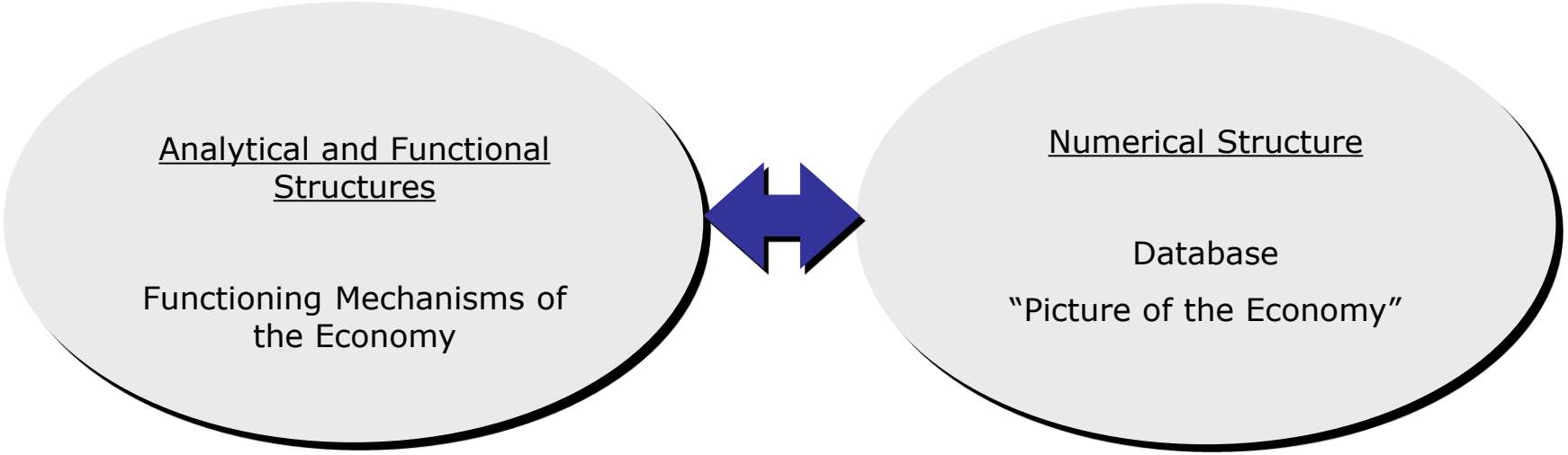
4. Linear equations evaluated at initial solution to the levels model

5. Exogenous variables chosen; model then solved for movements in endogenous variables, given user-specified values for exogenous variables

But, a problem: *linearization error*

Multi-step, extrapolation

Dealing with uncertainty



behavioral parameters and structural coefficients

Dealing with uncertainty

CGE models have been frequently criticized for resting on weak empirical foundations

It is not always easy to find empirical estimates of key parameters, such as substitution elasticities, in the literature.

If there is a considerable uncertainty surrounding the "right" parameters, and these are key elements in the CGE results, a consistent procedure in their evaluation is imperative

The problem in CGE models is compounded by the presence of a variety of parameters, some estimated with known probability distributions, others with no known distributions combined with input-output/SAM data that are provided as point estimates

Sensitivity analysis in CGE models

If a consistent econometric estimation for key parameters in a CGE model study is not possible, the effort should be directed to tests of the uncertainty surrounding these parameters in terms of their impact on the model

Estimate policy results based on different qualitative sets of values for the behavioral parameters and structural coefficients

Through the judgment of the modeler, a range of alternative combinations reflecting differential structural hypotheses for the regional economies can be used to achieve a range of results for a policy simulation

Systematic sensitivity analysis in CGE models

Problem of numerical integration:

CGE model: $F(v, a) = 0$

Solution vector: $v^*(a) \equiv H(a)$

Mean: $E[H(a)] = \int_\Omega H(a)g(a)da$

Variance:

$$E[(H(a) - E[H(a)])^2] = \int_\Omega (H(a) - E[H(a)])^2 g(a)da$$

Systematic sensitivity analysis in CGE models

Problem of numerical integration:

$$\int_a^b f(x)g(x)dx \longrightarrow \sum_{j=1}^{J} w_j \sum_a^b f(x^j)$$

Numerical approximation

Monte Carlo: J random numbers generated from $g(x)$, in the interval *[a,b]*, integrating J times with the weights $w_j = 1/\mathrm{J}$

Sensitivity analysis in CGE models

$$F(V) = 0$$

$$A(V)v = 0$$

$$A(V^I)v = A_\alpha(V^I)v_\alpha + A_\beta(V^I)v_\beta = 0$$

$$v_\alpha = -A(V^I)^{-1}A_\beta(V^I)v_\beta$$

$$v_\alpha = B(V^I)v_\beta$$

Sensitivity analysis in CGE models

$$\begin{bmatrix} v_{\alpha 1} \\ \dots \\ v_{\alpha m} \end{bmatrix} = \begin{bmatrix} B_{11} & \dots & B_{1(n-m)} \\ \dots & \dots & \dots \\ B_{m1} & \dots & B_{m(n-m)} \end{bmatrix} \begin{bmatrix} v_{\beta 1} \\ \dots \\ v_{\beta m} \end{bmatrix}$$

$$\begin{bmatrix} v_{\alpha 1} \\ \dots \\ v_{\alpha m} \end{bmatrix} = \begin{bmatrix} B_{11} \\ \dots \\ B_{m1} \end{bmatrix} v_{\beta 1} + \begin{bmatrix} B_{12} \\ \dots \\ B_{m2} \end{bmatrix} v_{\beta 2} + \cdots + \begin{bmatrix} B_{1(n-m)} \\ \dots \\ B_{m(n-m)} \end{bmatrix} v_{\beta (m-n)}$$

$$\widehat{v_\alpha} = \hat{B}\widehat{v_\beta} \quad \text{or} \quad \begin{bmatrix} \widehat{v_{\alpha 1}} \\ \dots \\ \widehat{v_{\alpha k}} \end{bmatrix} = \begin{bmatrix} \widehat{B_{11}} \\ \dots \\ \widehat{B_{k1}} \end{bmatrix} \widehat{v_{\beta 1}} + \begin{bmatrix} \widehat{B_{12}} \\ \dots \\ \widehat{B_{k2}} \end{bmatrix} \widehat{v_{\beta 2}} + \cdots + \begin{bmatrix} \widehat{B_{1j}} \\ \dots \\ \widehat{B_{kj}} \end{bmatrix} \widehat{v_{\beta j}}$$

$$\hat{v}_\beta^* = argmin \left\{ \frac{(\hat{v}_\alpha - t)^2}{t^2} \right\}$$

Applications of CGE models for impact assessment of natural and man-made disasters

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Are CGE models reliable for disaster impact analyses?

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ABSTRACT

This study investigates a fundamental issue of computable general equilibrium (CGE) modeling: are CGE models reliable for measuring the economic consequence analysis of disasters? We assess the outputs of CGE analyses after controlling for various modeling factors such as data, type of model, and modeling mechanisms via a meta-analysis of 253 CGE simulations in 57 empirical studies. Our study arrives at three major findings. First, we confirm that resilience significantly reduces business disruptions from disasters. Second, results using either real-world or hypothetical data tend to vary substantially by hazard type. Third, results are quite sensitive to model assumptions and modeling structure. Overall, we suggest that future impact assessments of disasters should be conducted more cautiously in terms of adopting appropriate data, models, and shock scenarios, in order to improve the validity of CGE modeling outcomes.

ARTICLE HISTORY
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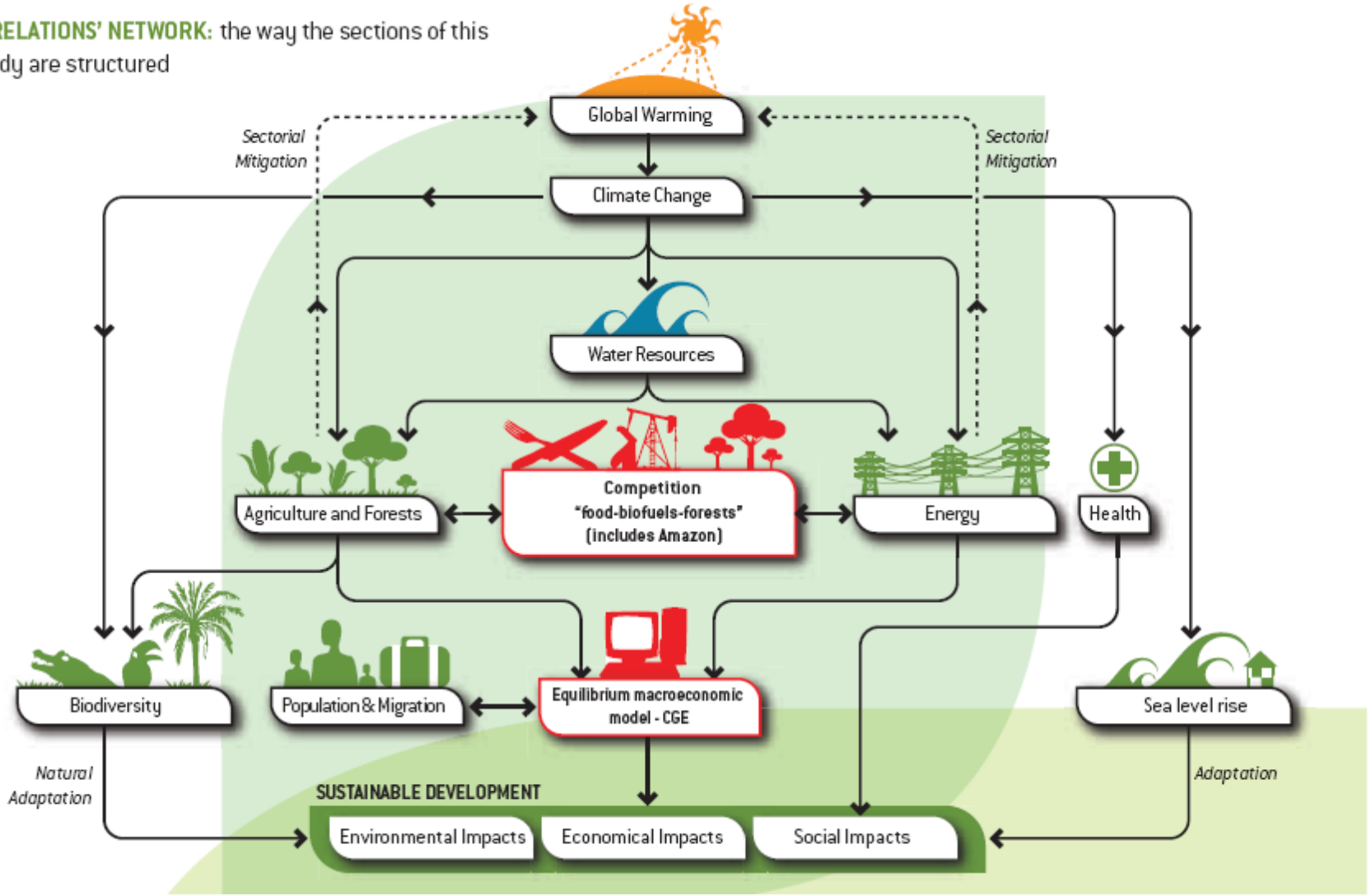
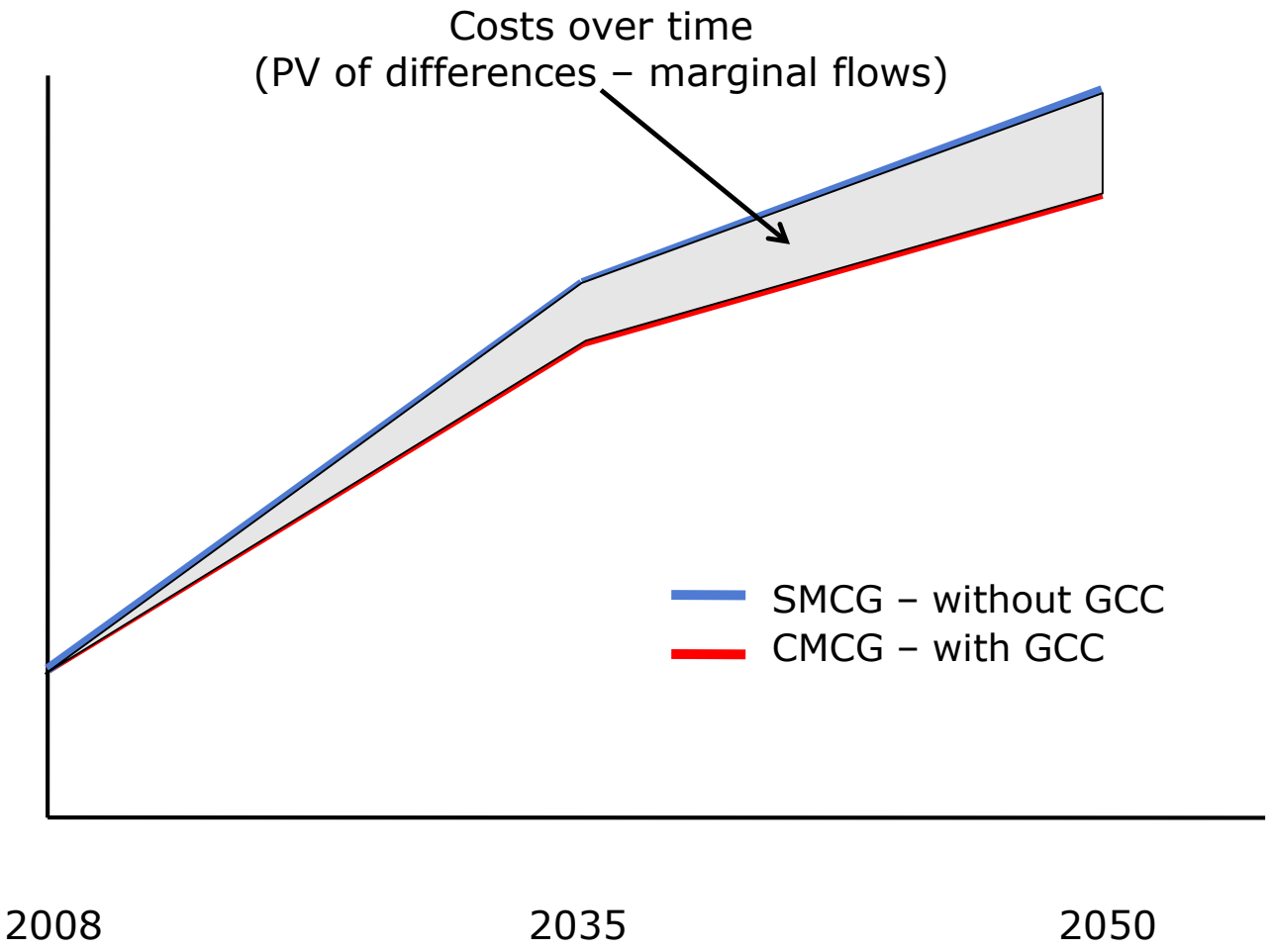
KEYWORDS
CGE model; disaster; meta-analysis; shocks; resilience

1. Insights from integrated assessment modeling experiences

A RELATIONS' NETWORK: the way the sections of this study are structured



Costs (benefits) of GCC



2. Sectoral-specific shocks

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Climate Change in Lebanon: Higher-order Regional Impacts from Agriculture*

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Help
del/Data | Closure | Shocks | Output files | Solve | Results

ARZ Model

Interregional Computable General Equilibrium Model for Lebanon

The University of Sao Paulo Regional and Urban Economics Lab - NEREUS

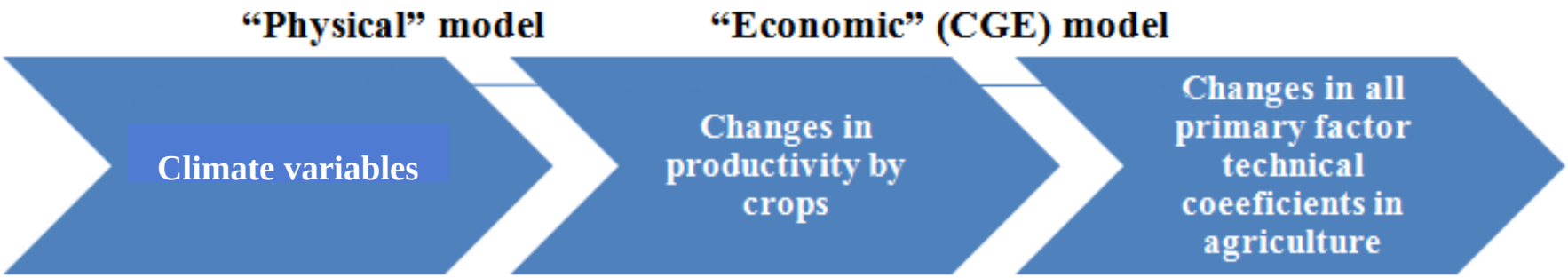
November 2011

Physical changes translated into shocks in the spatial CGE system

Systemic impacts of climate change in Lebanon **from agriculture**

What are the economic costs of climate change?

Which regions are chiefly affected and to what magnitude?



Differential results across sectors and regions, and over time

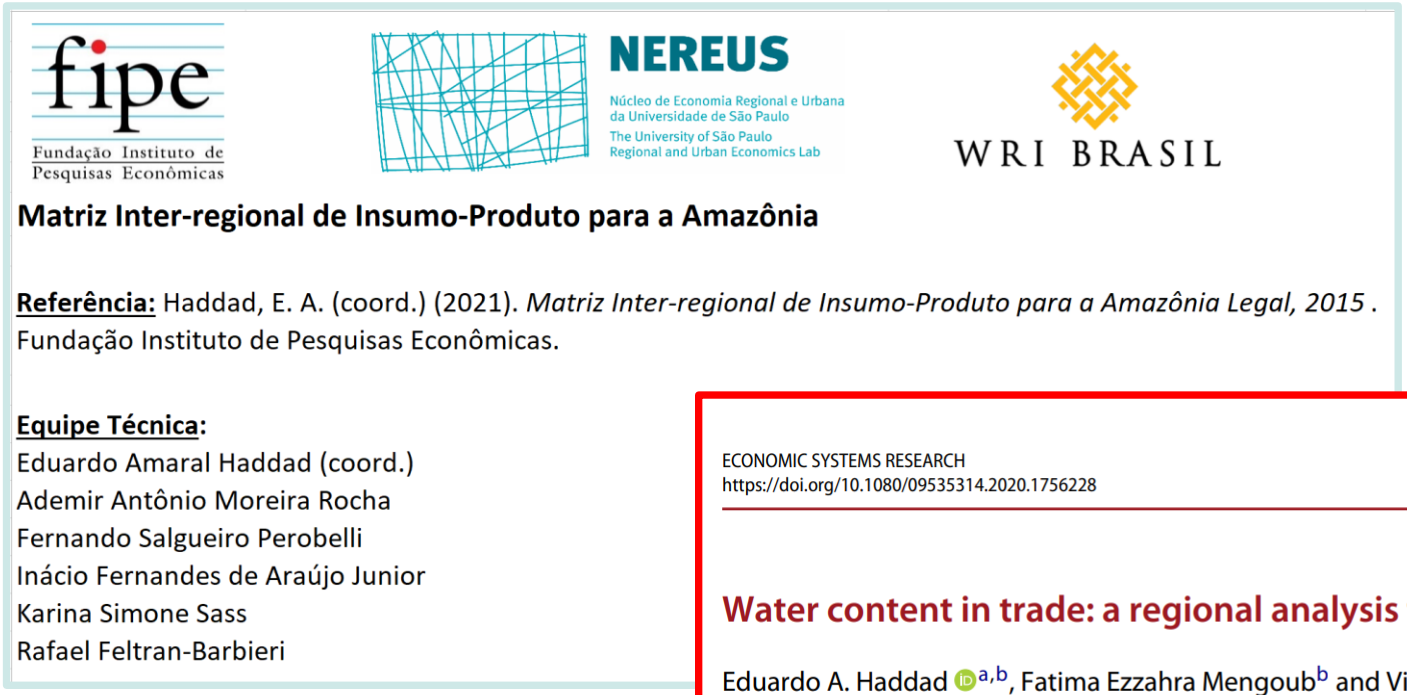
Table 5: Systemic impacts of productivity changes in agriculture due to climate change on selected variables (deviations from base case)

	2010	*2015*	*2020*	*2025*	*2030*	*2010–2030*	
						Accumulated	*% of 2010 values*
Macroeconomic indicators (Billions LBP 2010)							
GDP	**-28.6**	**-110.7**	**-228.7**	**-401.7**	**-522.0**	**-4770.9**	**-8.33%**
Household consumption	-22.3	-75.0	-132.0	-200.0	-223.6	-2457.4	-4.85%
Government expenditure	-3.0	-8.2	-12.6	-17.4	-17.9	-221.3	-3.12%
Investment	1.4	-5.0	-36.1	-103.6	-181.7	-1129.0	-7.94%
Exports of goods and services	-8.3	-29.8	-55.6	-86.1	-95.7	-1041.2	-5.01%
Imports of goods and services	3.5	7.3	7.7	5.4	-3.2	77.9	-0.22%
Sectoral value added (Billions LBP 2010)							
Agriculture	-6.2	-29.3	-62.2	-97.8	-105.9	-1169.1	-47.59%
Manufacturing	-2.1	-7.1	-12.9	-20.0	-22.2	-241.3	-4.80%
Services	-20.3	-74.4	-153.6	-284.0	-394.0	-3360.5	-6.75%
Gross Regional Product (Billions LBP 2010)							
Beirut	-2.8	-29.3	-62.2	-97.8	-105.9	-246.4	-3.24%
Mount Lebanon	-9.8	0.5	1.3	2.3	2.7	-1097.5	-4.32%
Northern Lebanon	-6.3	-7.1	-12.9	-20.0	-22.2	-1262.2	-12.33%
Bekaa	-3.6	-26.3	-72.3	-166.9	-274.2	-680.6	-11.15%
Southern Lebanon	-3.2	-3.3	-5.6	-8.4	-8.9	-807.2	-16.26%
Nabatieh	-2.9	-26.7	-46.1	-69.3	-75.4	-677.1	-22.64%

onomic growth (-) / Welfare (-) / Regional concentration (-) / Regional inequality (-) /
nigration (+) / Impacts are magnified over time

3. Linkages matter

Distribution of impacts depend on the degree of linkage within and leakage from the regional economy

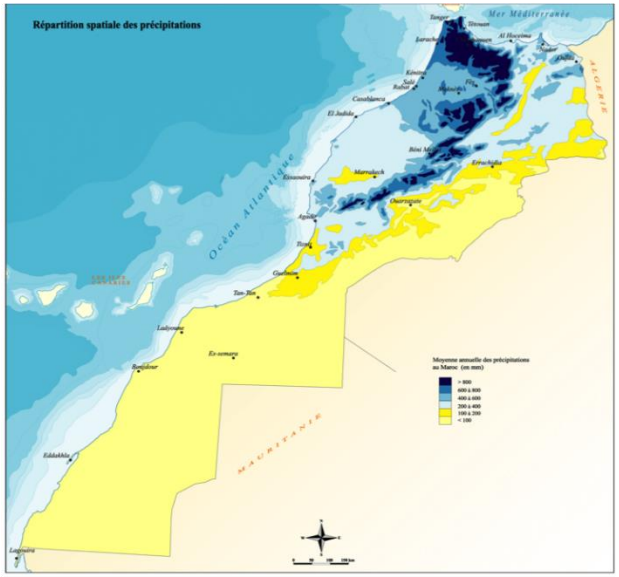


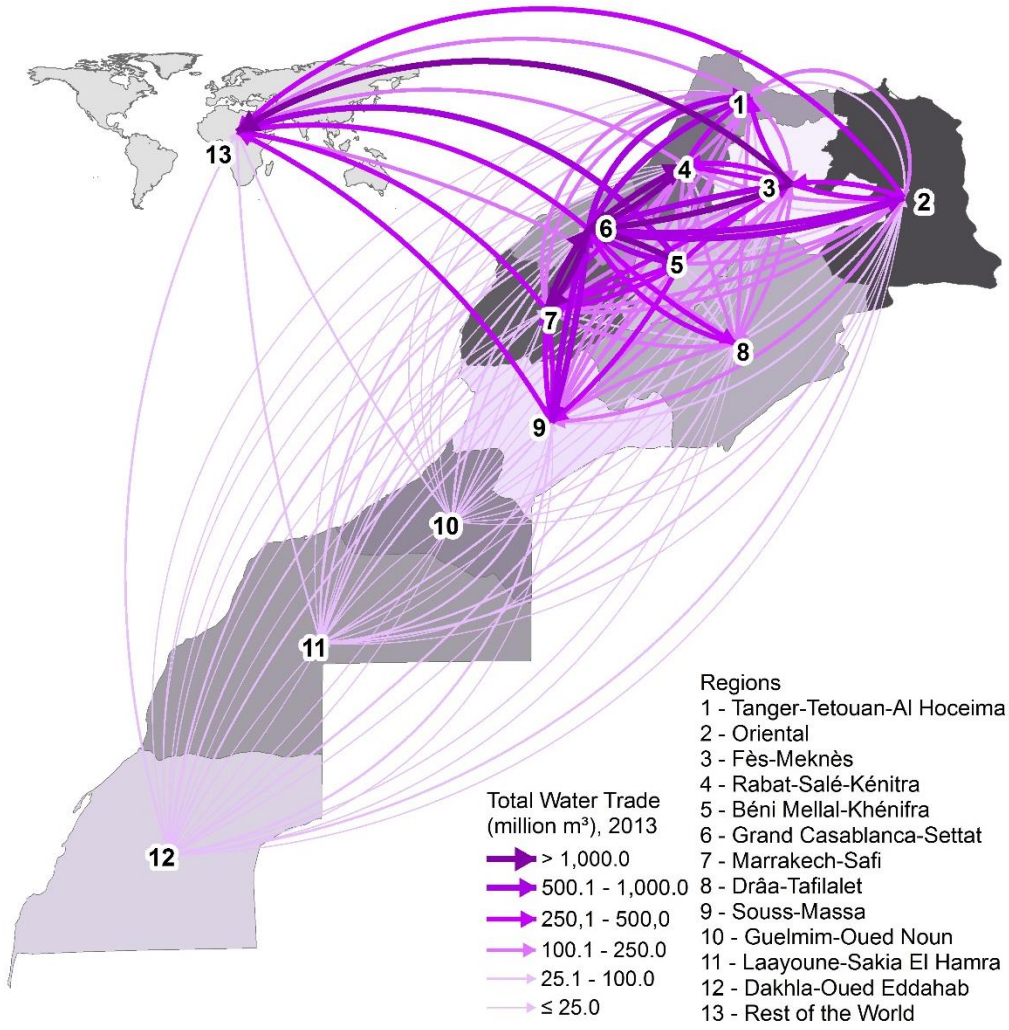
Regions within countries put pressure on the demand for natural resources

Table 2. Domestic total traded water in exports (DTW)

Hypothetical no export	to					
from	R_1	R_2	…	R_{n-1}	R_n	RoW
R_1		$DTW_{1,2}$	…	$DTW_{1,n-1}$	$DTW_{1,n}$	$DTW_{1,row}$
R_2	$DTW_{2,1}$		…	$DTW_{2,n-1}$	$DTW_{2,n}$	$DTW_{2,row}$
⋮	⋮	⋮		⋮	⋮	⋮
R_{n-1}	$DTW_{n-1,1}$	$DTW_{n-1,2}$	…		$DTW_{n-1,n}$	$DTW_{n-1,row}$
R_n	$DTW_{n,1}$	$DTW_{n,2}$	…	$DTW_{n,n-1}$		$DTW_{n,row}$

Trade in water in Morocco

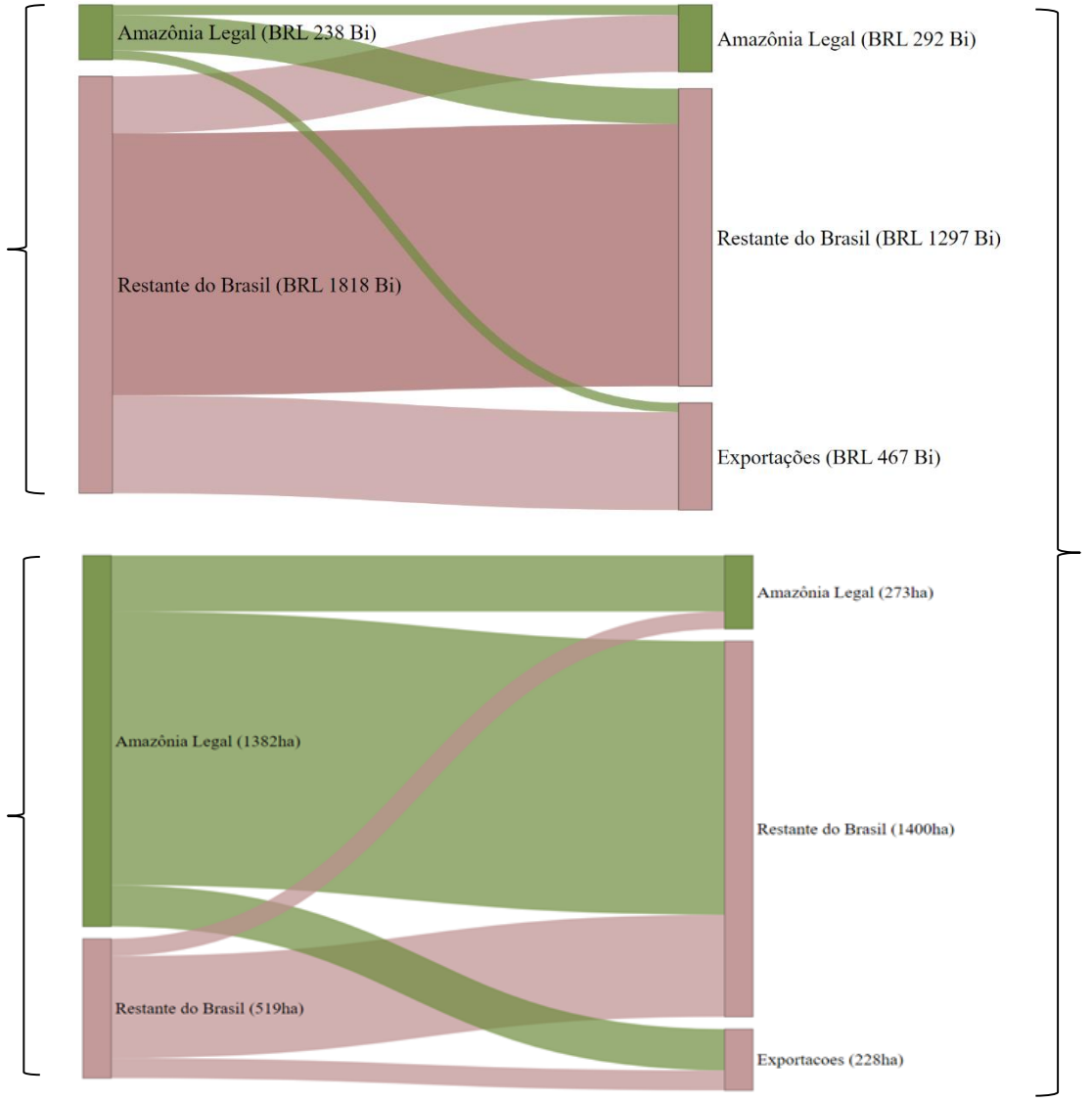




Domestic and international production chains and pressure on natural resources: Brazilian Amazon

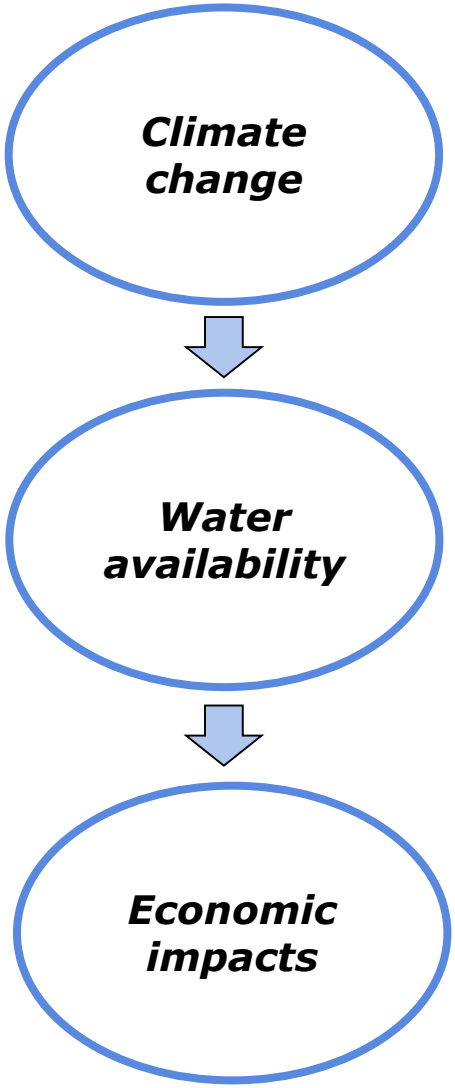
Trade in value-added

Trade in CO_2 emissions

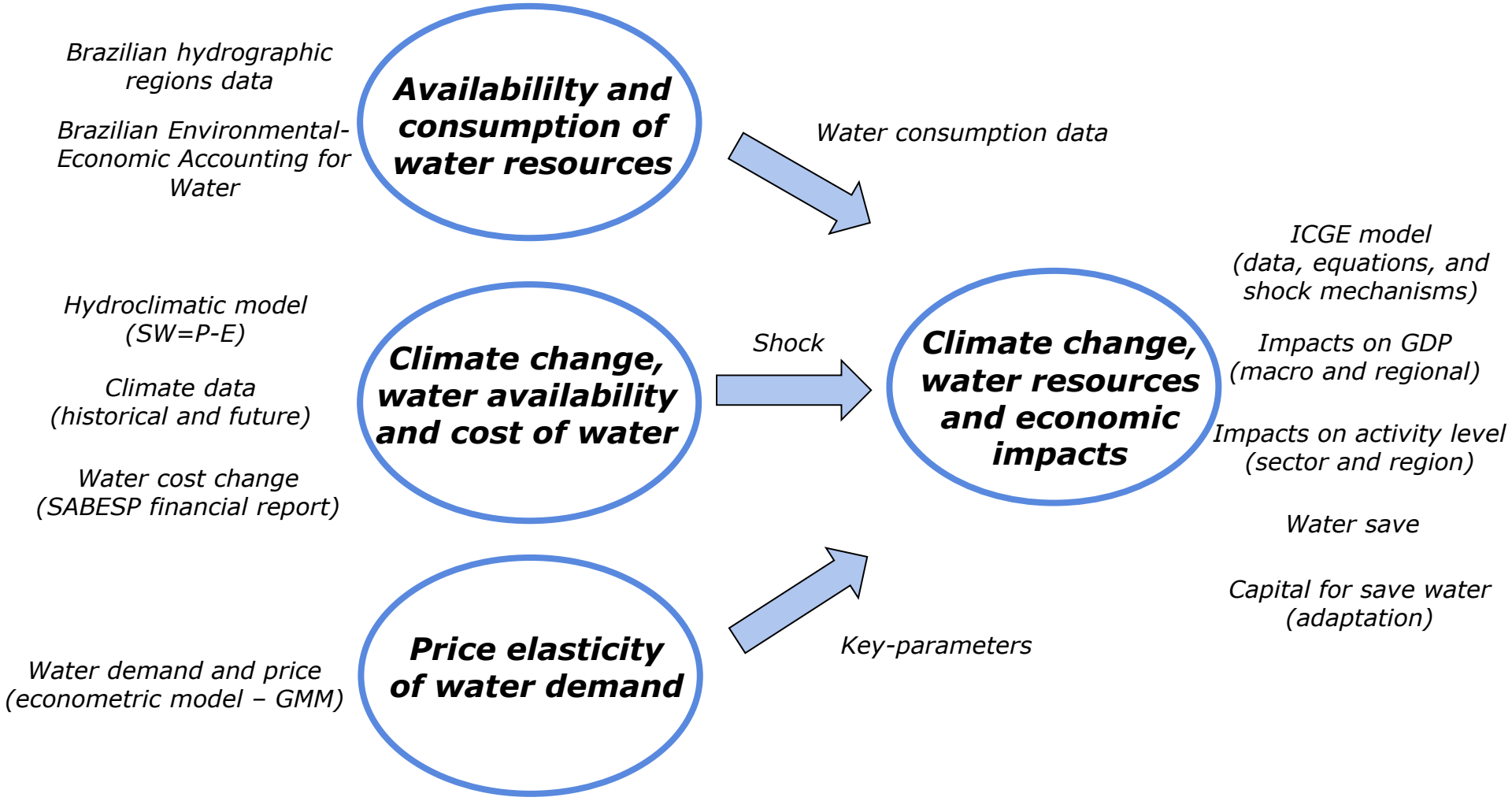


4. Use of expert-models in integrated frameworks improve simulations design (Rocha, 2022)

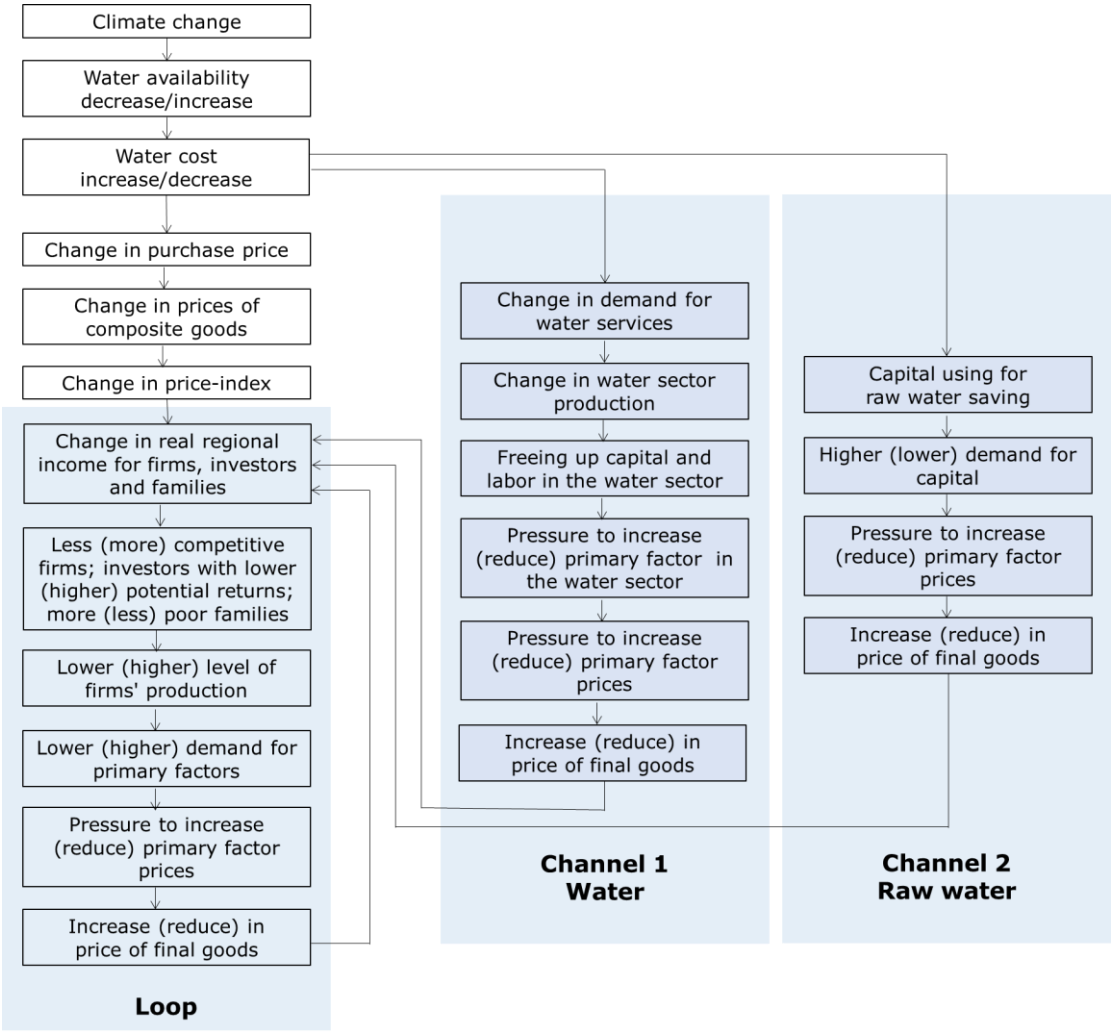
- Irregular water supply resulting from climate change brings limitations and risks to several economic and social activities
  - irrigated crops
  - livestock
  - forest production
  - fishing
  - tourism
  - hydroelectric power generation
  - industrial production
  - water distribution and sewage



How will Brazilian hydrographic regions and economic sectors be affected and adapt to change in water availability?



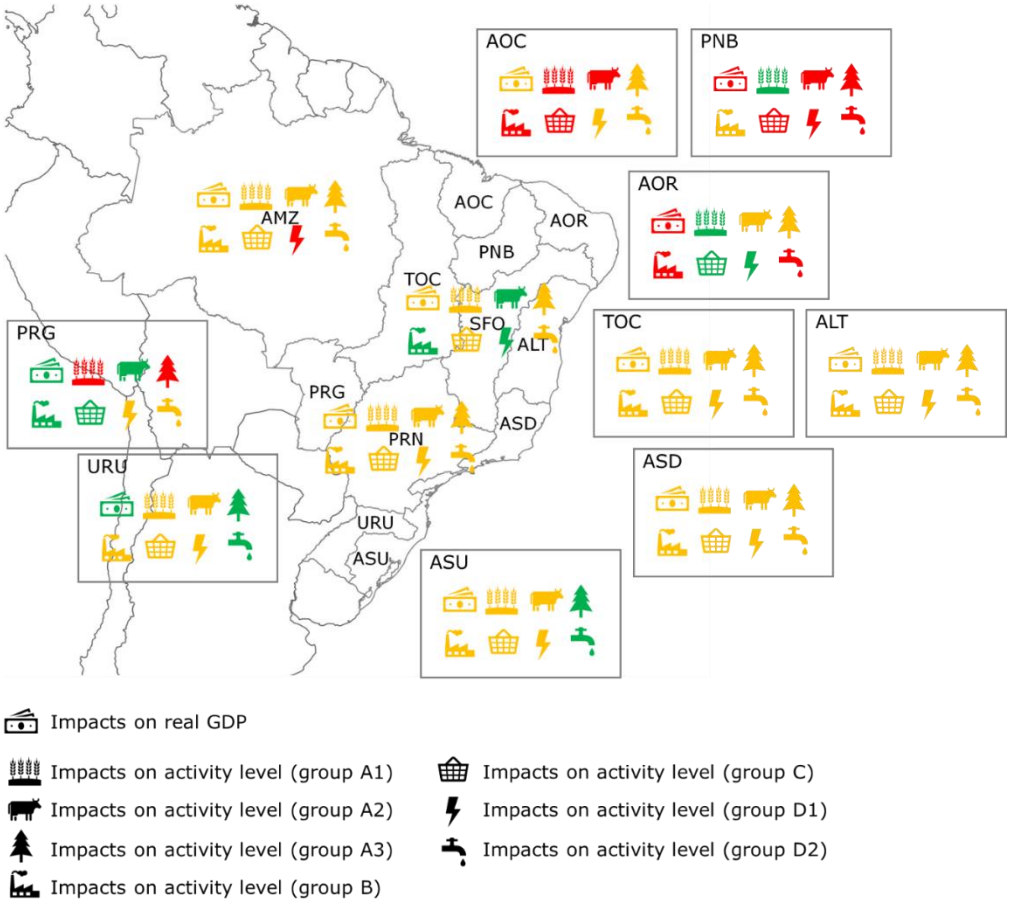
Understanding the analytical structure of the CGE model allows to identify the main adjustment mechanisms



Channel 1 represents an adaptation by increasing the water price. In other words, with the changes in water availability, it will be necessary to adjust the price of water in order to adapt demand to the new reality.

Channel 2 represents a productive adaptation in which the primary factors raw water and capital can be replaced (this is limited by the dependence of the economic sector on the water input).

Impacts on GDP, by hydrographic region

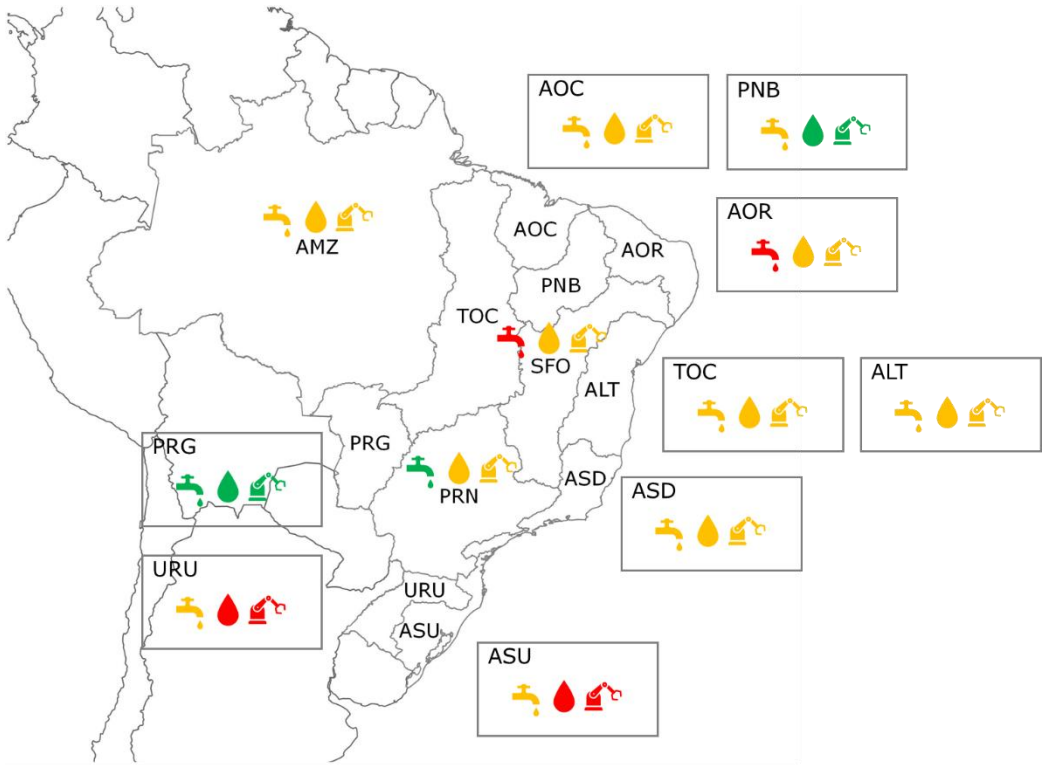


Impacts on regional GDP and sectoral activity level.

Green icons *represent low impact of climate change (positive or small negative values),* ***yellow icons*** *represent medium impact (negative values), and* ***red icons*** *represent high impacts (negative values).*

Hydrographic regions located in the semi-arid Northeast and their neighbors, PNB, AOR, ALT, and AOC, are mainly affected.

Impacts on water demand and capital used for saving water, by hydrographic region, long-run



Green icons *indicate large reduction in water demand due to climate change and increased use of capital to save water,* ***yellow icons*** *indicate medium impact on water demand reduction and capital purchase to save water, and* ***red icons*** *indicate low capacity to reduce demand (sometimes even increases water consumption) and purchase of capital.*

PRN, PRG and PNB have a high capacity to reduce water demand, whether due to economic scale (PRN case) or due to the impact of climate change (PNB and PRG). Agriculture, livestock and forestry sectors play an important role in this change.

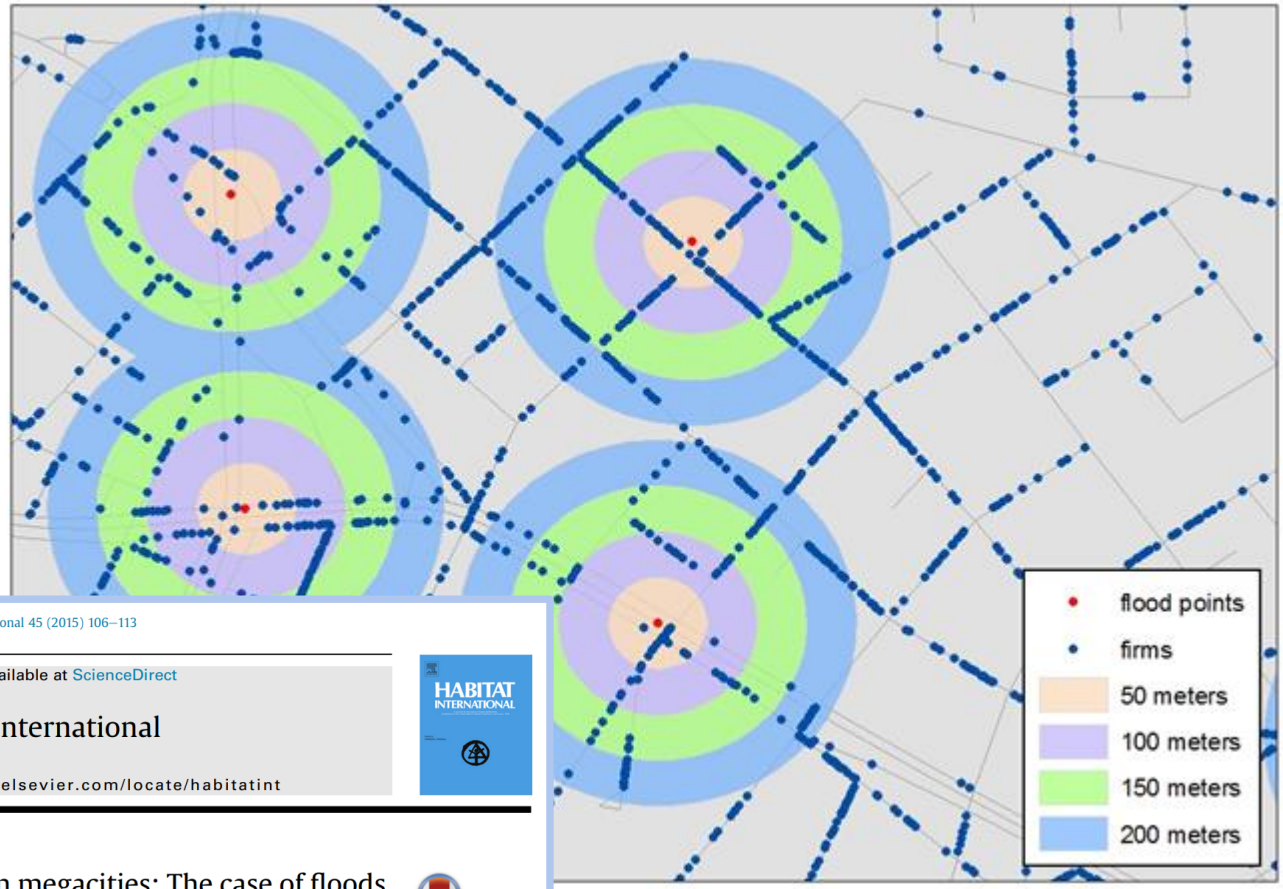
Capital for save water: PNB and PRG are expected to see the biggest changes in these inversions. On the other hand, ASU and URU are expected to spend less on this adaptation.

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

What are the economic costs of floods in São Paulo?

Haddad, E. A. and Teixeira, E. (2015). "Economic Impacts of Natural Disasters in Megacities: The Case of Floods in São Paulo, Brazil", *Habitat International,* 45, p. 106-113

Example of GIS-based influence area of flood points, for different scenarios (50m, 100m, 150m, 200m)



Habitat International 45 (2015) 106–113

Contents lists available at ScienceDirect

Habitat International

journal homepage: www.elsevier.com/locate/habitatint

Economic impacts of natural disasters in megacities: The case of floods in São Paulo, Brazil

Eduardo Amaral Haddad [a, b, c, *], Eliane Teixeira [a, b, c]

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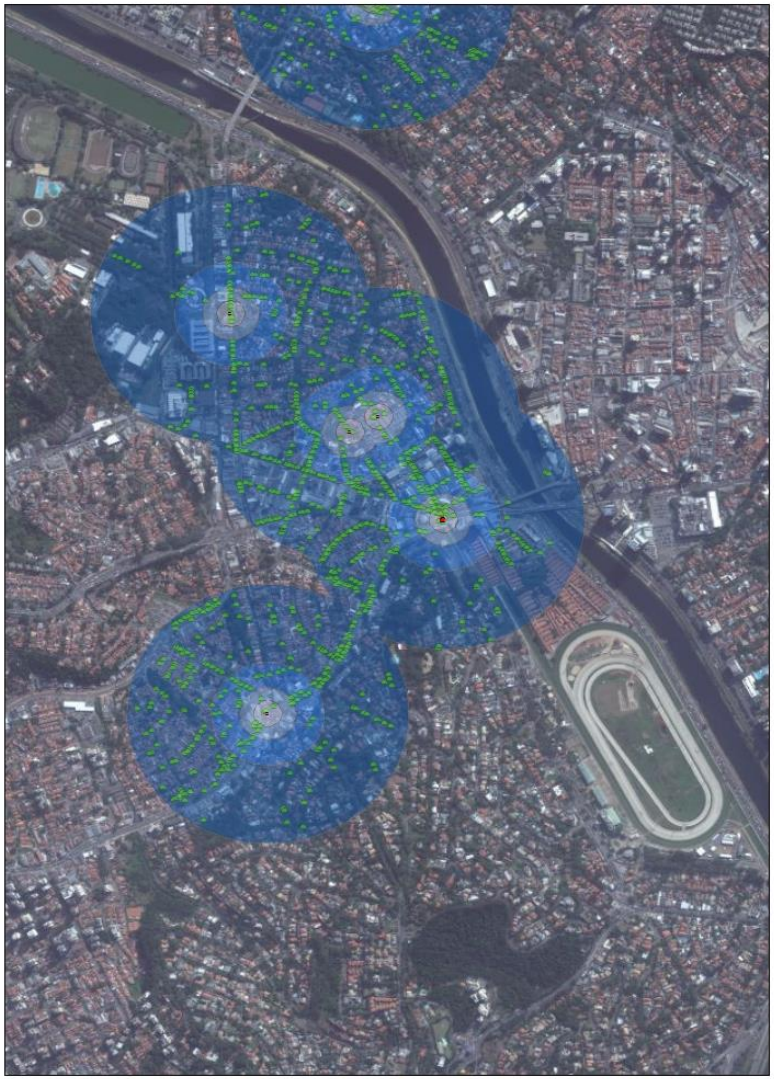
[b] NEREUS, The University of Sao Paulo Regional and Urban Economics Lab, Departamento de Economia, FEA-USP, Av. Prof. Luciano Gualberto, 908, FEA I, Cidade Universitária, São Paulo, SP, 05508-900, Brazil
[c] Institute of Economic Research Foundation, FIPE, Brazil

Case study: São Paulo, 2008



The most severe flood point in 2008

Latitude -23.57267 Longitude -46.70449	
Influence Zone	Affected Firms
100 m	**137**

Direct damage is estimated based on the characteristics of the affected firms

Assumptions:

- Technology based on a continuous-time production function approach
- One day of flood affects one day of production of firms within the influence zone (working days) – confirmed by surveys in affected areas
- Information on the average sectoral labor productivity from input-output data used to assess direct damages
- Reweighting scheme

Higher-order impacts estimated using a spatial CGE model (shift in the production frontier)

What if floods had not occurred in 2008?

What would have been the difference in terms of regional output?

Estimated foregone (reweighted) labor income (in BRL thousand)

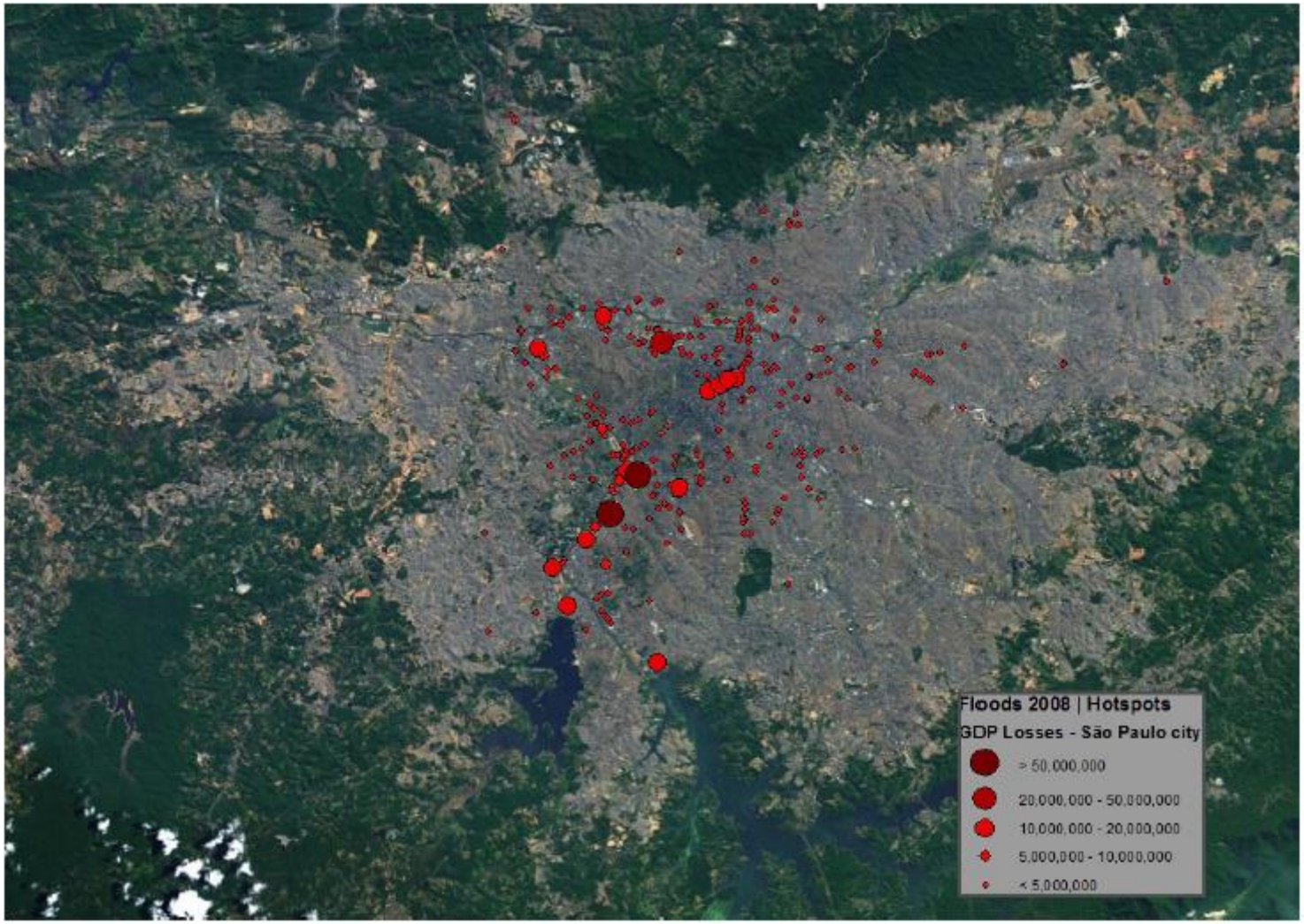
	Impact radius			
	50 m	*100 m*	*150 m*	*200 m*
Primary	7.08	9.92	22.39	33.13
Manufacturing	454.01	2,014.94	3,131.36	5,557.37
Utilities	673.48	1,444.40	1,795.81	2,146.47
Construction	185.72	589.96	1,034.77	1,778.95
Commerce	1,057.58	2,046.03	3,702.56	6,024.32
Transportation	663.62	948.01	1,483.51	1,933.59
Services	3,132.72	9,034.60	16,445.59	31,519.12
Public administration	300.43	1,354.86	15,233.56	16,317.47
TOTAL	6,474.63	17,442.72	42,849.55	65,310.42
# of affected firms	8,577	19,784	35,896	57,938

Loss in space – spatial spillovers

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

	Impact radius			
	50m	*100m*	*150m*	*200m*
Direct loss				
São Paulo City (SPC)	16.63	43.54	88.30	143.53
Total loss				
São Paulo City (SPC)	40.08	94.38	150.34	248.55
Rest of SPMR (SPMR)	3.35	9.05	12.72	19.66
Rest of São Paulo State (RSP)	9.14	21.04	32.49	49.86
Rest of Brazil (RB)	39.95	93.72	154.91	246.10
Brazil	92.52	218.19	350.46	564.17
Intra-city total impact-damage ratio	***2.4***	***2.2***	***1.7***	***1.7***
Economy-wide total impact-damage ratio	***5.6***	***5.0***	***4.0***	***3.9***

Reaching the planner: Hotspots 2008



Source: Teixeira and Haddad (2014)

6. Total costs will depend on the degree of resiliency of the economic system

What are the economic costs of the 2006 War in Lebanon?

Methodological experimentation with **alternative approaches to assess the economic impacts of extreme events**

Disasters impact analysis as an "inexact science"

Focus on the higher-order economic impacts associated with direct damage

Uncertainty about key trade elasticities: qualitative sensitive analysis to look at the potential range of the **total costs under different degrees of resilience** (both technological and spatial)

Destruction of capital stocks (percentage change)

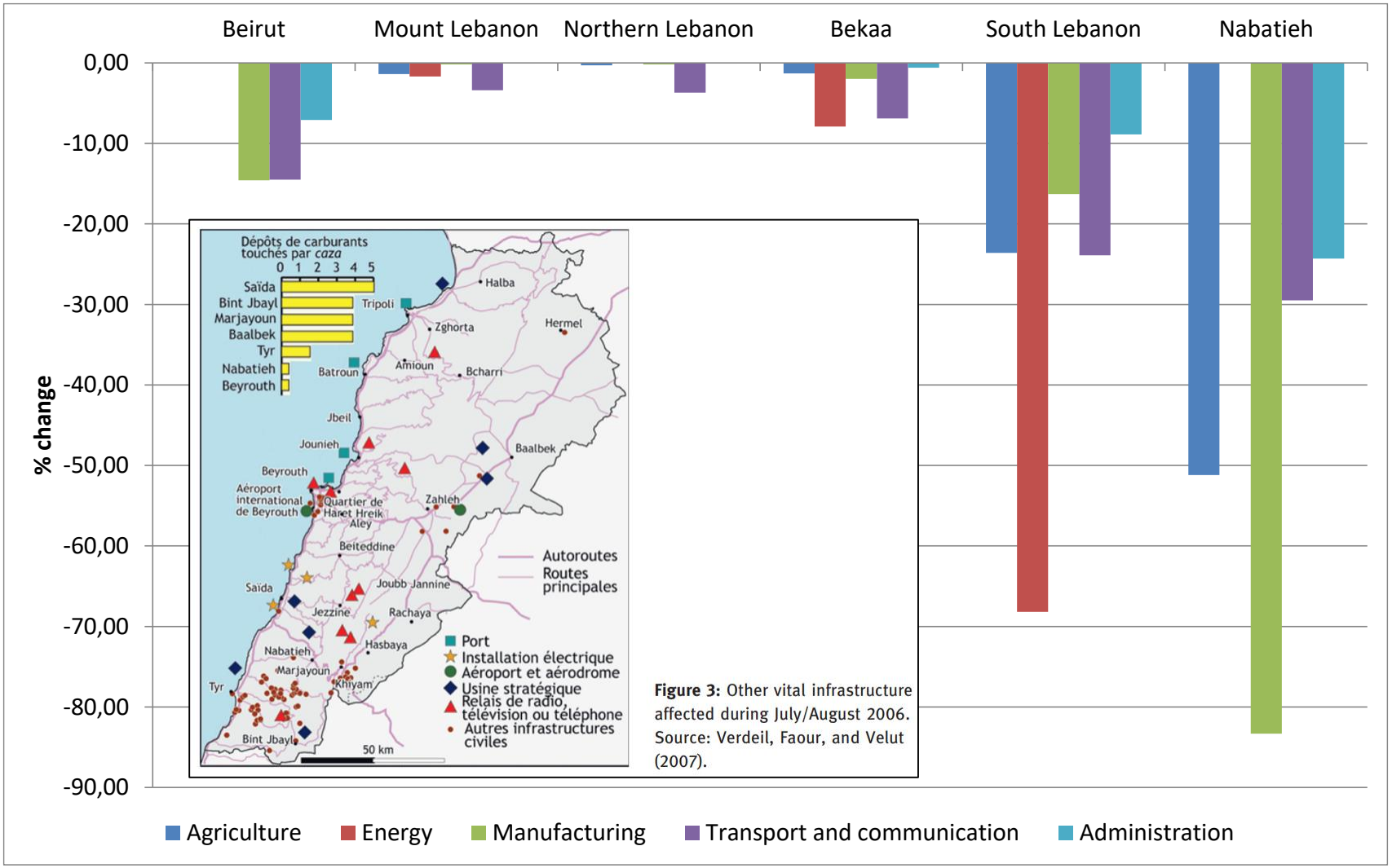


Figure 3: Other vital infrastructure affected during July/August 2006. Source: Verdeil, Faour, and Velut (2007).

Summary of results

DE GRUYTER Rev. Middle East Econ. Fin. 2016; 12(3): 225–256

Eduardo Amaral Haddad* and Yasuhide Okuyama

Spatial Propagation of the Economic Impacts of Bombing: The Case of the 2006 War in Lebanon

Low degree of technological resilience (substitution of primary inputs)

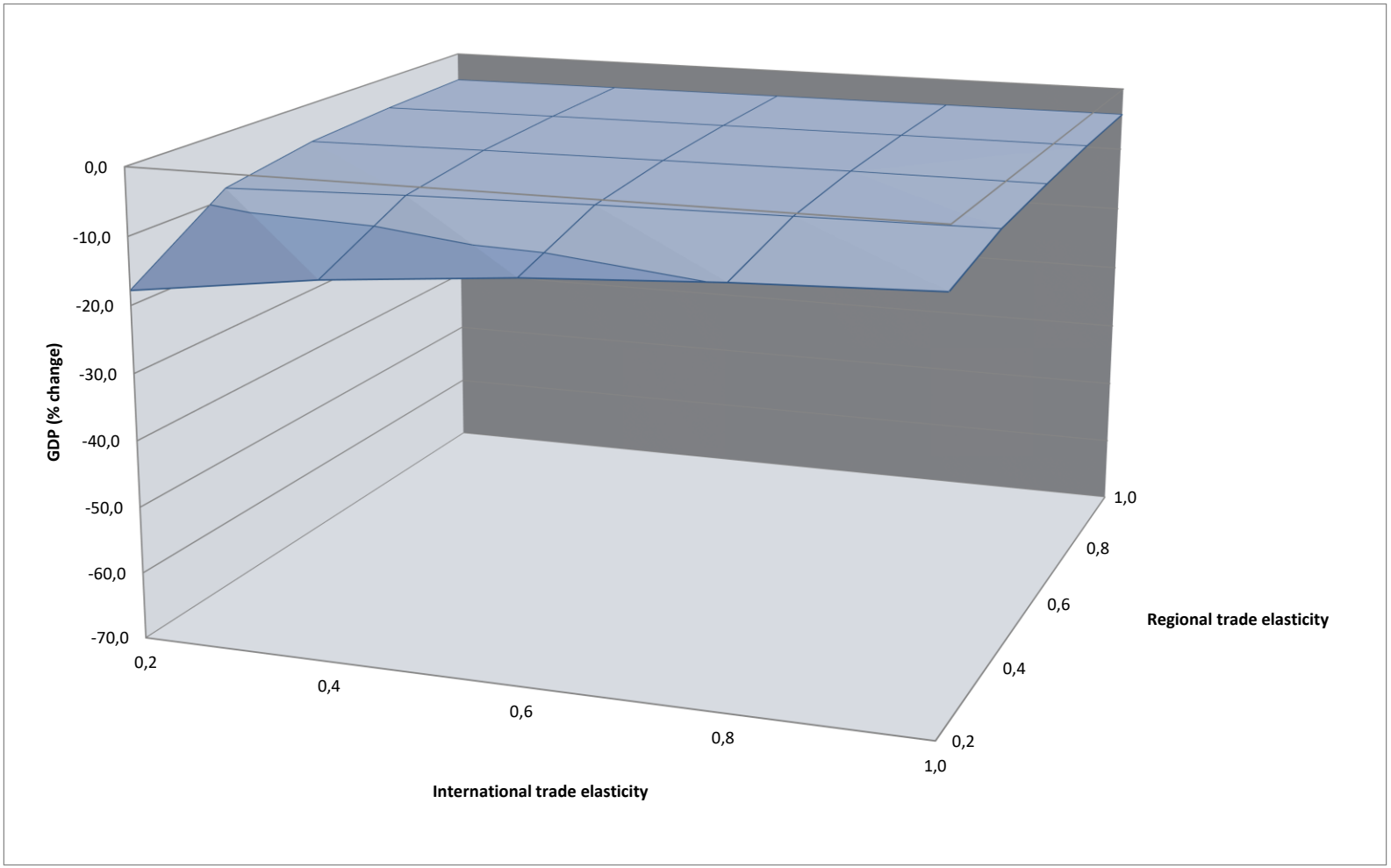
Spectrum of spatial resilience (substitution of suppliers)

Direct damage: USD million 1.105

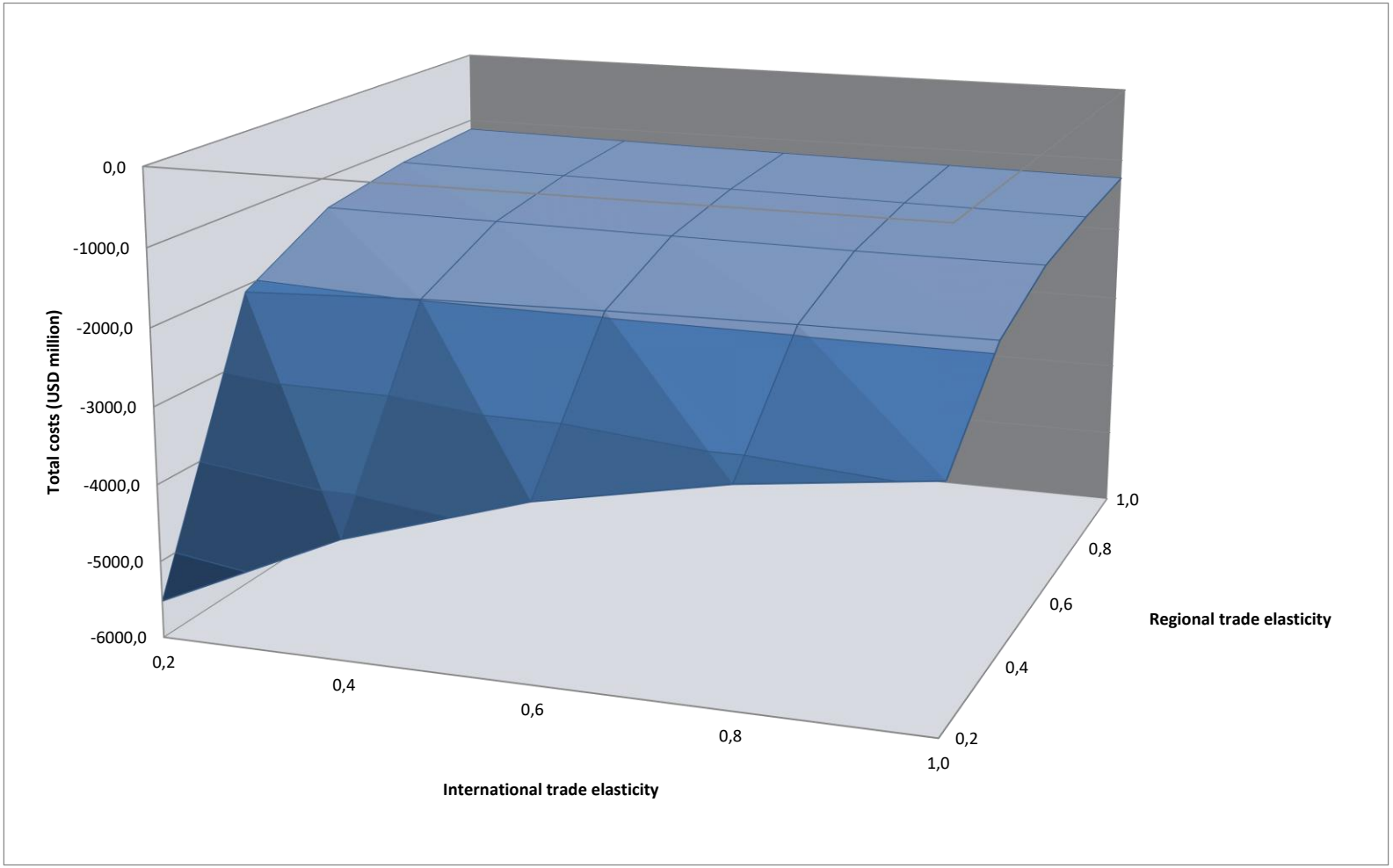
Total damage: USD million 1.644 [1.138; 5.521]

Multiplier: 1,49 [1,03; 5,00]

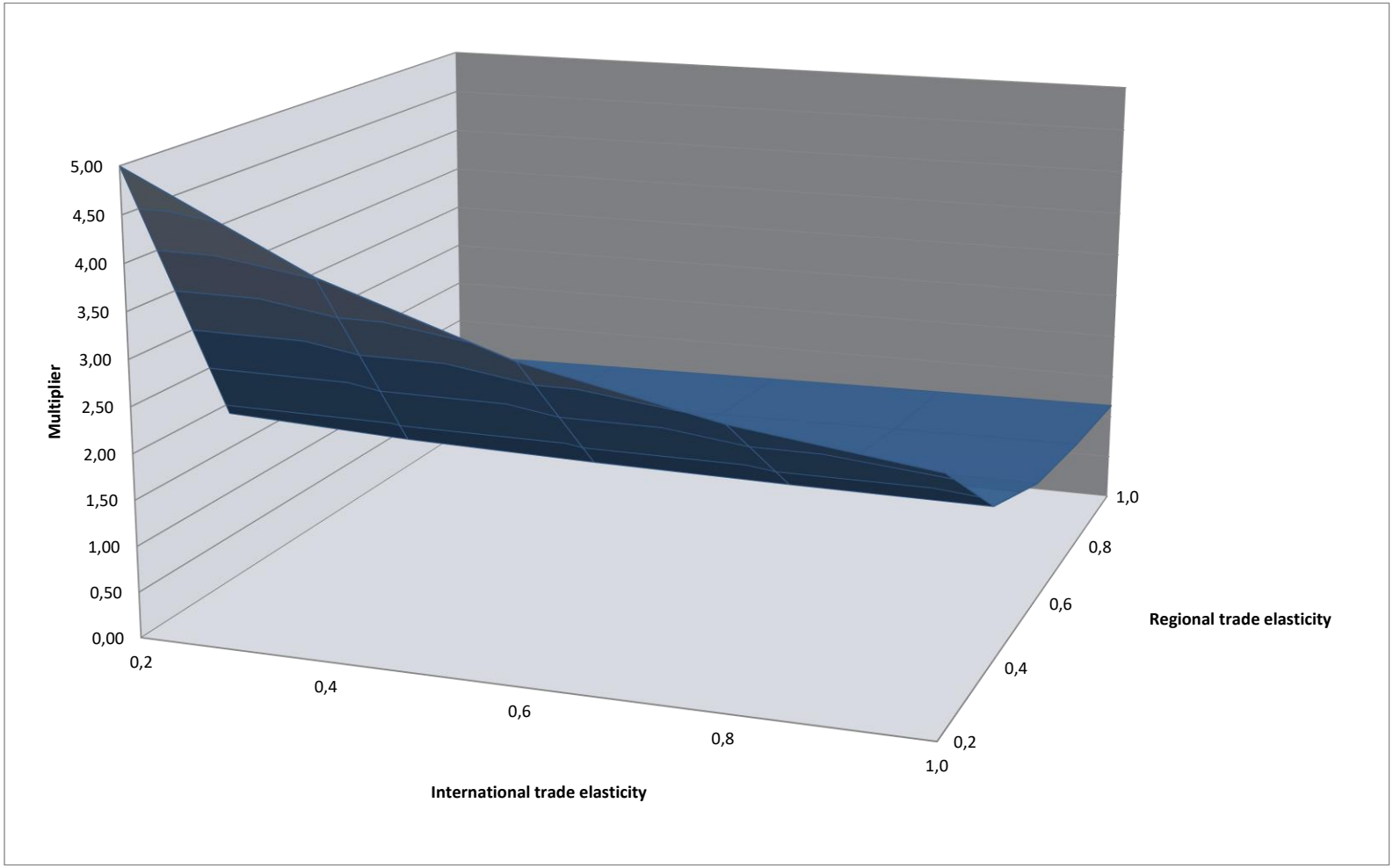
GDP – Lebanon


0,0
-10,0
-20,0
-30,0
-40,0
-50,0
-60,0
-70,0
GDP (% change)
0,2
0,4
0,6
0,8
1,0
International trade elasticity
0,2
0,4
0,6
0,8
1,0
Regional trade elasticity

Total costs – USD million

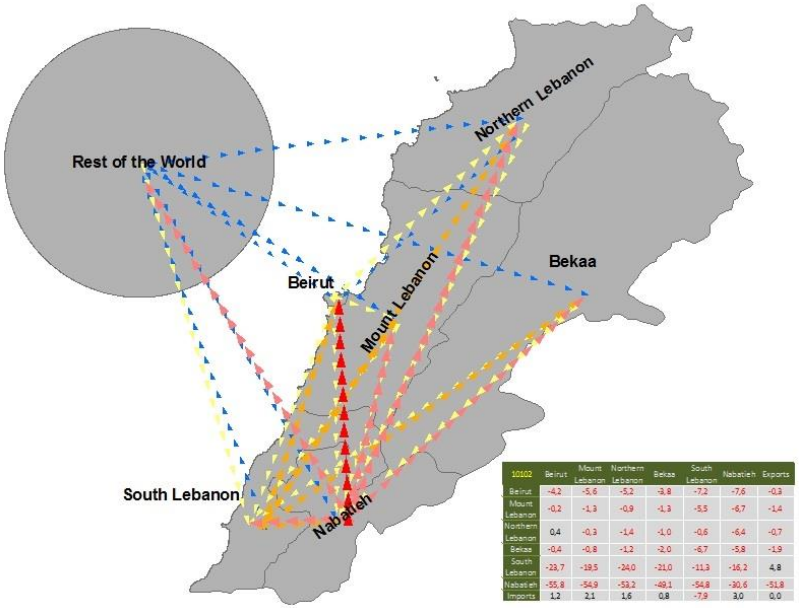


Multiplier


Multiplier
5,00
4,50
4,00
3,50
3,00
2,50
2,00
1,50
1,00
0,50
0,00
0,2
0,4
0,6
0,8
1,0
International trade elasticity
0,2
0,4
0,6
0,8
1,0
Regional trade elasticity

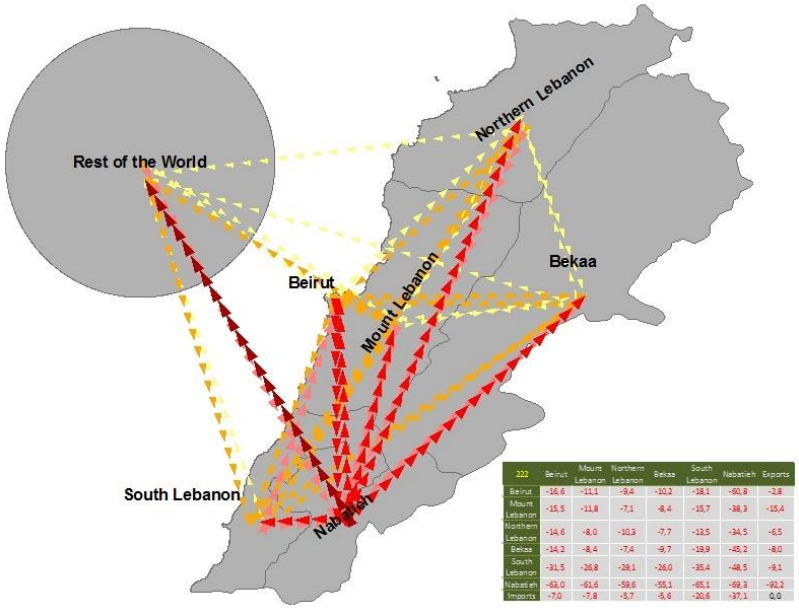
Interregional and international trade may serve as a shock absorber

Higher degree of resilience



10102	Beirut	Mount Lebanon	Northern Lebanon	Bekaa	South Lebanon	Nabatieh	Exports
Beirut	-4,2	-5,6	-5,2	-3,8	-7,2	-7,6	-0,3
Mount Lebanon	-0,2	-1,3	-0,9	-1,3	-5,5	-6,7	-1,4
Northern Lebanon	0,4	-0,3	-1,4	-1,0	-0,6	-6,4	-0,7
Bekaa	-0,4	-0,8	-1,2	-2,0	-6,7	-5,8	-1,9
South Lebanon	-23,7	-19,5	-24,0	-21,0	-11,3	-16,2	4,8
Nabatieh	-55,8	-54,9	-53,2	-49,1	-54,8	-30,6	-51,8
Imports	1,2	2,1	1,6	0,8	-7,9	3,0	0,0

Lower degree of resilience



222	Beirut	Mount Lebanon	Northern Lebanon	Bekaa	South Lebanon	Nabatieh	Exports
Beirut	-16,6	-11,1	-9,4	-10,2	-18,1	-60,8	-2,8
Mount Lebanon	-15,5	-11,8	-7,1	-8,4	-15,7	-38,3	-15,4
Northern Lebanon	-14,6	-8,0	-10,3	-7,7	-13,5	-34,5	-6,5
Bekaa	-14,2	-8,4	-7,4	-9,7	-19,9	-45,2	-8,0
South Lebanon	-31,5	-26,8	-29,1	-26,0	-35,4	-48,5	-9,1
Nabatieh	-63,0	-61,6	-59,6	-55,1	-65,1	-69,3	-92,2
Imports	-7,0	-7,8	-5,7	-5,6	-20,6	-37,1	0,0

What if the São Paulo subway system did not exist?

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journal homepage: www.elsevier.com/locate/tra

The underground economy: Tracking the higher-order economic impacts of the São Paulo Subway System

Eduardo A. Haddad [a,*], Geoffrey J.D. Hewings [b], Alexandre A. Porsse [c], Eveline S. Van Leeuwen [d], Renato S. Vieira [a]

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[b] University of Illinois, USA
[c] Federal University of Parana, Brazil
[d] VU University Amsterdam, The Netherlands

Agência FAPESP — News Agency of the São Paulo Research Foundation

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

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

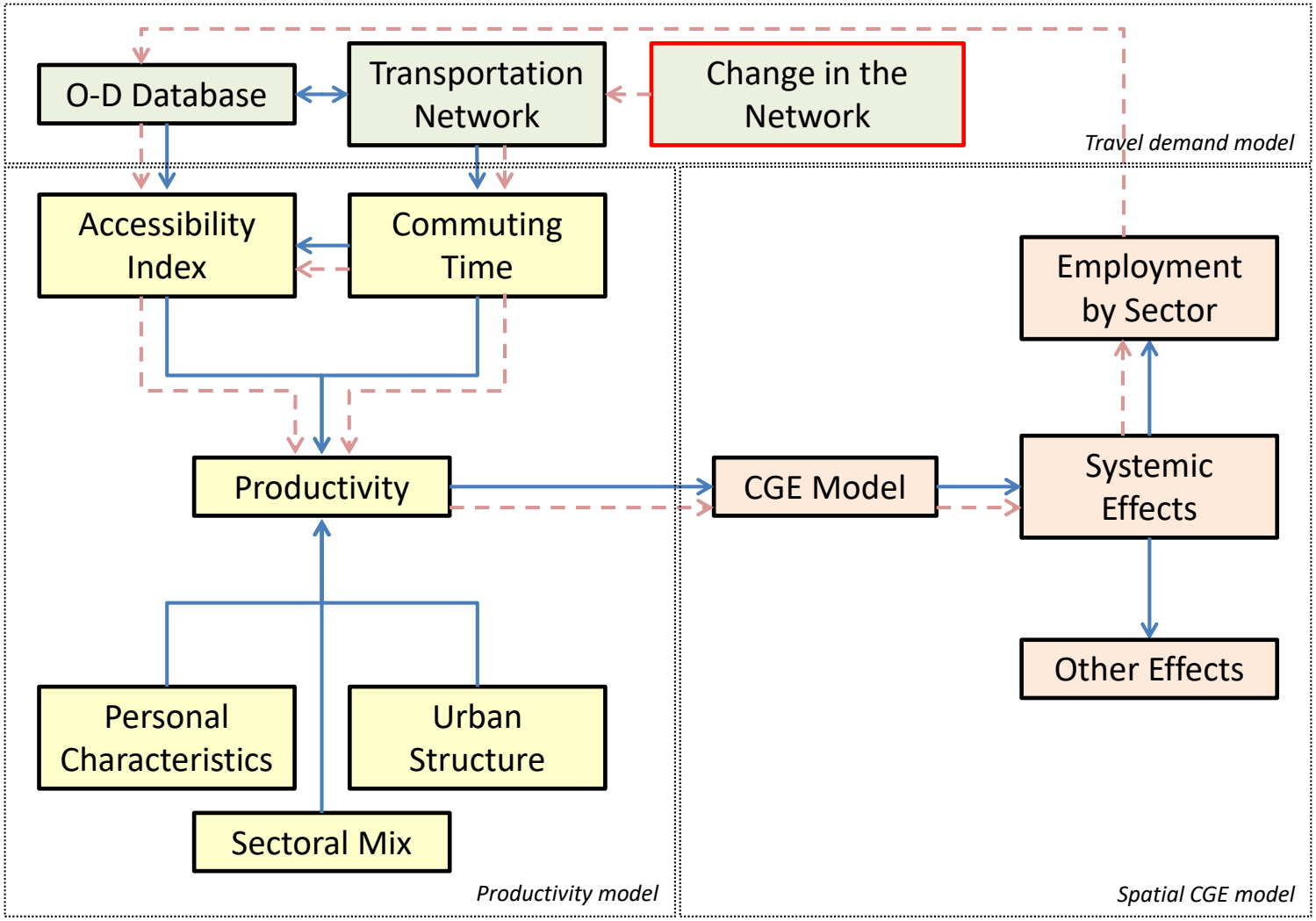
Jaguars could disappear from the Atlantic Rainforest
Brazilian researchers warn that the biome only has 250 adult animals distributed across eight isolated populations, and only 50 are reproducing.

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.

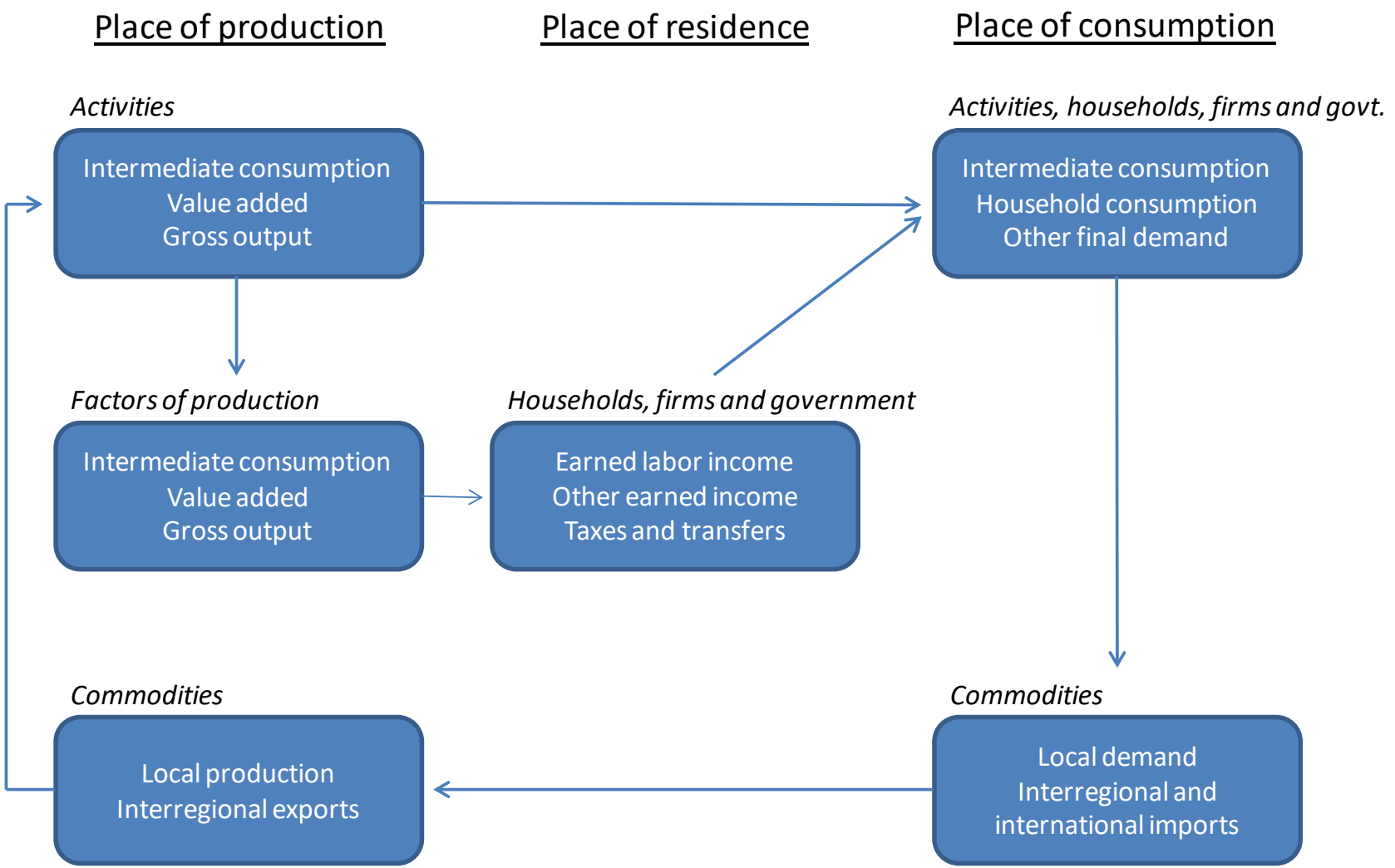
Brazilian researchers develop healthier beef
The meat, shown here prepared for analysis, was enriched with vitamin E, canola oil and selenium and contains

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

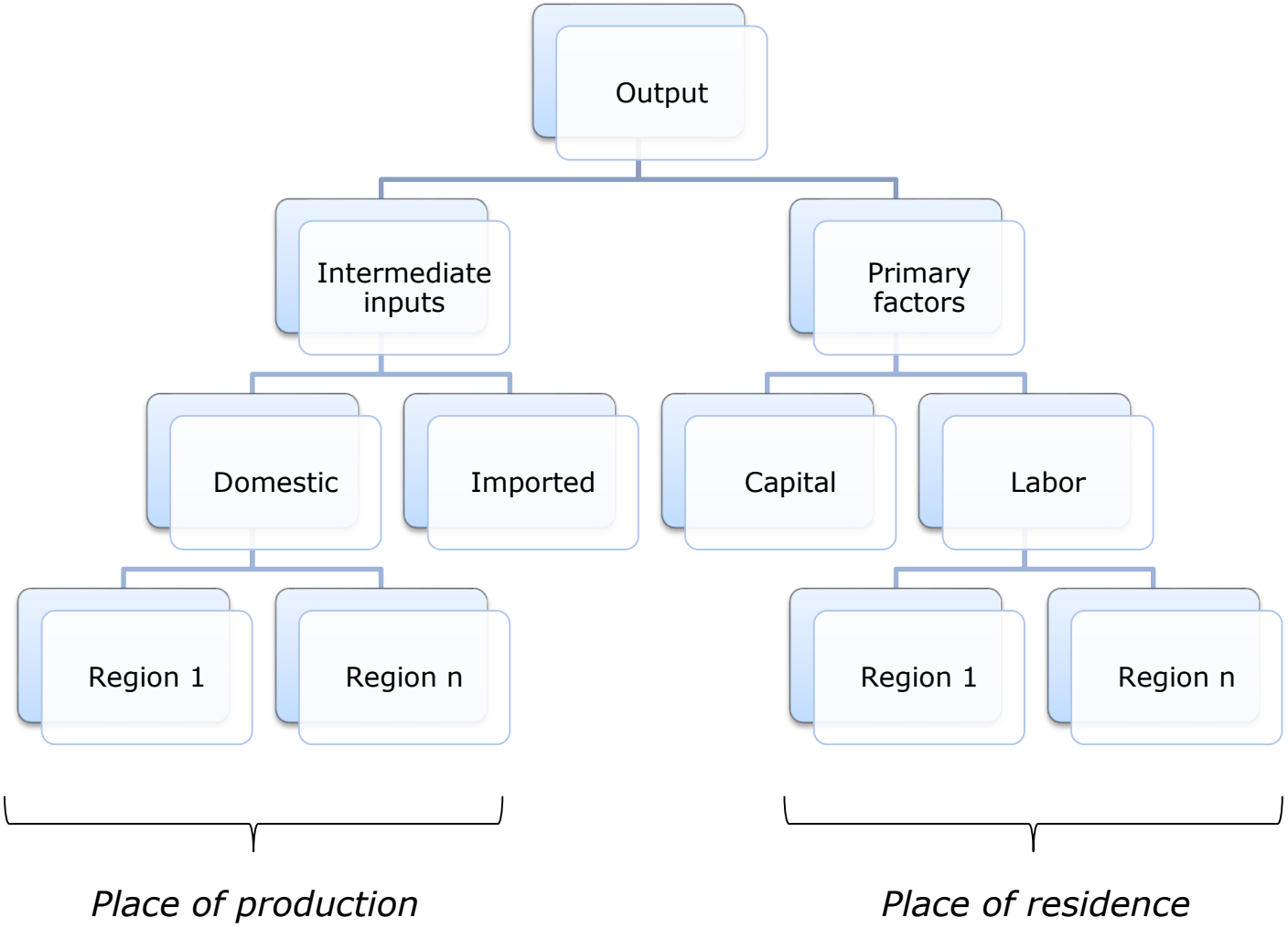
The integrated modeling framework



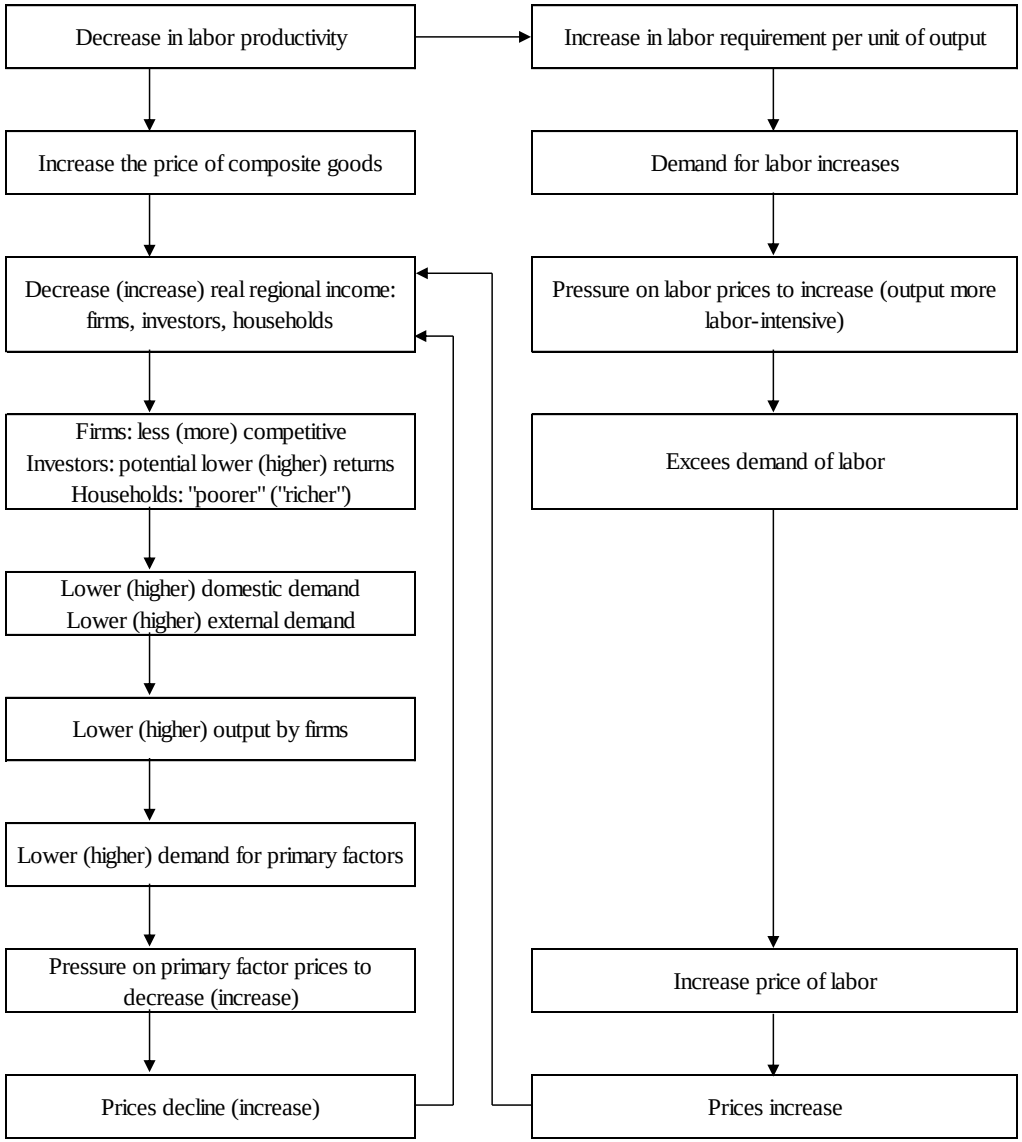
Input-output relations embedded in the SCGE model

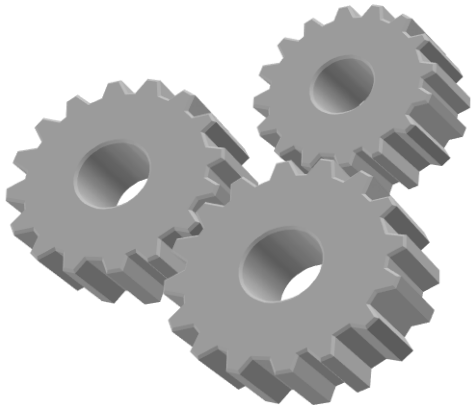


Production function of sector *j* in municipality *r* (nested CES)



Causal relations underlying the system of equations of the SCGE model



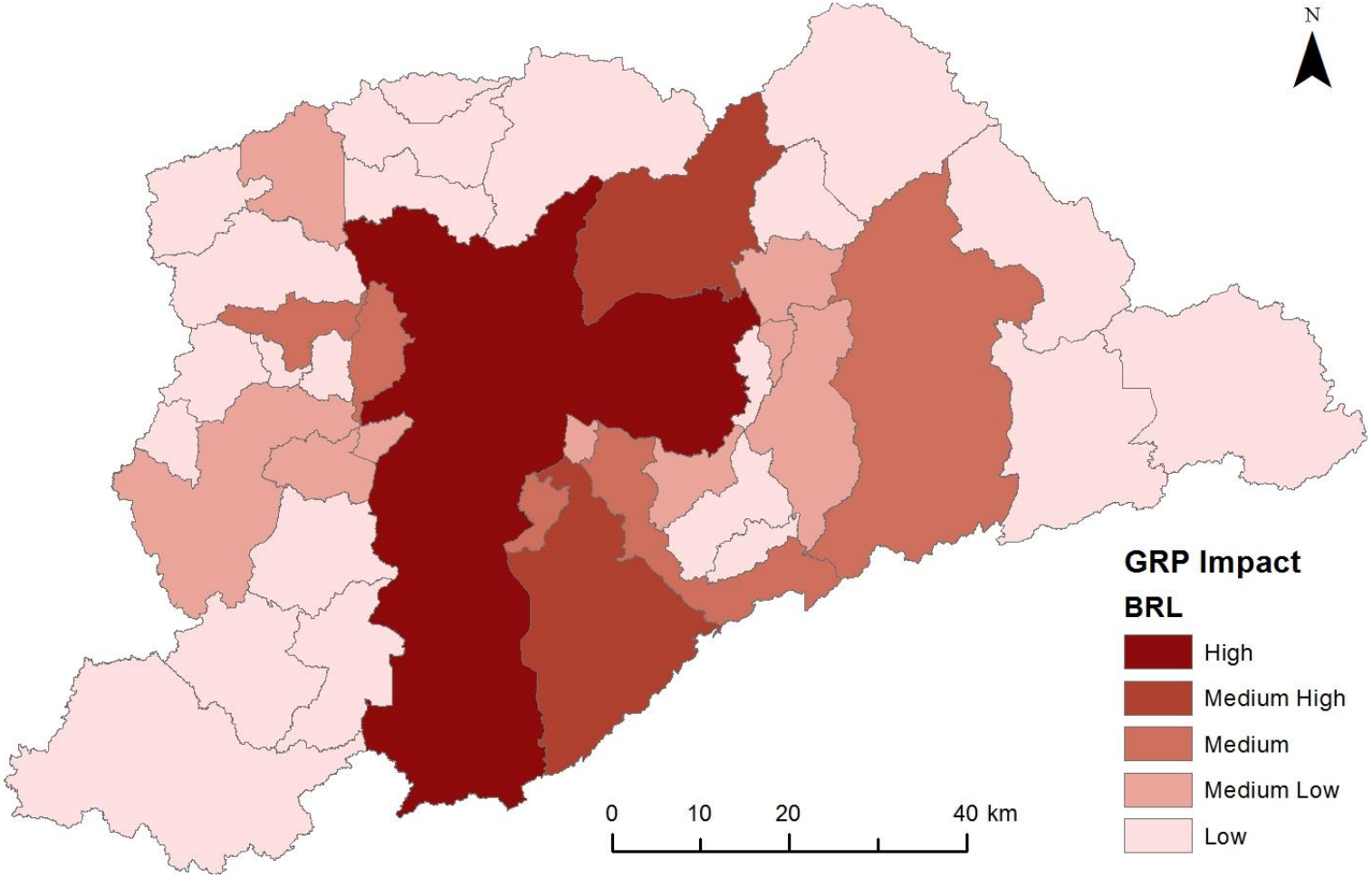


Direct and total GRP/GDP impact (in BRL million)

Capital costs per route-kilometer = BRL 400 million

	Simulation		*Difference*
	Extraction	*BRT*	
Direct (place of work)			
São Paulo City (SPC)	3358.0	1954.2	1403.8
Rest of SPMR (SPMR)	838.5	633.2	205.3
Total			
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
Intra-city multiplier	***1.8***	***2.0***	***1.6***
Economy-wide mutliplier	***4.6***	***5.0***	***4.0***

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



8. Traffic data help understanding localized impacts of unexpected events

How do temporary disruption events affect cities?

Measure hourly congestion in São Paulo Metropolitan Region (SPMR) using information from **Uber Movement**

- ✓ Average travel time (OD pairs)
- ✓ Different levels of aggregation (space and time)
- ✓ Free flow approach

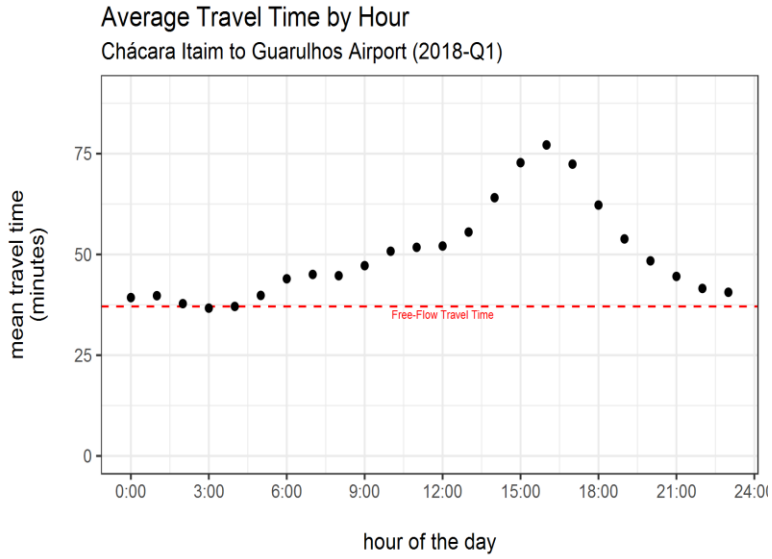
Travel Time Index (TTI)

$$i_{odp} = \frac{t_{odp}}{t^*_{od}} - 1$$

i_{odp} : TTI of trips made between TZs *o* and *d* during period *p* (*odp*)

t_{odp}: observed travel time (*odp*)

t^*_{od}: free-flow travel time (*odp*)



Interpreting the TTI

• Average TTI on weekdays:	41.2%
• Individuals traveling by car (OD):	3.62 million
• Total time spent on these trips :	5.47 million hours
• Time that would be spent under free flow:	3.87 million hours
• Time lost due to congestion:	1.6 million hours/day 26.4 minute per capita
• Time gained with the 2016 congestion reduction:	180,000 hours/day 3 minute per capita

TTI Application

Analyzing the impact of different events of traffic congestion

- Rainy days;
- A national truck drivers' strike between May 21 to May 31, 2018;
- The 2018 FIFA World Cup (especially when the Brazilian national team was playing);
- School holidays;
- The closing of part of Marginal Pinheiros due to the collapse of a bridge (Nov. 15, 2018).

TTI Application

Analyzing the impact of different events of traffic congestion

$$C_t = \alpha_t + \delta_t + \beta R_t + \sigma S_t + \gamma W_t + \gamma WB_t + \eta H_t + \theta E_t + \zeta SH_t + \omega_t \mathrm{t}_\mathrm{t} + \varepsilon_t$$

C_t: the congestion index *C* in the MRSP during each date t;

α_t: a vector of year specific intercepts;

δ_t: a vector of fixed effects associated with each day of the week (Mon, Tue, ...);

R_t: a dummy variable indicating days with more than 0.1mm of accumulated rain in the RMSP;

S_t: a dummy indicating the dates of the truck drivers' strike (May 21-31, 2018);

W_t: the 2018 FIFA World Cup dates (06/14/2013-07/15/2018)

WB_t: The Brazilian National team games during the World Cup;

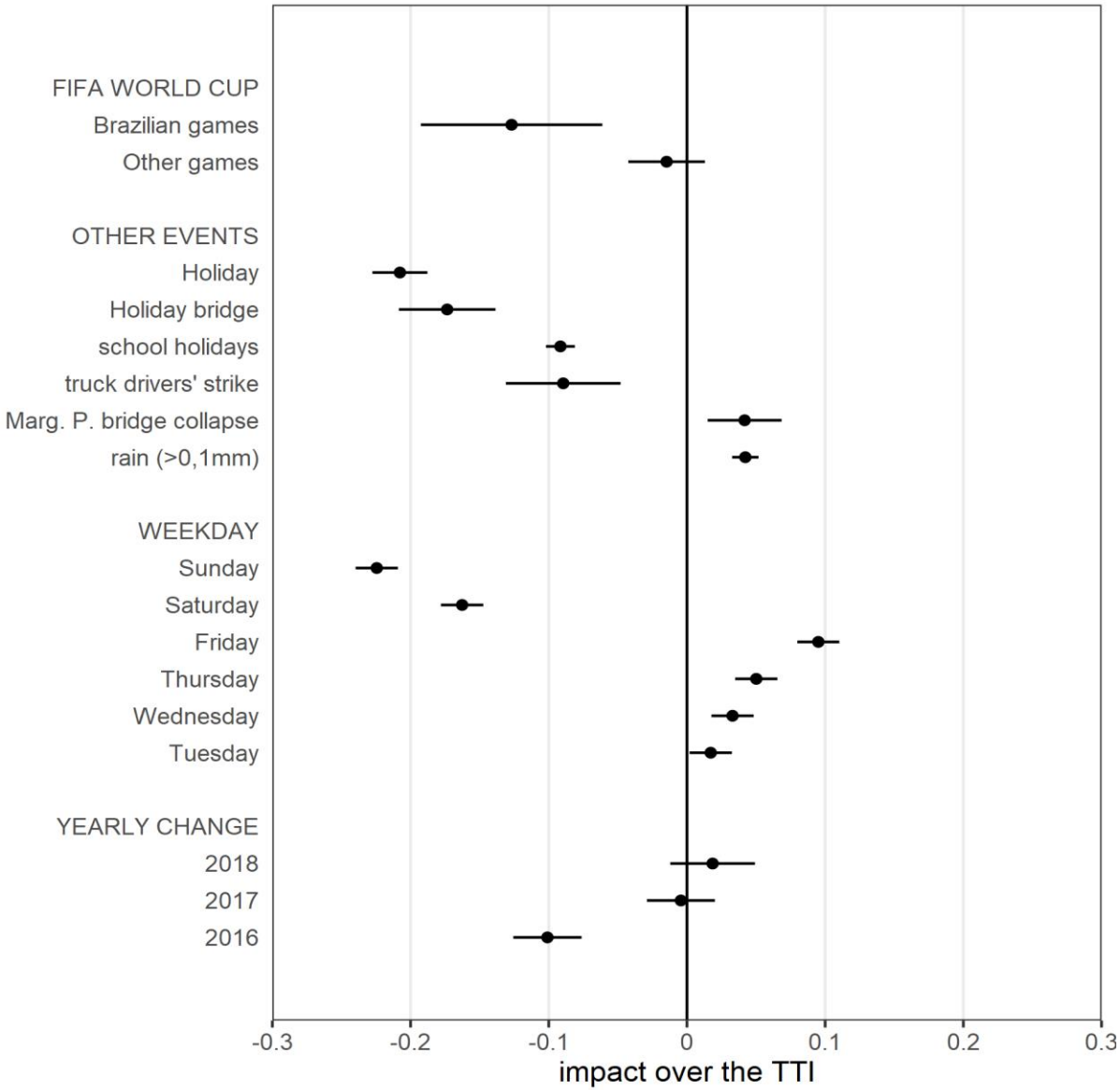
H_t: holidays;

E_t: holiday bridges;[1]

SH_t: school holidays (winter and summer);

ω_t: year specific linear time trends.

TTI Application



Economic cost of time (CGE estimates)

Tabela 3 – Valor econômico do tempo de deslocamento dos trabalhadores da RMSP, por dimensão econômica e região (em R$ de 2010/hora)

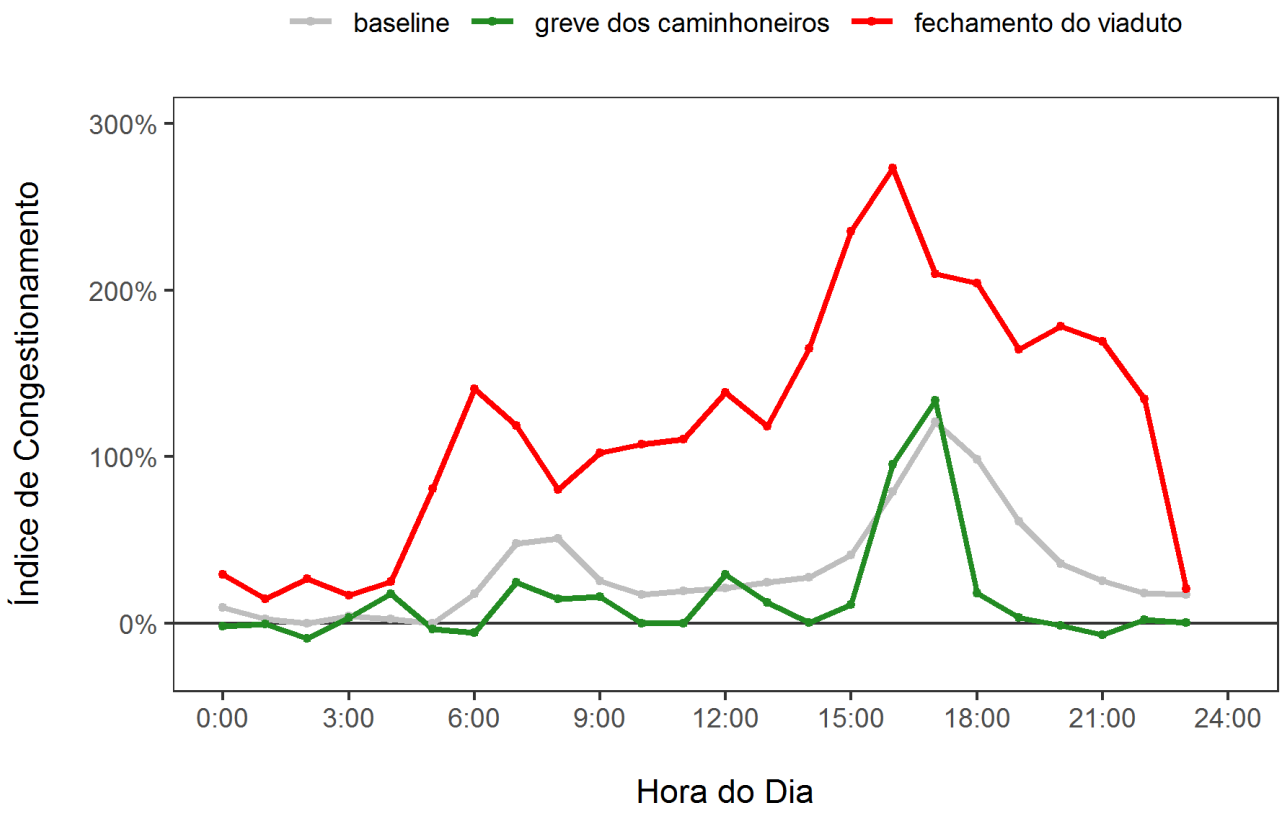
	Consumo			PIB		
	Curtíssimo prazo	Curto prazo	Longo prazo	Curtíssimo prazo	Curto prazo	Longo prazo
São Paulo	0,54	9,14	15,27	0,57	9,16	25,93
RMSP	0,32	6,06	10,77	0,23	4,86	12,73
Resto do Estado	0,03	0,52	3,96	0,03	0,53	5,99
Resto do Brasil	0,00	0,09	-0,61	0,04	0,49	6,36
Brasil	0,90	15,81	29,40	0,88	15,04	51,01

Nota: Salário-hora = R$ 12,60.
Fonte: Elaboração própria.

Fonte: Haddad, E. A. e Vieira, R. S. (2015). Mobilidade, Acessibilidade e Produtividade: Nota sobre a Valoração Econômica do Tempo de Viagem na Região Metropolitana de São Paulo. **Revista de Economia Contemporânea**, v. 19, n. 3, pp. 343-365.

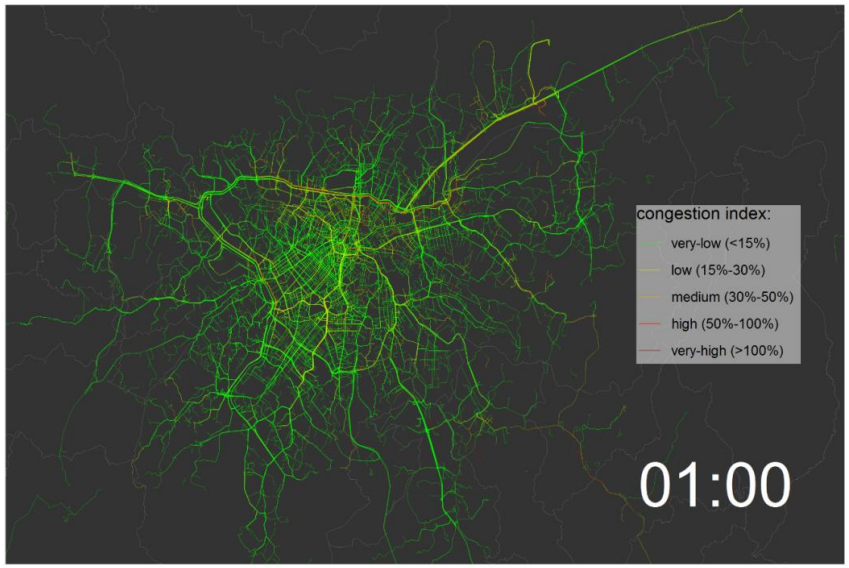
“Quick” impact assessment

<u>Example</u>: Trips between Alto de Pinheiros (O) and Tamboré (D)



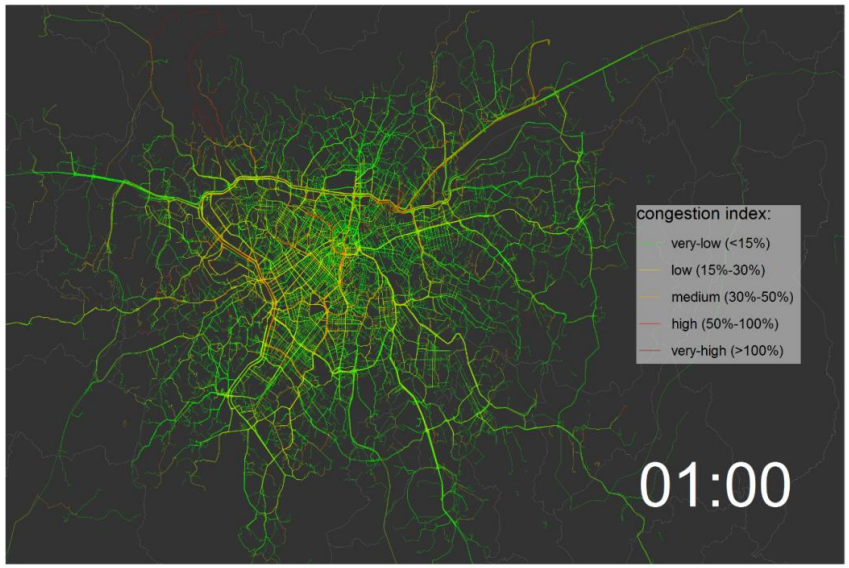
Example: Working day *versus* Holiday

Dia Útil
08/11/2017 - Quarta-feira



Working day

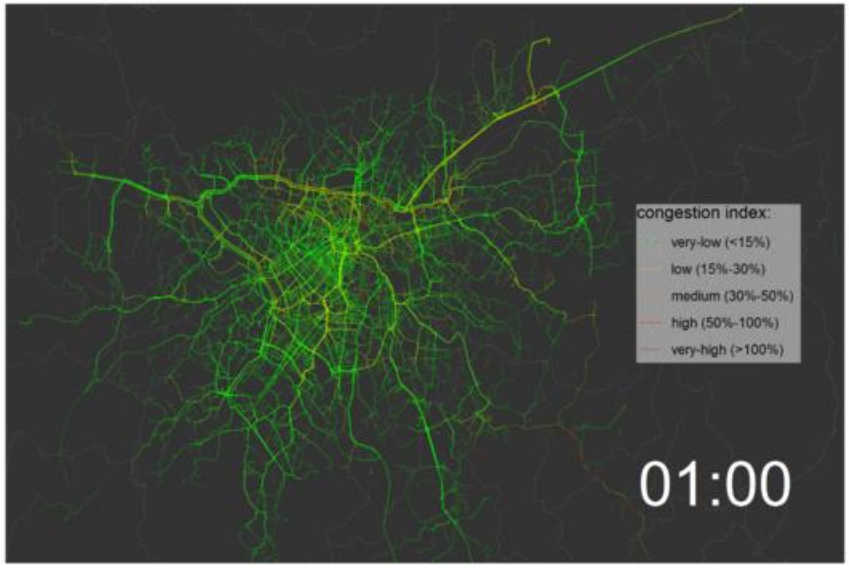
Feriado
15/11/2017 - Quarta-feira - Dia da Republica



Holiday

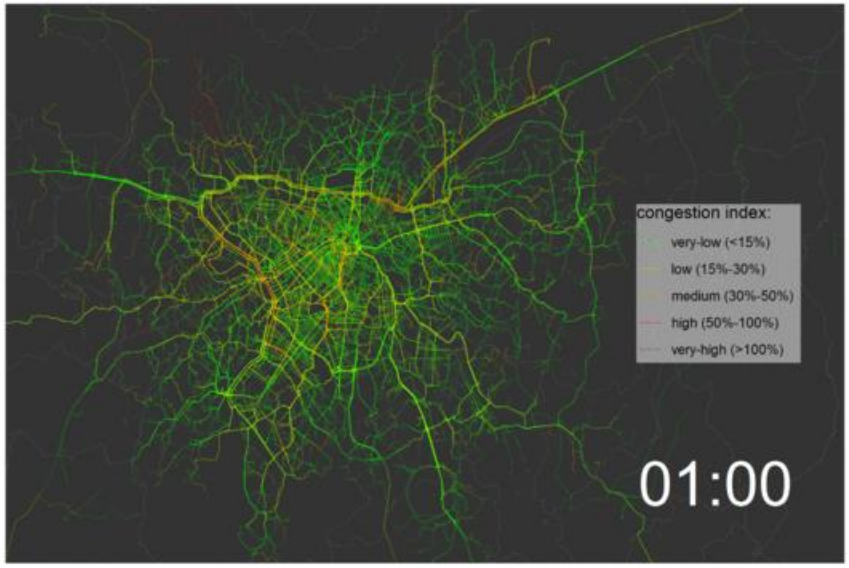
Example: Working day *versus* Holiday

Dia Útil
08/11/2017 - Quarta-feira



Working day

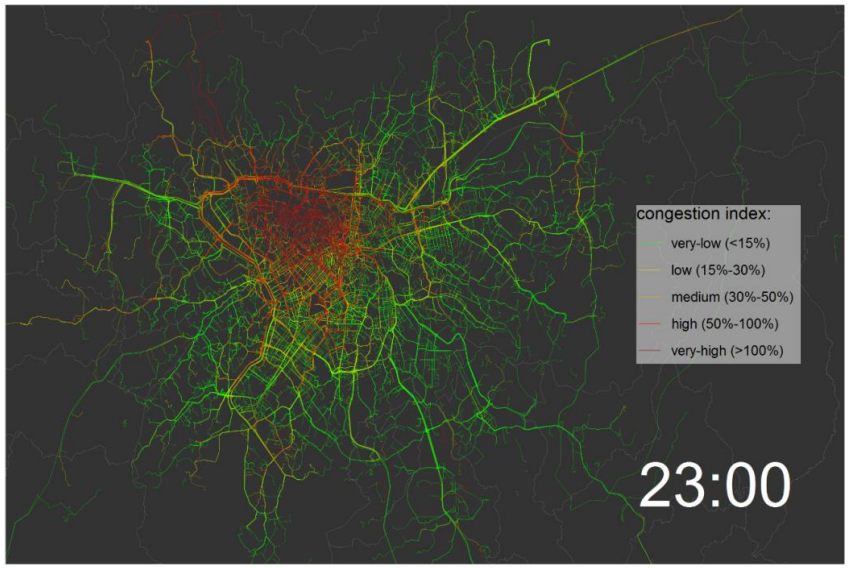
Feriado
15/11/2017 - Quarta-feira - Dia da Republica



Holiday

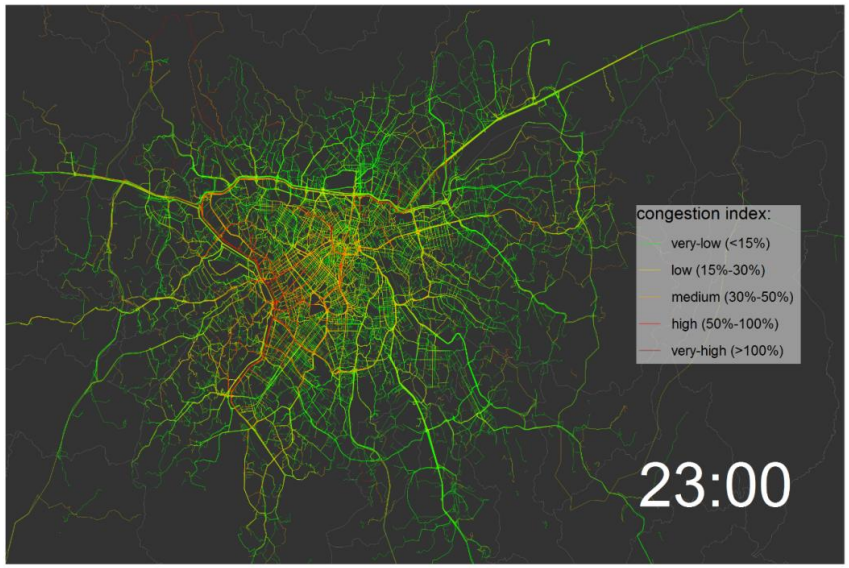
Example: Working day *versus* Holiday

Dia Útil
08/11/2017 - Quarta-feira



Working day

Feriado
15/11/2017 - Quarta-feira - Dia da Republica



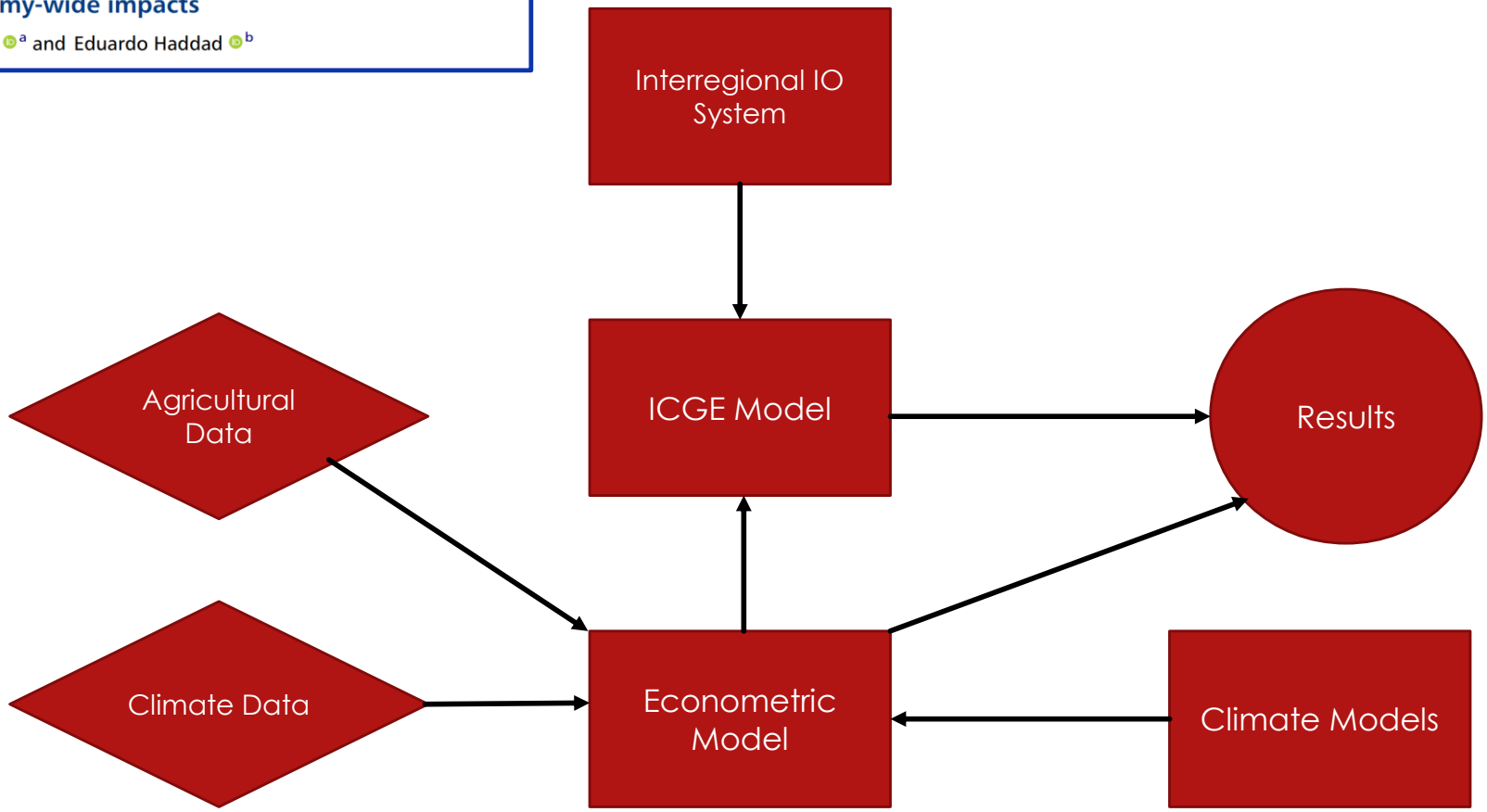
Holiday

9. Never forget about uncertainty on the numerical structure of the model

SPATIAL ECONOMIC ANALYSIS
https://doi.org/10.1080/17421772.2021.1934524
Routledge Taylor & Francis Group
RSA Regional Studies Association
Check for updates

Climate change in Brazil: dealing with uncertainty in agricultural productivity models and the implications for economy-wide impacts

Bruno Souza [a] and Eduardo Haddad [b]



The snowball effect of uncertainty

Interregional CGE Model for Paraguay

NEREUS

Núcleo de Economia Regional e Urbana da Universidade de São Paulo

The University of São Paulo Regional and Urban Economics Lab

Interregional Input-Output System for Paraguay 2014

Reference: Haddad, E. A., Perobelli, F. S., Araújo, I. F., Castro, G., Ramirez-Alvarez, P. E. and Fernandes, R. P. (2021). Tool Kits in Multi-regional and Multi-sectoral General Equilibrium Modeling for Paraguay, *TD NEREUS 01-2021* , The University of São Paulo Regional and Urban Economics Lab (NEREUS).

CRunGEM - BMPY

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Picture | Text | Model/Data | Closure | Shocks | Output files | Solve | Results

BM-PY Model

Interregional Computable General Equilibrium Model for Paraguay

The University of Sao Paulo Regional and Urban Economics Lab - NEREUS

January 2021

Accumulated productivity changes in the agriculture sector due to climate change: Paraguayan regions, 2010-2100

Econometric estimates of crop yield models

+ Climate scenarios

+ Regional distribution of crops in Paraguay

CUADRO A.1

VARIACIÓN DEL RENDIMIENTO MEDIO DE LA AGRICULTURA EMPRESARIAL PARA EL ESCENARIO A2, 2010-2100, CON INTERVALOS DE CONFIANZA

(En porcentajes y nivel de confianza al 99%)

Cultivo	Rango inferior	Cambio medio	Rango superior
Soja	-28,6	-14,2	0,2
Trigo	-27,4	-17,2	-7,1
Maíz	4,7	7,3	10,0

Fuente: Elaboración propia.

Introducing uncertainty

CUADRO A.1

VARIACIÓN DEL RENDIMIENTO MEDIO DE LA AGRICULTURA EMPRESARIAL PARA EL ESCENARIO A2, 2010-2100, CON INTERVALOS DE CONFIANZA

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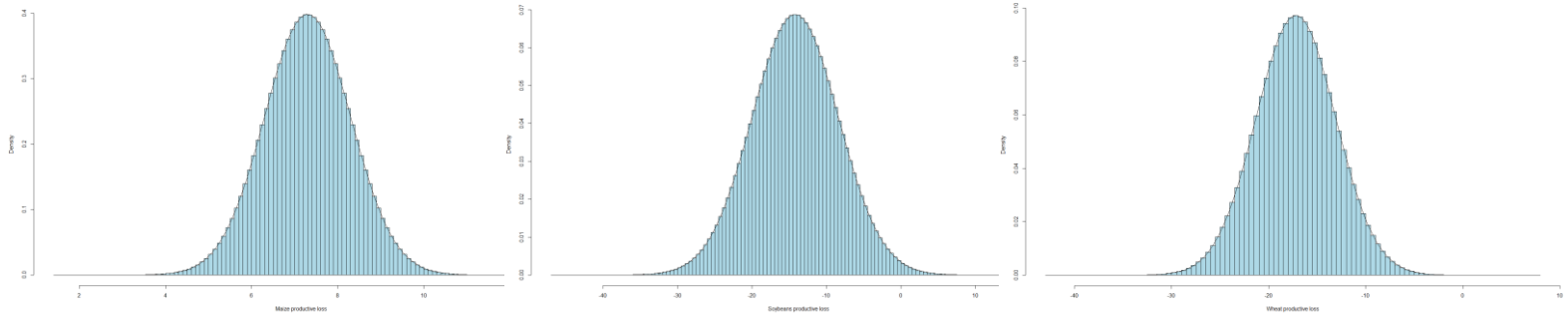
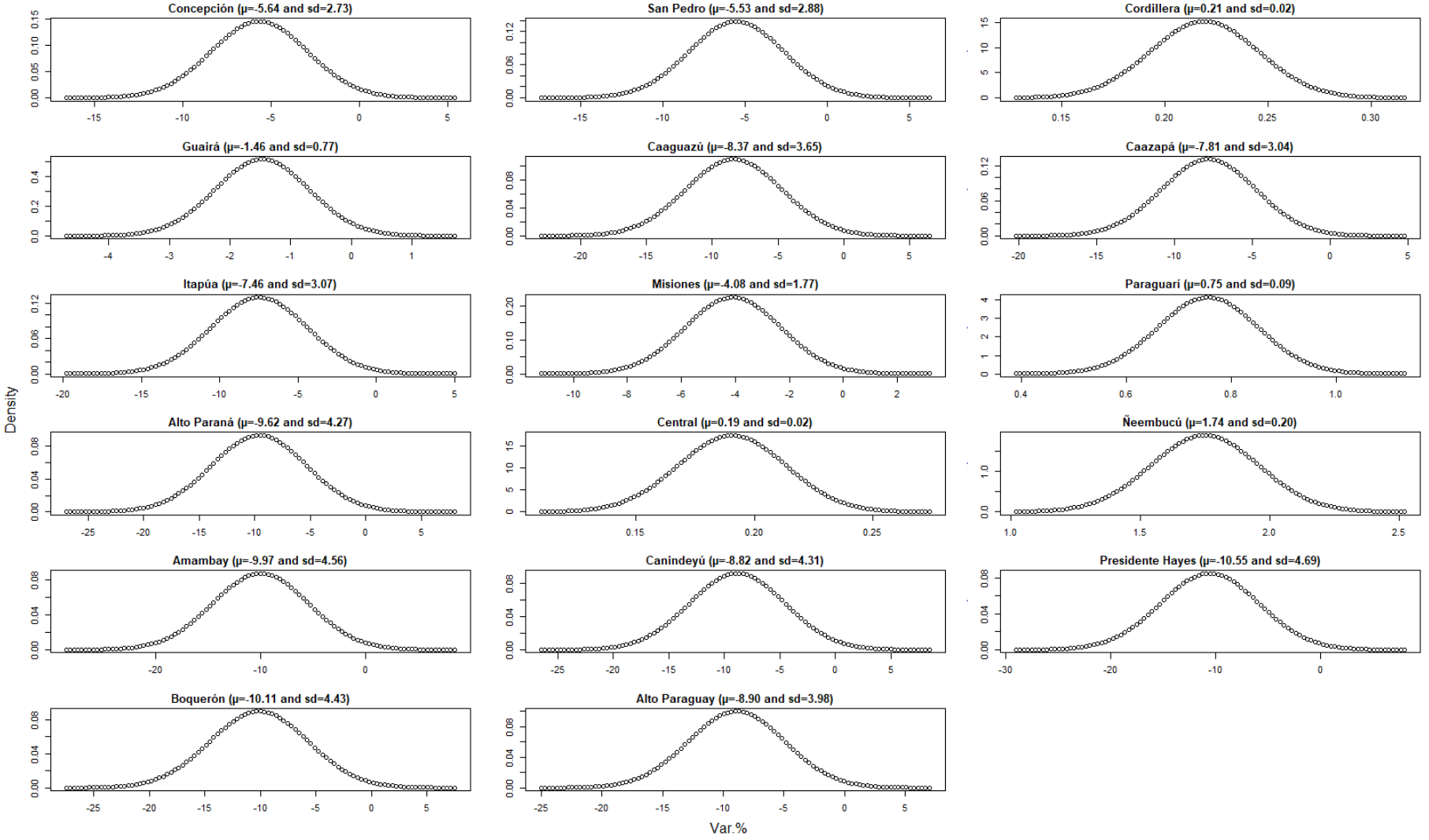
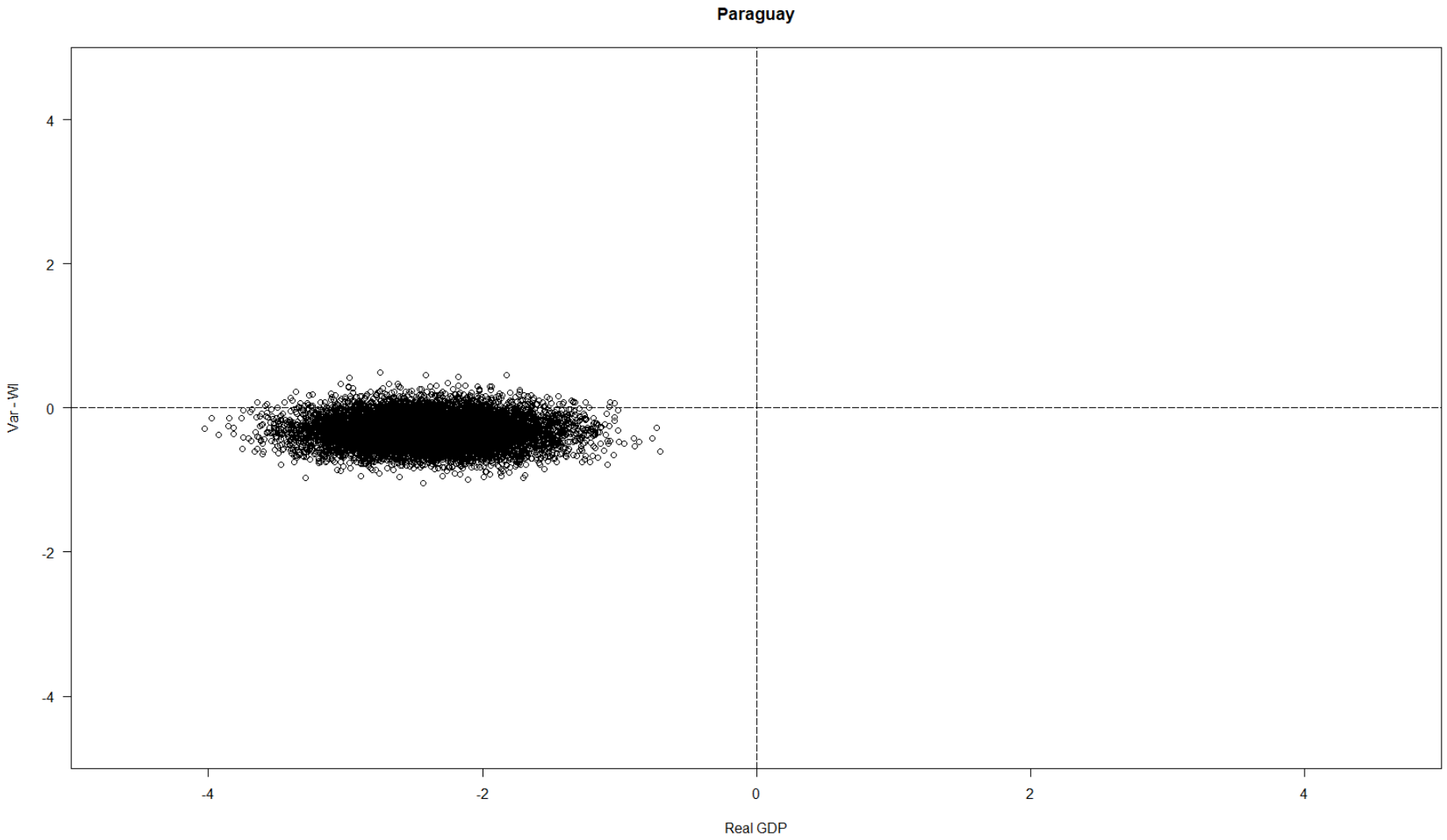
Fuente: Elaboración propia.



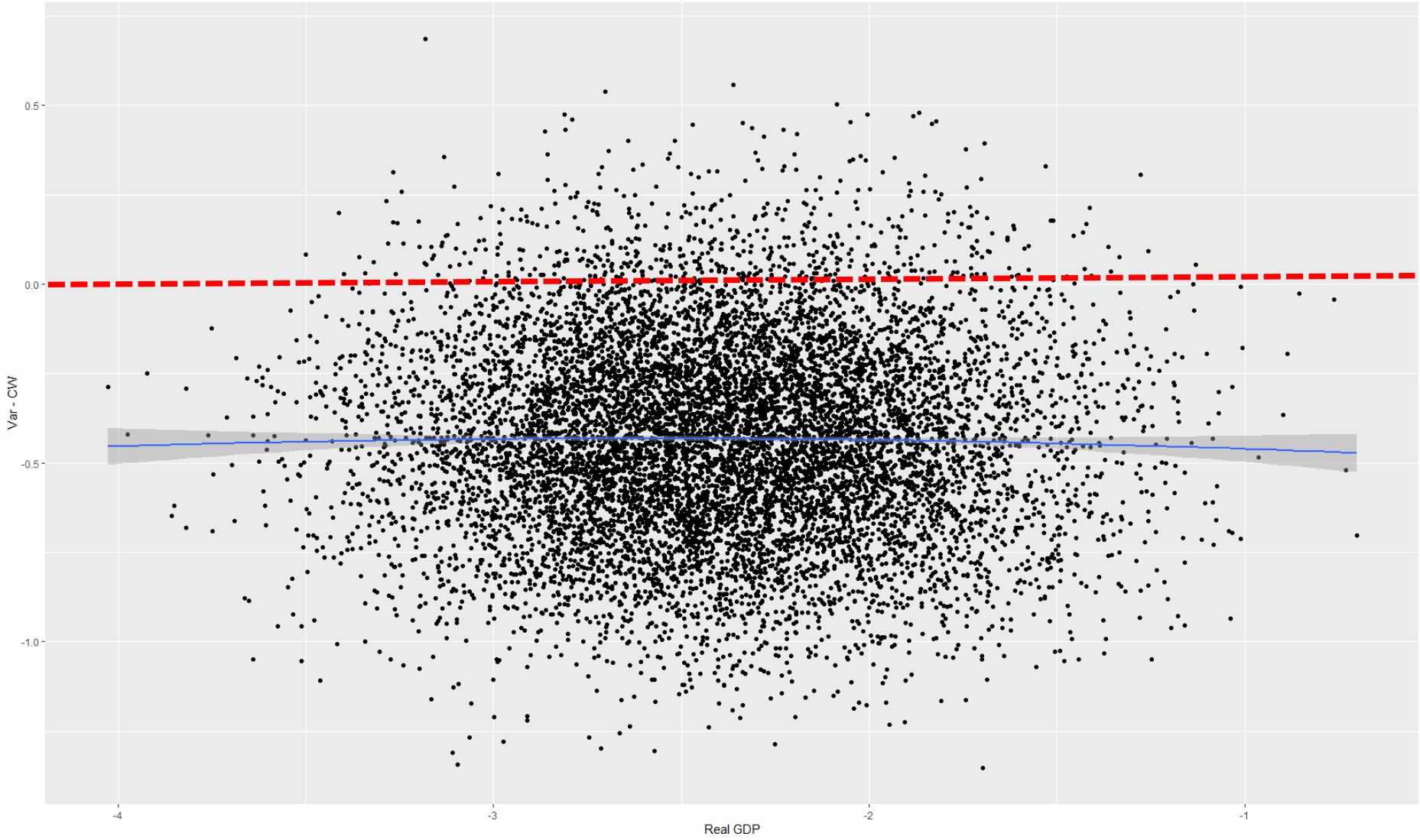
Regional shocks



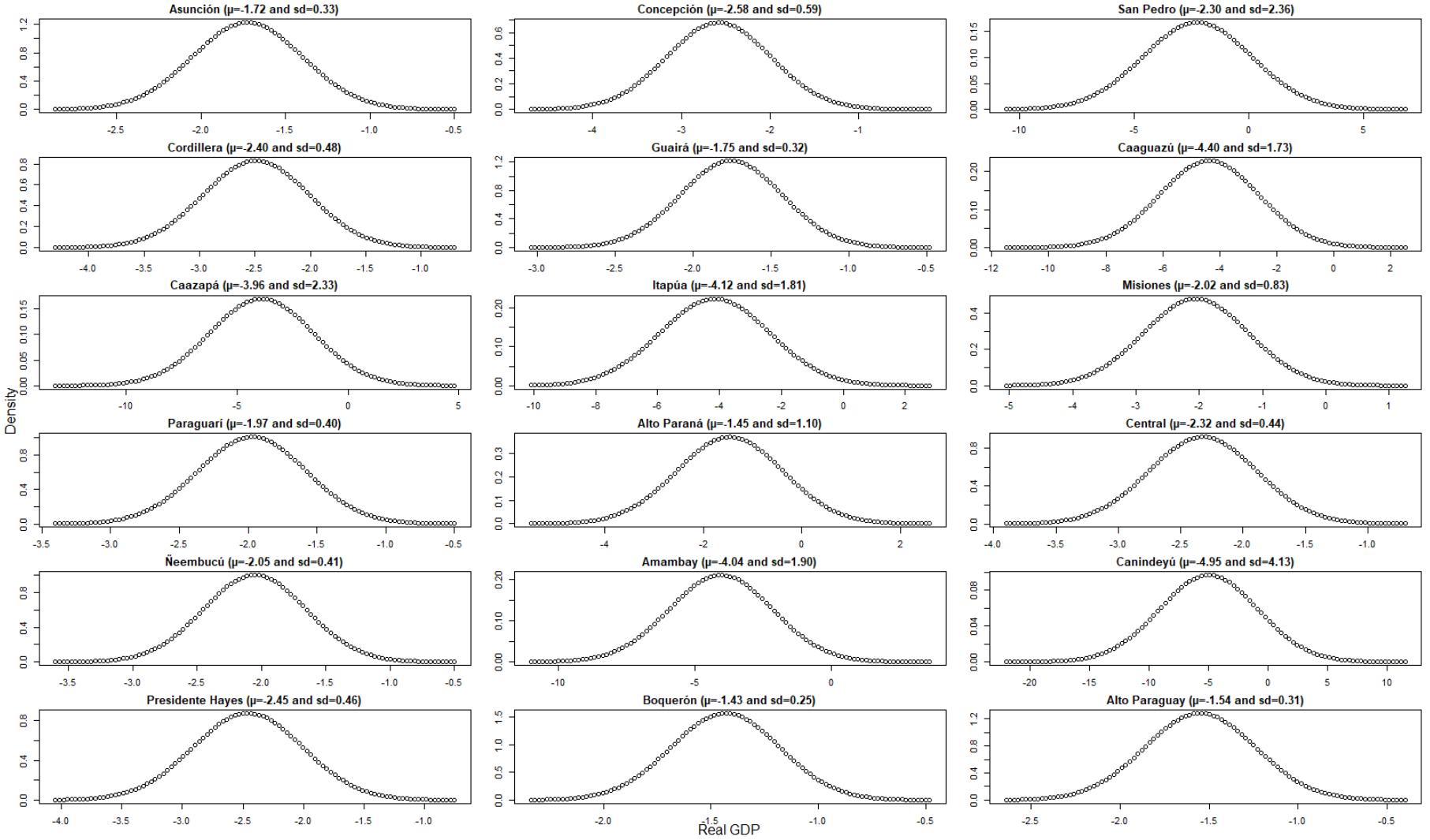
Regional equity-efficiency trade-off



Regional equity-efficiency trade-off



Real GRP


Asunción (μ=-1.72 and sd=0.33)
Concepción (μ=-2.58 and sd=0.59)
San Pedro (μ=-2.30 and sd=2.36)
Cordillera (μ=-2.40 and sd=0.48)
Guairá (μ=-1.75 and sd=0.32)
Caaguazú (μ=-4.40 and sd=1.73)
Caazapá (μ=-3.96 and sd=2.33)
Itapúa (μ=-4.12 and sd=1.81)
Misiones (μ=-2.02 and sd=0.83)
Paraguarí (μ=-1.97 and sd=0.40)
Alto Paraná (μ=-1.45 and sd=1.10)
Central (μ=-2.32 and sd=0.44)
Ñeembucú (μ=-2.05 and sd=0.41)
Amambay (μ=-4.04 and sd=1.90)
Canindeyú (μ=-4.95 and sd=4.13)
Presidente Hayes (μ=-2.45 and sd=0.46)
Boquerón (μ=-1.43 and sd=0.25)
Alto Paraguay (μ=-1.54 and sd=0.31)
Density
Real GDP

10. More on linkages: analytically important structural links

Disequilibrium-based methods depart from disturbances in the existing system to generate a new equilibrium comparable to the original one

Under the **field of influence** approach:

- ✓ Small coefficient changes in order to assess how "influential" a coefficient or a set of coefficients is to the system as a whole
- ✓ For known structural changes, one might be interested in assessing the impacts of given functional changes

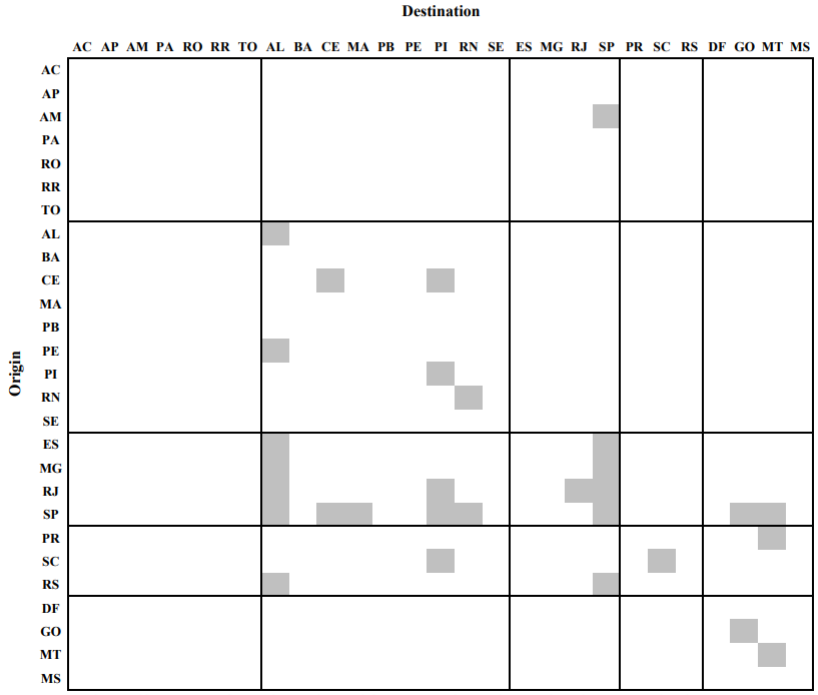
Application to transportation links

In order to address the issue of identification of the *analytically* most important structural links in generating CGE model outcomes for the case where a CGE model has been linked with a network-based transportation system, we proceed with a thorough decomposition of the results of simulations that considers the role played by various small changes in specific transportation costs

These incremental changes are associated with (a group of) coefficient changes computed from the information contained in the initial solution, V^*

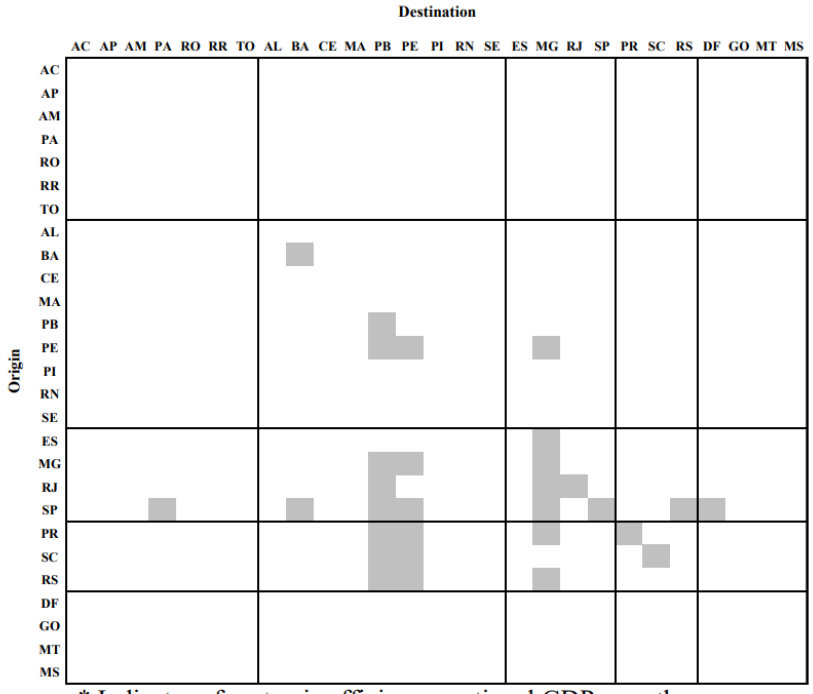
Application to transportation links

Figure 6
Long-Run Analytically Important Transportation Links Based on National Welfare*: Brazil



* Indicator of regional welfare: national equivalent variation

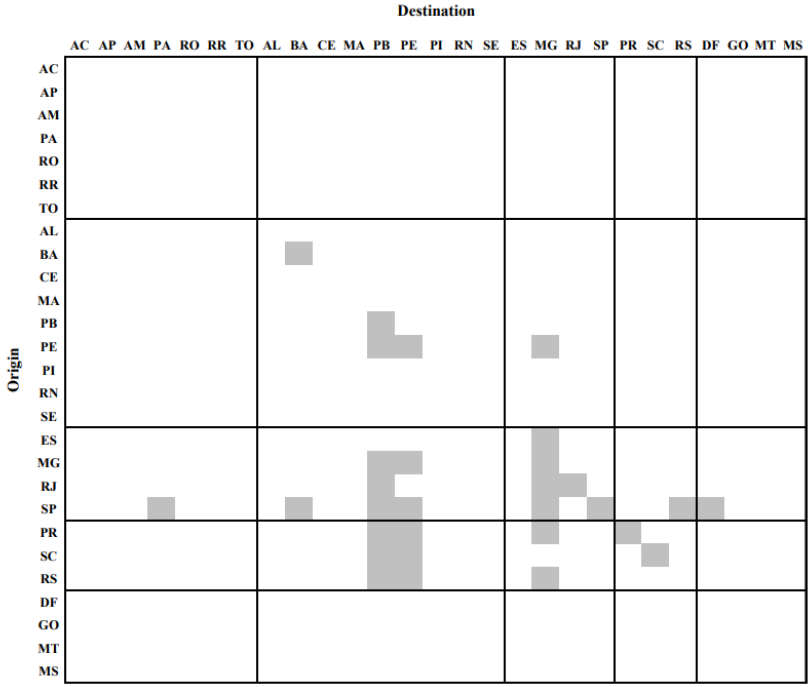
Figure 12
Long-Run Analytically Important Transportation Links Based on Systemic Efficiency*: Brazil



* Indicator of systemic efficiency: national GDP growth

Application to transportation links

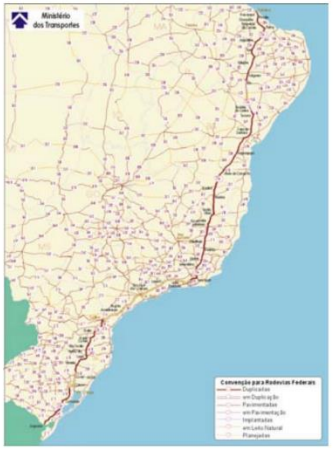
Figure 12
Long-Run Analytically Important Transportation Links Based on Systemic Efficiency*: Brazil



* Indicator of systemic efficiency: national GDP growth

Map 2. Selected Roads

BR-101 ***BR-116***



INÍCIO / ARQUIVOS / V.1 N.1 (2007): REVISTA BRASILEIRA DE ESTUDOS REGIONAIS E URBANOS / Artigos

ANALYTICALLY IMPORTANT TRANSPORTATION LINKS: A FIELD OF INFLUENCE APPROACH TO CGE MODELS

Eduardo Haddad
University of São Paulo, Brazil and REAL, University of Illinois, USA. CNPq and FAPESP scholar.

Geoffrey Hewings

11. State-of-the-art

nature COMMUNICATIONS

ARTICLE

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https://doi.org/10.1038/s41467-022-30504-3 OPEN

Risk caused by the propagation of earthquake losses through the economy

J. A. León [1✉], M. Ordaz [1], E. Haddad [2,3,4] & I. F. Araújo [2,4]

The economy of a country is exposed to disruptions caused by natural and man-made disasters. Here we present a set of probabilistic risk indicators, the Average Annual Loss (AAL) and the Loss Exceedance Curve (LEC), regarding to production, employment, Gross Domestic Product (GDP), Gross Regional Product (GRP), export volume, inflation, tariff revenue, among others, due to earthquakes. All indicators are computed using a systematic probabilistic approach, which integrates the seismic risk assessment with spatial computable general equilibrium models, both robust and well-known frameworks used worldwide in their respective fields. Our approach considers the induced damage and frequency of occurrence of a vast collection of events that collectively describe the entire seismic hazard of a country, giving us a better and more complete understanding of the full consequence of earthquakes. We illustrate this approach with an example developed for Chile.

Obrigado!

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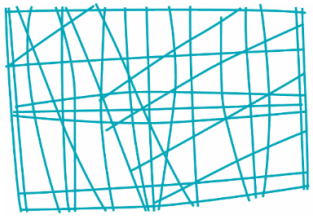

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