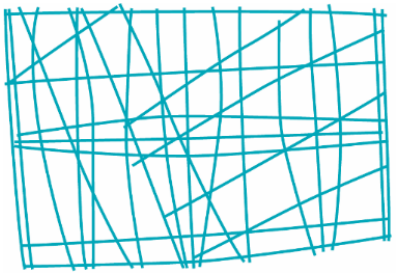

NEREUS

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

Tool Kits in Multi-regional and Multi-sectoral General Equilibrium Modeling for Colombia

"International Workshop on Interregional Economic Modeling: Applications for the Colombian Economy"

Banco de la República, Cartagena, Colombia
March 19-21, 2020

Eduardo Haddad

Research team – NEREUS

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Alexandre Gomes
Carlos Eduardo Espinel
Eduardo Sanguinet
Inácio Fernandes Araújo
Márcia Istake
Maria Aparecida Oliveira
Pedro Oliveira
Pedro Sayon
Rodrigo Pacheco

Background

EAE 5918 – "Applied General Equilibrium Models"

- Greece (2017), Chile (2018)
- Part 1 – Input-Output models
- Part 2 – CGE models
- Modeling Marathons (2x)
- Publication process

Enhance broader scientific communication skills

- **Project 2019: Colombia**
- Jaime Bonet and Luis Galvis

Cartagena, July 2019

I Modeling Marathon – Input-output

Date: September 12, 2019
Time: 8:00 – 18:00
Place: NEREUS meeting room

12.09 Quinta

MARATONA DE MODELAGEM 2019: MODELO DE INSUMO-PRODUTO PARA COLÔMBIA
Evento fechado
Das 8h às 18h, na sala 111, FEA-2
Responsável: Prof. Dr. Eduardo Amaral Haddad
Realização: Nereus
Inf.: 3093-0944

II Modeling Marathon – CGE

Date: November 21, 2019
Time: 8:00 – 18:00
Place: NEREUS meeting room

Outcomes

Interregional Input-Output System for Colombia

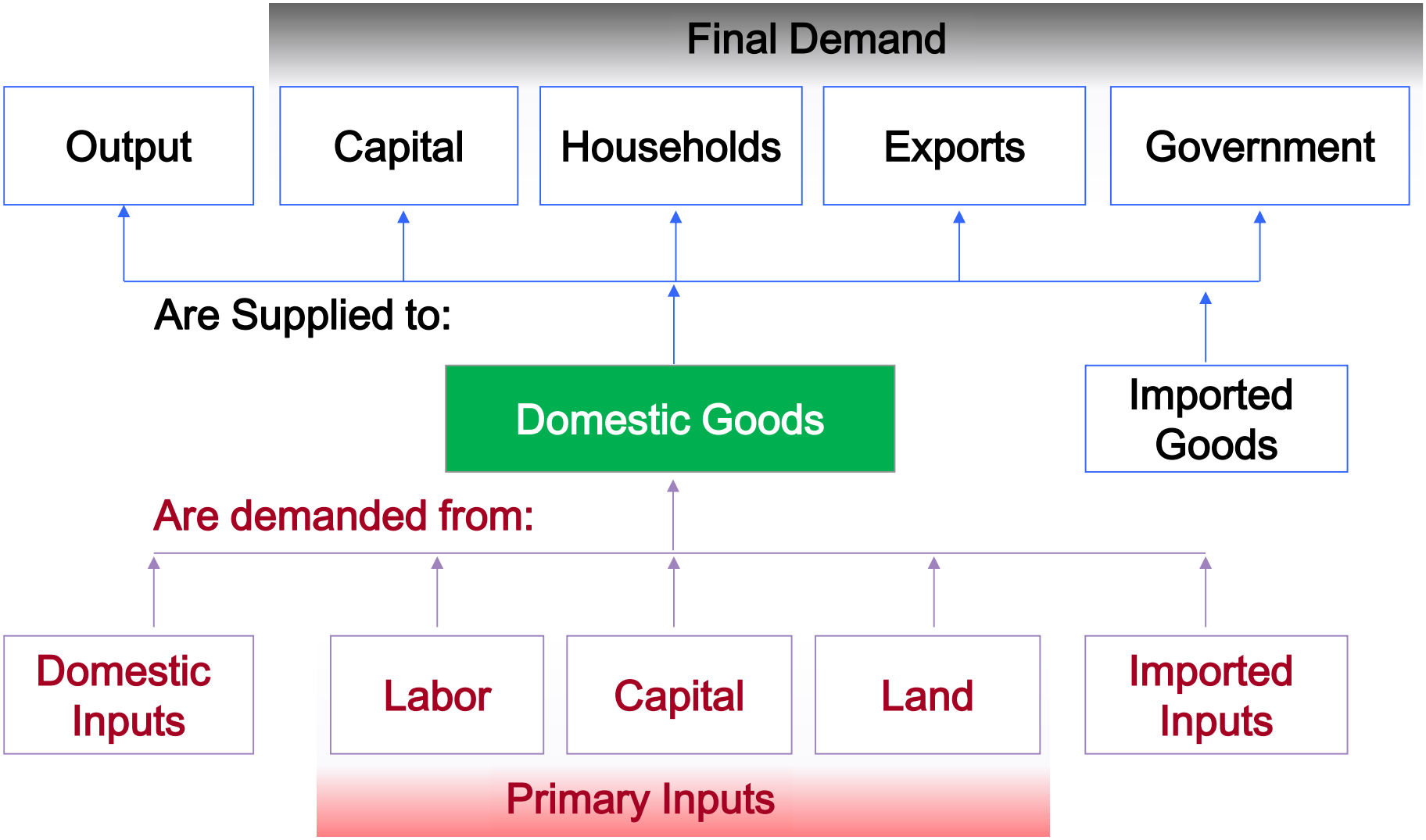
National CGE Model for Colombia (ORANI-COL)

Interregional CGE Model for Colombia (BMCOL)

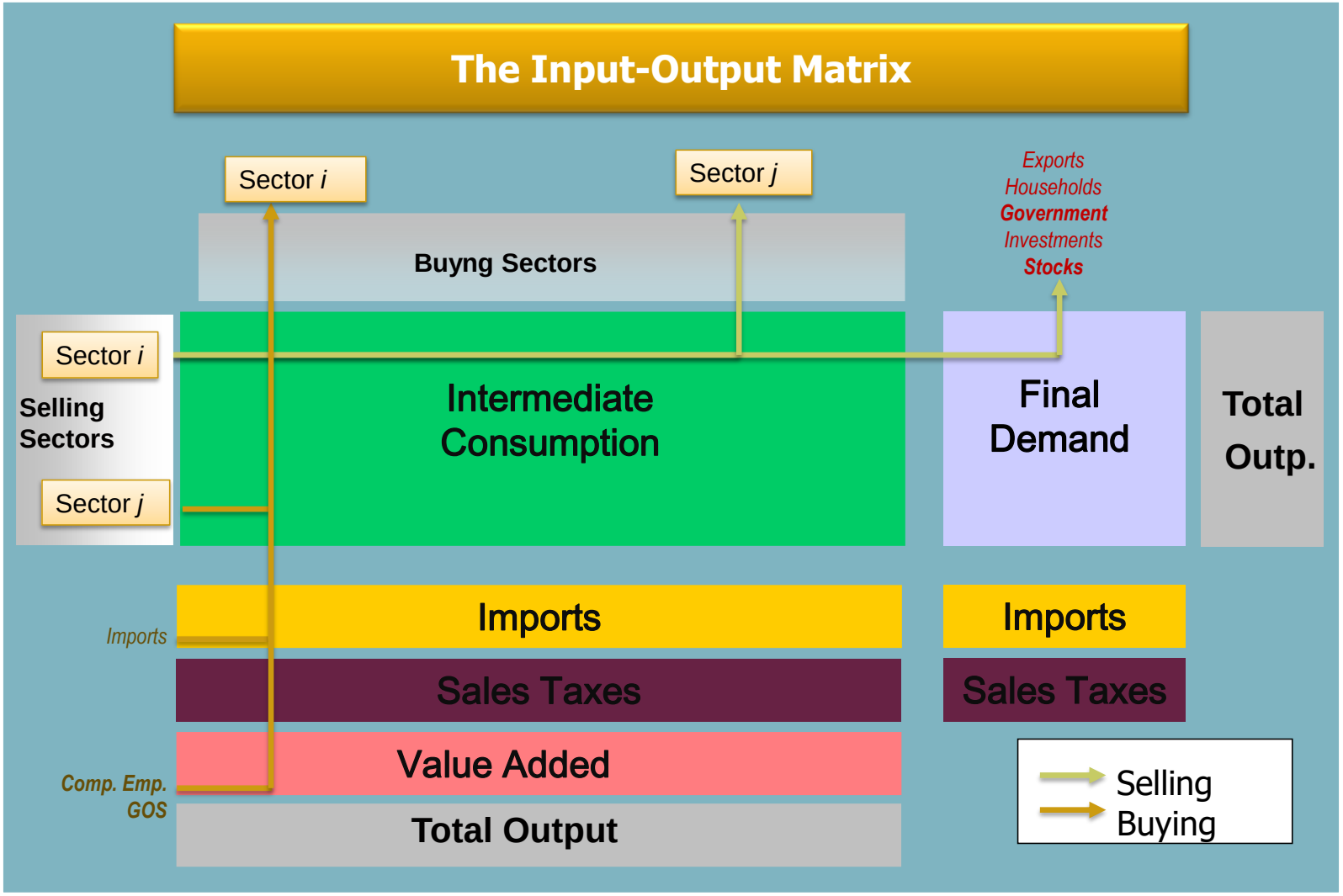
Seven different applications

"International Workshop on Interregional Economic Modeling: Applications for the Colombian Economy"

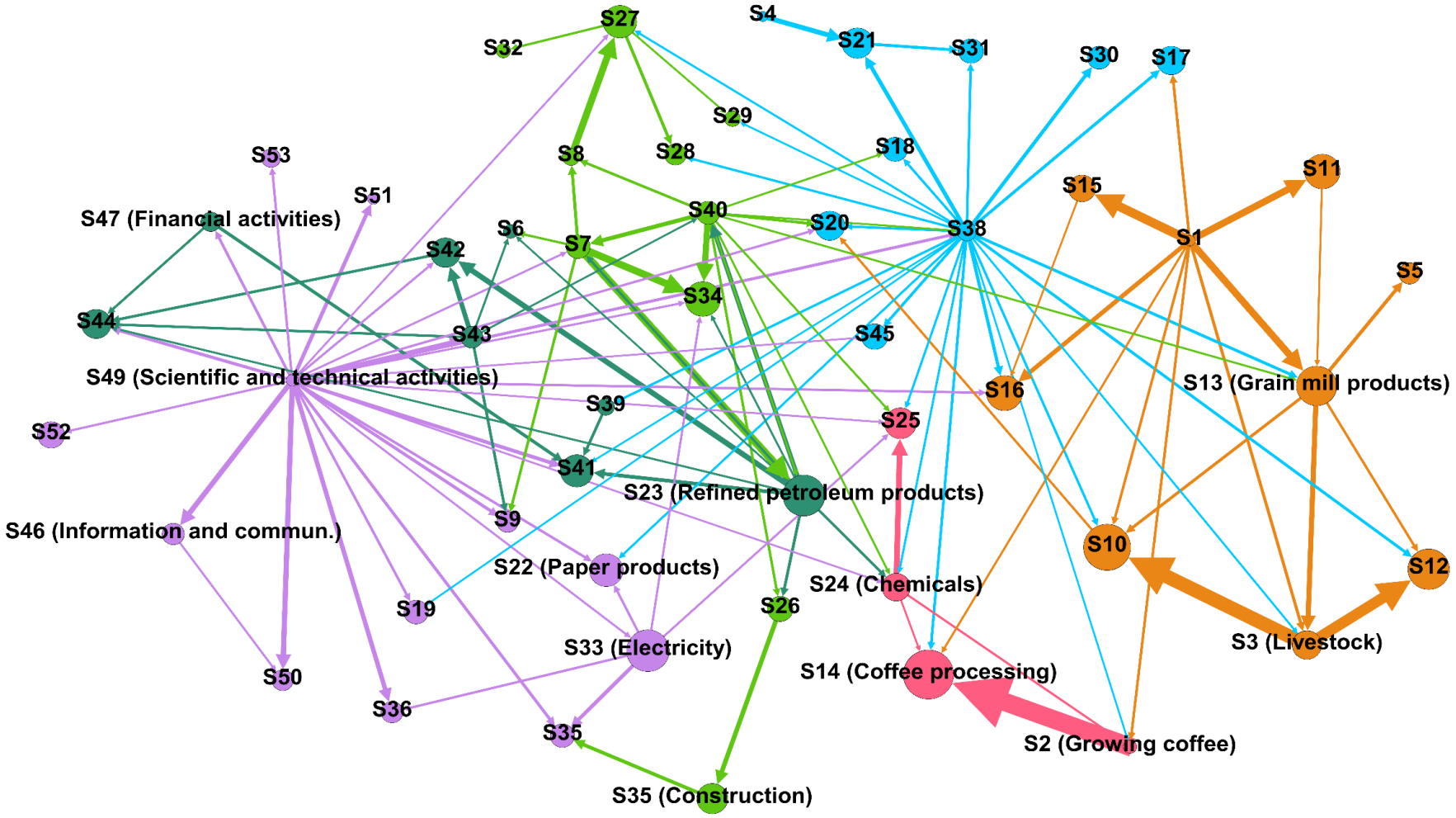
Input-output flows



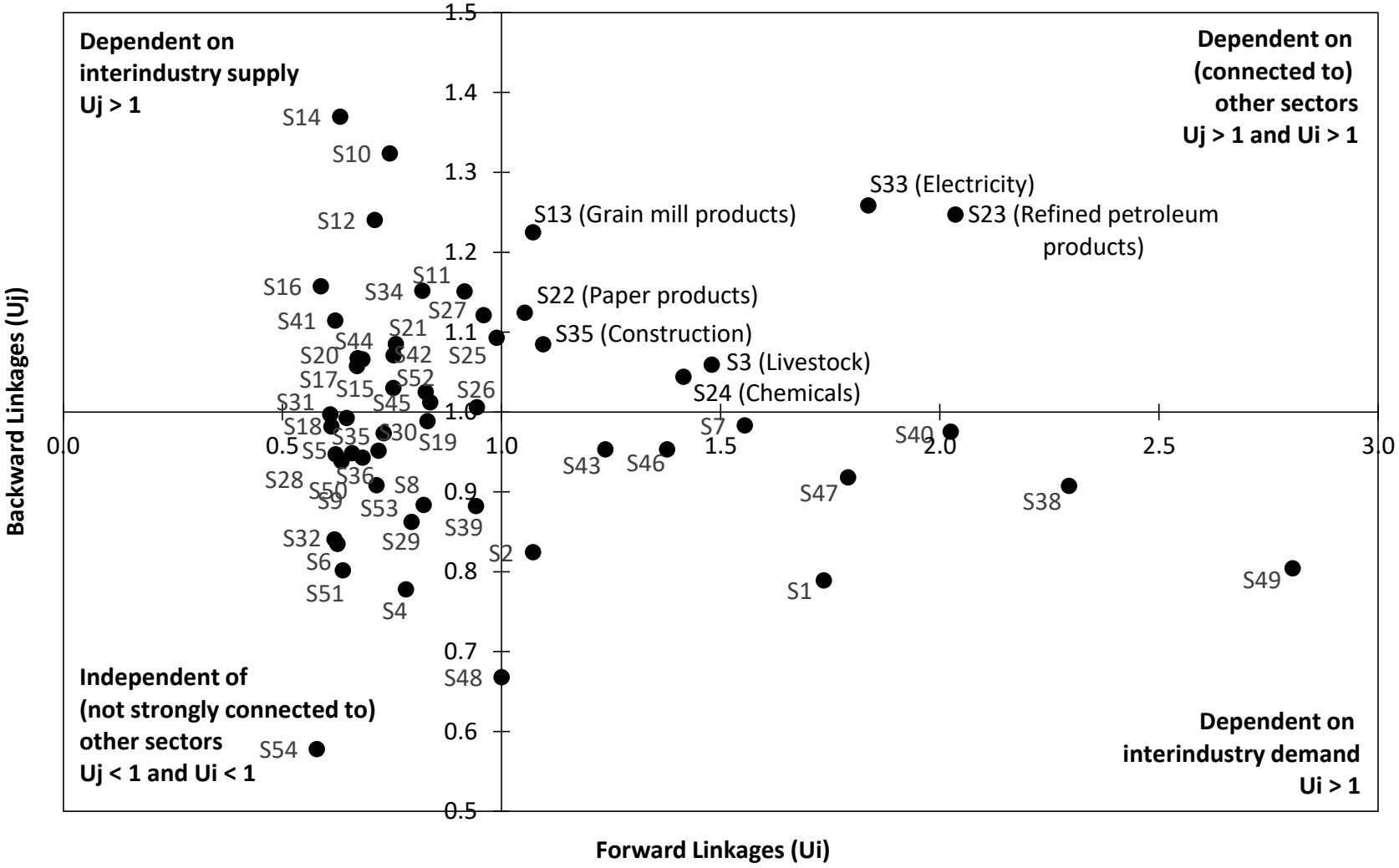
Input-output table



Input-output network in Colombia



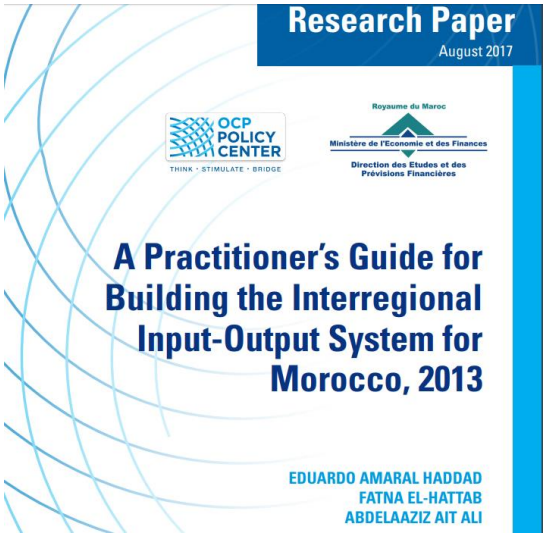
R-H backward and forward linkages



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			

Methodology



Revista Brasileira de Estudos Regionais e Urbanos (RBERU)
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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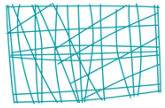

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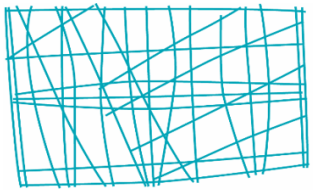
Interregional Input-Output Tables for Mexico, 2013

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).

Interregional Input-Output System for Colombia, 2015



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Banco de la República | Colombia

Investigaciones económicas

Interregional Input-Output Tables for Colombia 2015

Reference: Haddad, E. A., Araújo, I. F., Galvis, L. A. (2019). Matriz Insumo-Producto Interregional de Colombia, 2015 (Nota Técnica), *TD NEREUS 10 - 2019* , The University of São Paulo Regional and Urban Economics Lab (NEREUS).

http://www.usp.br/nereus/?txtdiscussao=matriz-insumo-producto-interregional-de-colombia-2015-nota-tecnica

Estimation of trade matrices

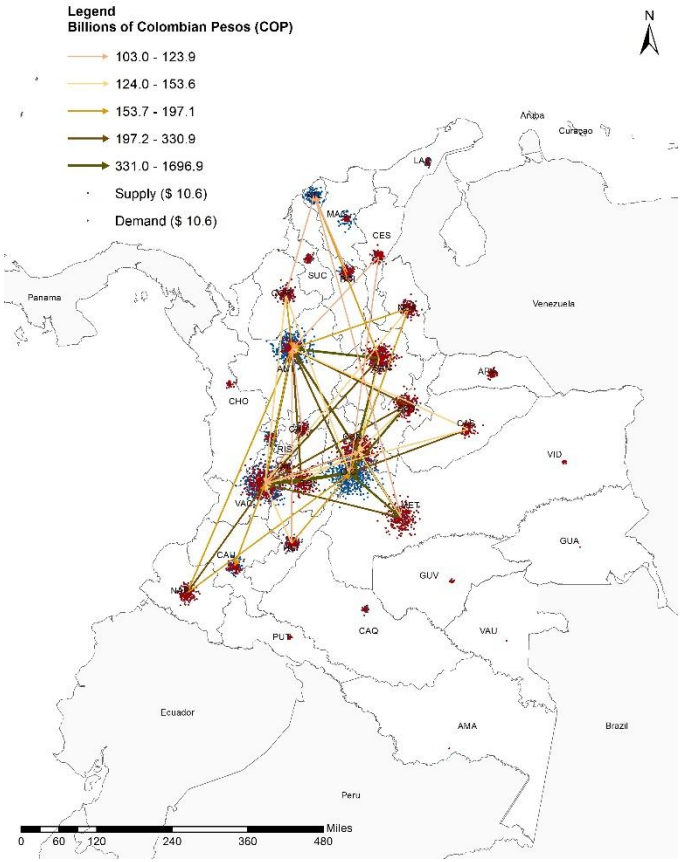
Impedance factor estimated for 27 sectors (4 groups) using OD-2013 database

VARIABLES	(1) Setor0	(2) Setor1	(3) Setor2	(4) Setor3	(5) Setor4
log_pib_origin	0.984***	1.268***	0.965***	0.641***	1.040***
	(0.088)	(0.205)	(0.126)	(0.096)	(0.155)
log_pib_dest	1.090***	0.948***	1.076***	0.940***	1.146***
	(0.091)	(0.141)	(0.120)	(0.210)	(0.176)
log_tiempo_minutos	-0.561***	-0.723***	-0.652***	-0.790***	-0.640***
	(0.083)	(0.097)	(0.076)	(0.199)	(0.070)
Constant	-5.420***	-7.972***	-4.826**	-2.955	-7.746***
	(1.634)	(2.905)	(2.098)	(3.135)	(2.717)
Observations	812	784	812	812	812
R-squared	0.719	0.690	0.763	0.750	0.801
Dep_Origin FE	YES	YES	YES	YES	YES
Dep_Destiny FE	YES	YES	YES	YES	YES

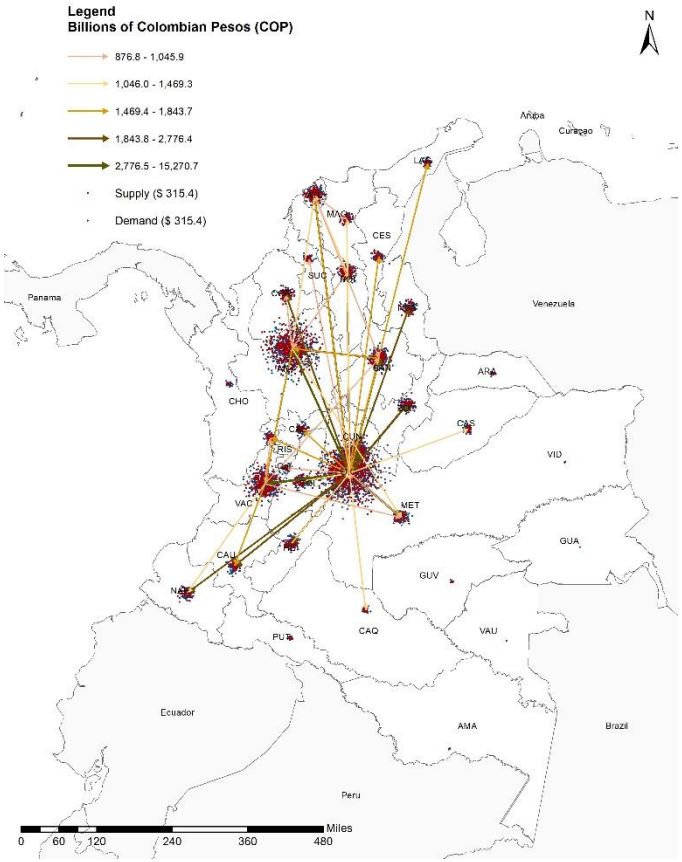
0. Total, 1. Agroindustriales, 2. Industriales, 3. Minero, 4. Productos Agrícolas

Trade matrices: examples

Agriculture



Services



Sectors/commodities

54 sectors/commodities:

- 5 sectors - Agriculture and fishing
- 4 sectors – Mining
- 23 sectors – Manufacturing
  - 14 low technology
  - 4 medium technology
  - 5 high technology
- 22 sectors – Services
  - 3 KIBS

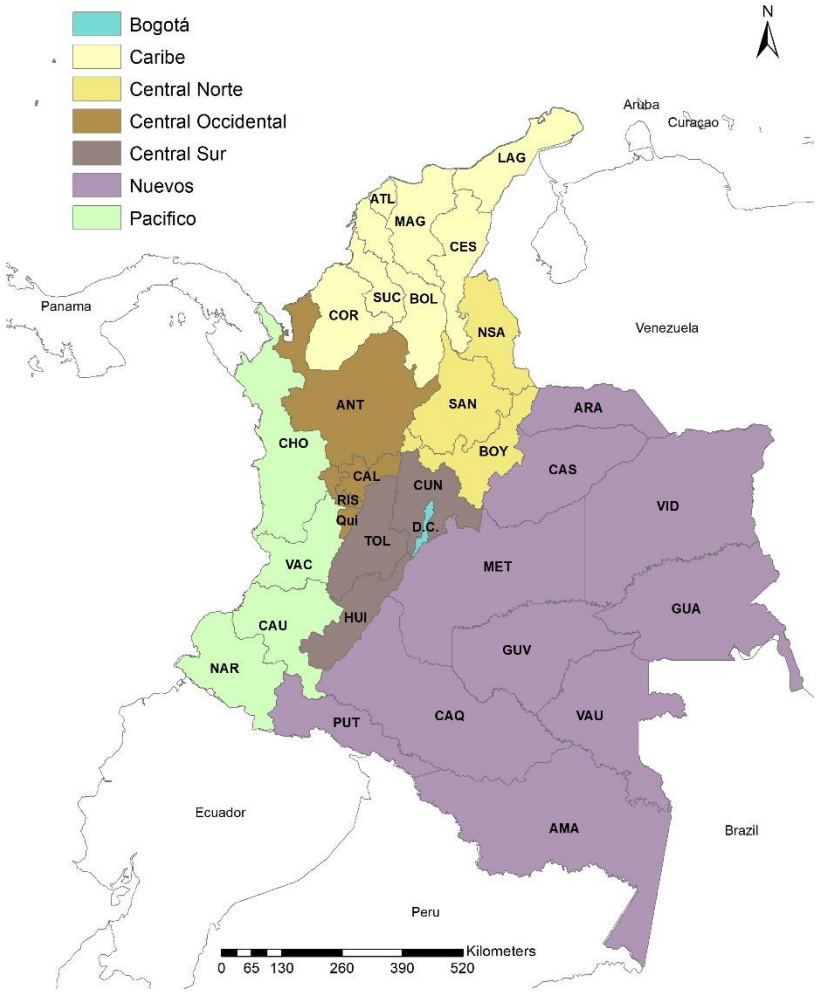
S2 – Coffee growing

S6 – Coal
S7 – Petroleum
S8 – Metal ores
S9 – Other mining

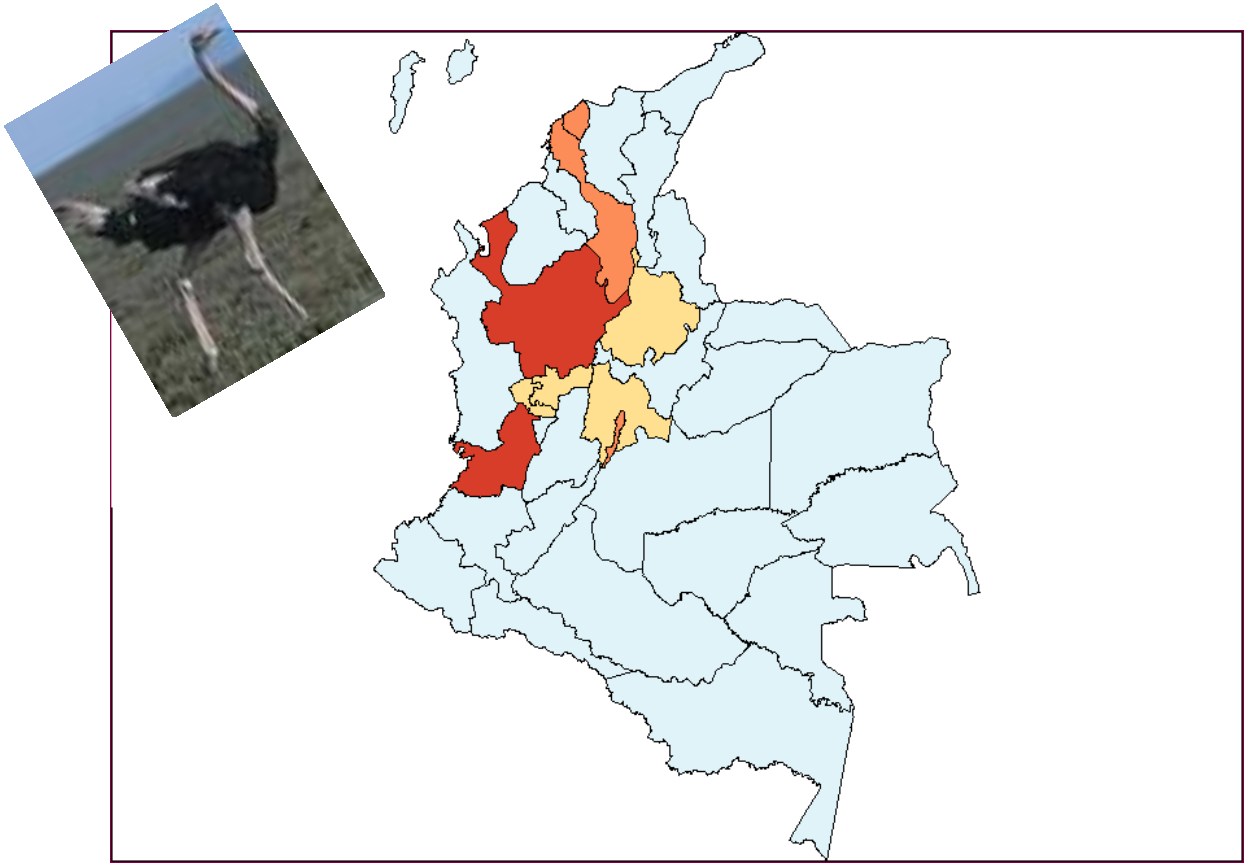
S14 – Coffee processing

S46 – Information and communication
S47 – Financial
S49 – Professional, scientific and technical

Regions


Bogotá
Caribe
Central Norte
Central Occidental
Central Sur
Nuevos
Pacifico
N
Aruba
Curaçao
Panama
Venezuela
Ecuador
Peru
Brazil
LAG
ATL
MAG
CES
SUC
BOL
COR
NSA
ANT
SAN
ARA
CHO
BOY
CAS
CAL
CUN
VID
RIS
Qui
D.C.
TOL
MET
VAC
GUA
HUI
CAU
GUV
NAR
CAQ
VAU
PUT
AMA
Kilometers
0 65 130 260 390 520

What do you see in this picture?



Interregional CGE Model for Colombia

CRunGEM - BMCOL

File Copy View Options Help

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

BMCOL Model

Interregional Computable General Equilibrium Model for Colombia

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

November 2019

What is a CGE model ?

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

What is a CGE model good for?

Analyzing policies that affect different sectors and regions in different ways

The effect of a policy on different:

- ✓ Sectors
- ✓ Regions
- ✓ Factors (Labor, Capital)

Policies that help one sector/region a lot, and harm all the rest a little

What-if questions

What if productivity in the coffee-growing sector decreased due to a permanent climate shock?

What if the climate shock also affected the quality of Colombian coffee?

What if climate change affected coffee yields in regionally-differentiated ways?

What if productivity in manufacturing sectors increased?

What if productivity in KIBS also increased?

What if Colombia faced (uncertain) commodity price shocks?

BMCOL, a bottom-up spatial CGE model of Colombia

A multi-sectoral, multi-regional bottom-up CGE model of Colombia's 32 Departments and the capital city, Bogotá

- each region is modeled as an economy in its own right
- region-specific prices
- region-specific industries
- region-specific consumers

Based on the comparative-static B-MARIA and MMRF models

- CGE core of the CEER model

Database makes allowance for interregional, intra-regional and international trade

- Potential for the representation of regional and central government financial accounts

BMCOL like other CGE models

Equations typical of a CGE model, including:

- ✓ 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;
- ✓ a few 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

Features of database

Commodity flows are valued at "basic prices" (do not include user-specific taxes or margins)

For each user of each imported good and each domestic good, there are numbers showing:

- ✓ tax levied on that usage
- ✓ usage of several margins (trade, transport) – specified but not calibrated yet

For each **industry** the total cost of production is equal to the total value of output (**column** sums of MAKE).

For each **commodity** the total value of sales is equal to the total value of output (**row** sums of MAKE).

No data regarding direct taxes or transfers: not a full SAM

Model Database – Structural coefficients

(Billions of COP 2015)

LABELS	User (1j)	User (2j)	User (3)	User (4)	User (5)	User (6)	User (7)	TOTAL
i∈G, s∈S	B(i,s,(1j))	B(i,s,(2j))	B(i,s,(3))	B(i,s,(4))	B(i,s,(5))	B(i,s,(6))	B(i,s,(7))	B(i,s,(•),•)
i∈G, s∈S	M(i,s,(1j))	M(i,s,(2j))	M(i,s,(3))	M(i,s,(4))	M(i,s,(5))	M(i,s,(6))	-	M(i,s,(•),•)
i∈G, s∈S	T(i,s,(1j))	T(i,s,(2j))	T(i,s,(3))	T(i,s,(4))	T(i,s,(5))	T(i,s,(6))	-	T(i,s,(•),•)
s∈F	V(g+1,s,(1j))	-	-	-	-	-	-	V(g+1,s,(•),•)
TOTAL	Y(•,•,1j)	V(•,•,(2j))	V(•,•,(3))	V(•,•,(4))	V(•,•,(5))	V(•,•,(6))	V(•,•,(7))	V(•,•,(•),•)

2015	User (1j)	User (2j)	User (3)	User (4)	User (5)	User (6)	User (7)	TOTAL
i∈G	678,239	185,927	512,504	118,997	71,202	50,838	-	1,617,707
i∈G, s∈S	-	-	-	-	-	-	-	-
i∈G, s∈S	32,160	5,378	30,862	263	185	132	0	68,981
s∈F	730,543	-	-	-	-	-	-	730,543
TOTAL	1,440,942	191,305	543,366	119,260	71,387	50,971	0	2,417,231

Model Database – Behavioral parameters

SIGMA1FAC – CES between primary factors: **0.5**

*SIGMA*O* – International Armington elasticities:

- GTAP values

*SIGMA*C* – Interregional Armington elasticities:

- 2*GTAP values

FRISCH – **-1.6578**

Expenditure elasticities – Cortés & Pérez (2010)

Cuadro 2. Elasticidades estimadas del sistema lineal de gasto.

Elasticidad	SALIM	SCEDU	SSVIV	SSALU	STRAN	SVEST	SOTRO
Gasto	0,786	1,186	1,043	0,973	1,115	1,025	1,131
	(0,028)	(0,038)	(0,016)	(0,045)	(0,041)	(0,033)	(0,048)
Precio no compensada	-0,903	-1,267	-1,120	-1,175	-1,195	-1,138	-1,203
	(0,146)	(0,145)	(0,108)	(0,143)	(0,117)	(0,137)	(0,157)
Precio compensada	-0,695	-1,185	-0,776	-1,147	-1,073	-1,056	-1,068
	(0,140)	(0,146)	(0,111)	(0,143)	(0,120)	(0,139)	(0,152)

Nota: El significado de las abreviaciones de las variables aparece en el cuadro A2 del anexo. Las elasticidades se calculan para el gasto medio de la muestra, 1.567.007. Los errores estándar se calculan utilizando el *delta method*. Todas las elasticidades son significativas al 1%.

Fuente: ENIG 2006-2007, cálculos propios.

Export demand elasticities

EXP_ELAST

"Estadísticas de Exportaciones – EXPO – 2011 A 2019"

Fixed effects model

Dependent variable:

ln_export_volume

Independent variable:

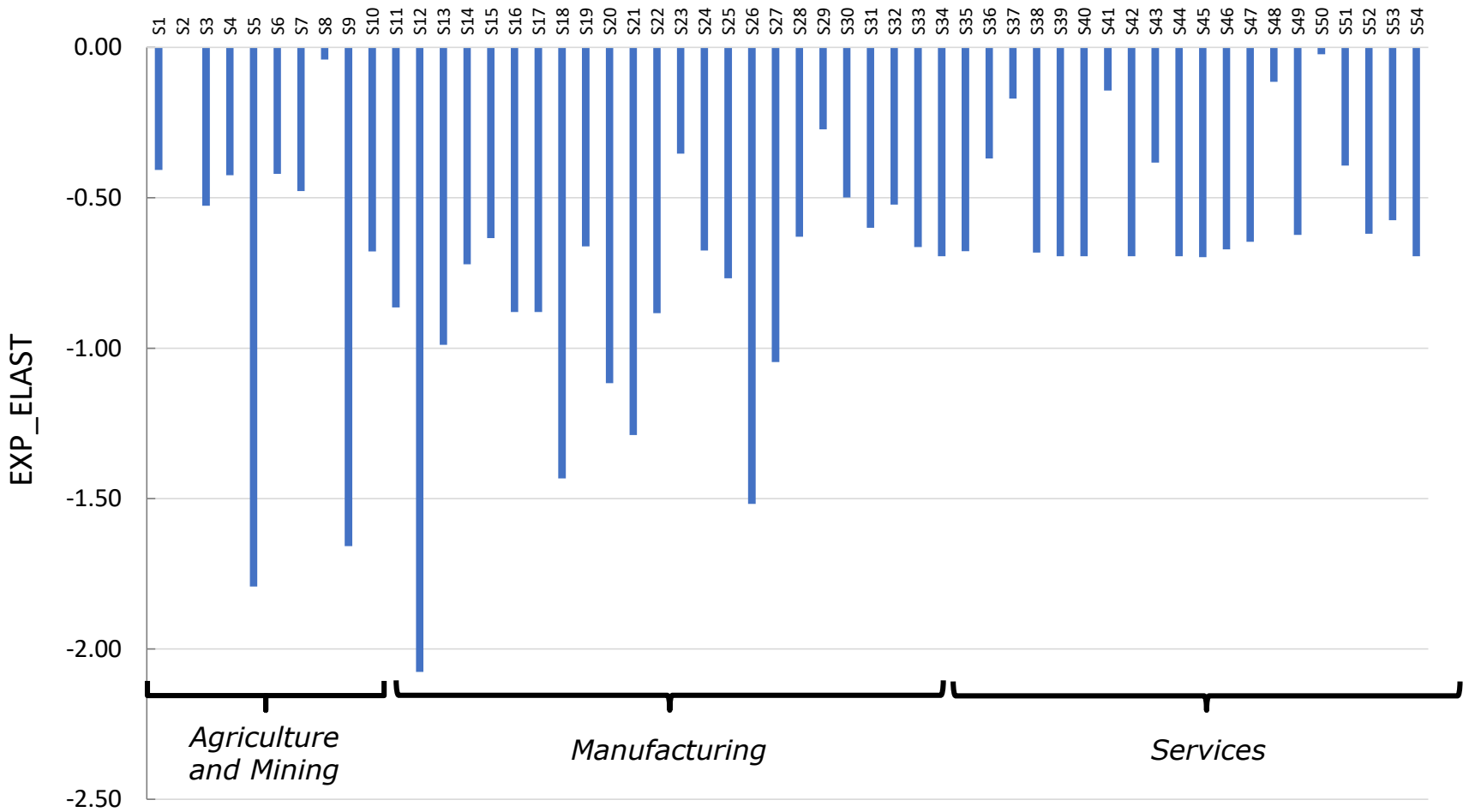
ln_price (export value/quantity)

+ year_dummies

	(1)
VARIABLES	All products
ln_price	-0.694498***
	(0.024796)
_Iyear_2012	0.022090
	(0.028988)
_Iyear_2013	0.034348
	(0.031168)
_Iyear_2014	0.036174
	(0.032946)
_Iyear_2015	-0.004496
	(0.034094)
Constant	10.482435***
	(0.058428)
Observations	23,913
R-squared	0.143684
Number of POSAR	6,081

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

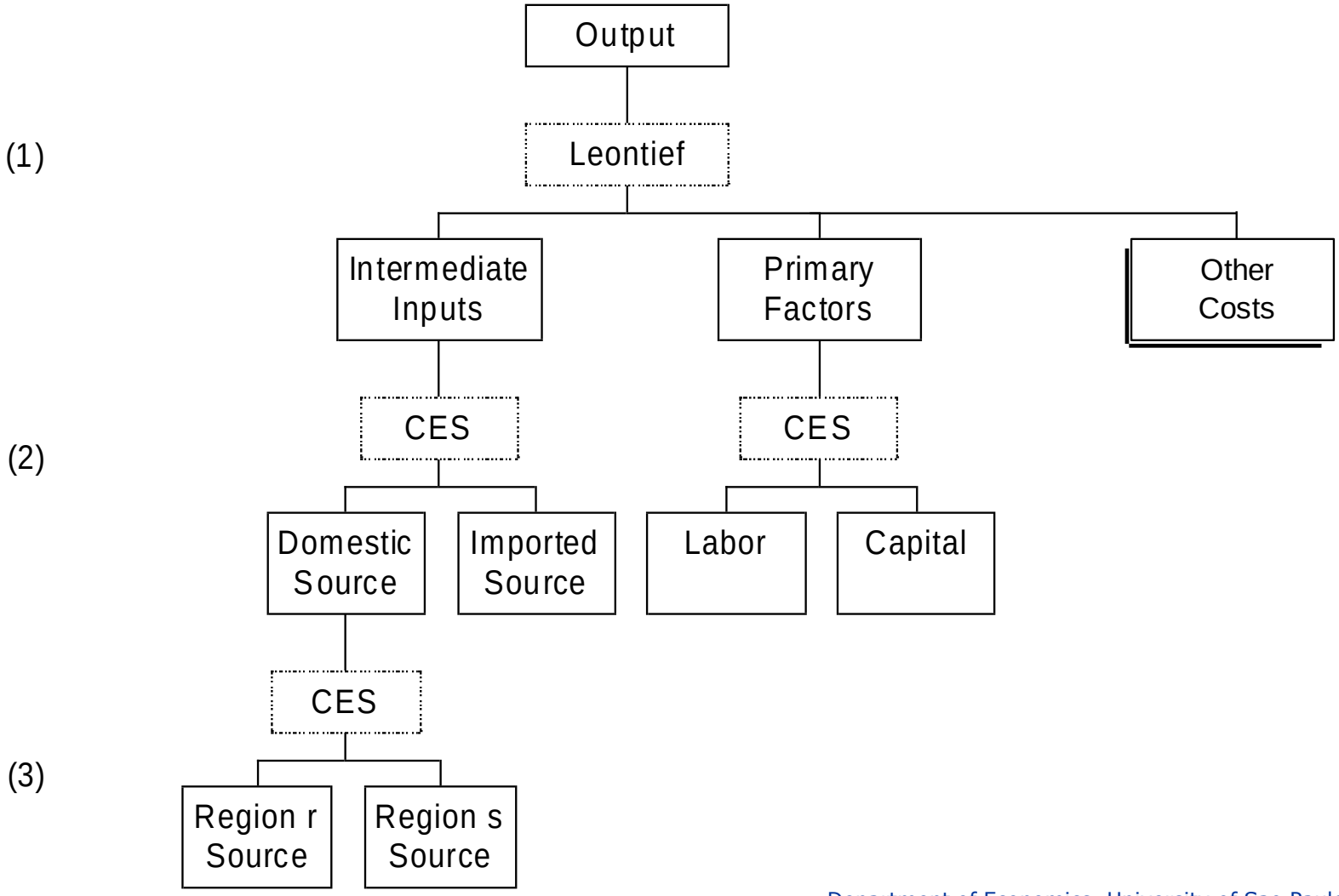
Export demand elasticities – estimates



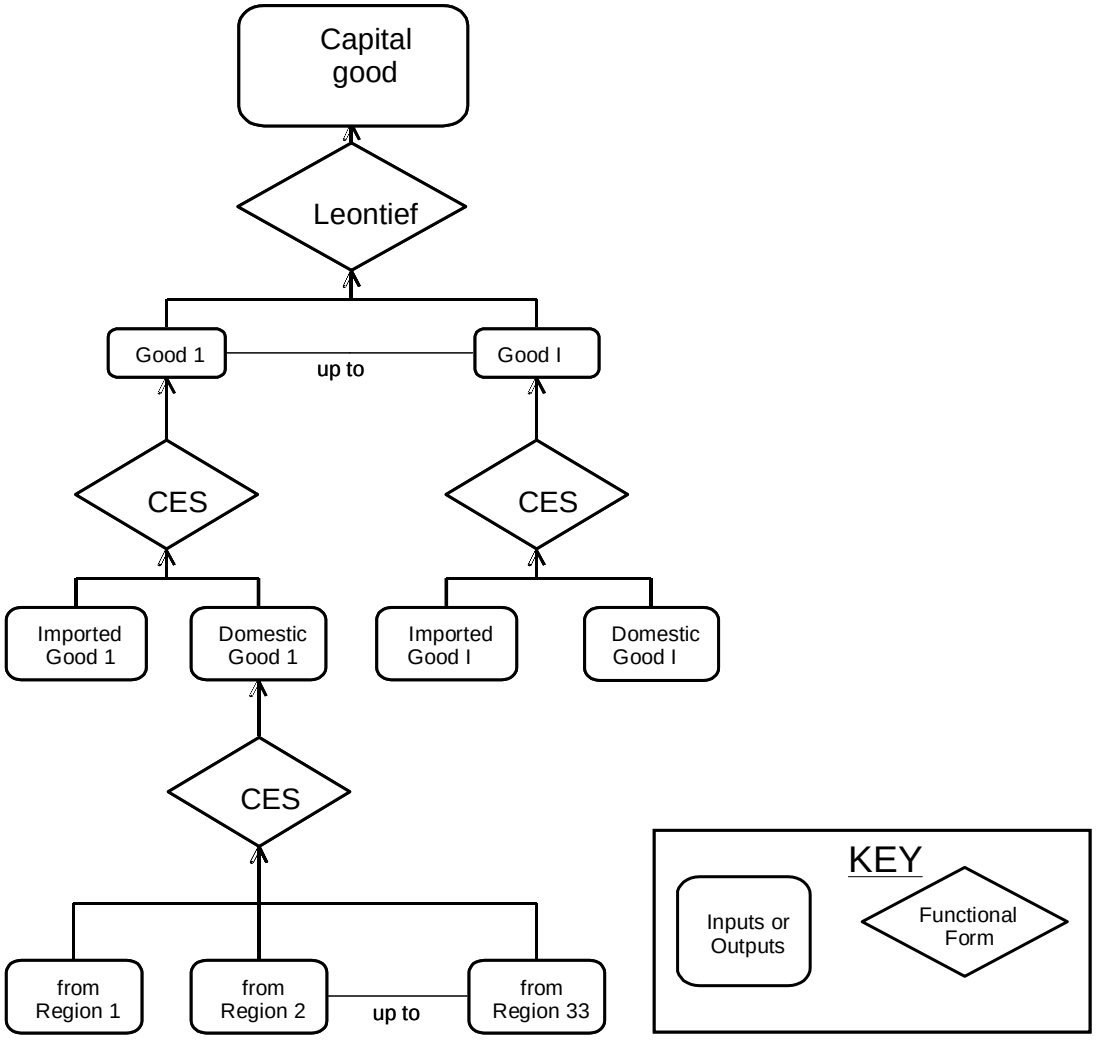
Building blocks

- ✓ Producer's demands for inputs
- ✓ Investor demands
- ✓ Household demands
- ✓ Export demands
- ✓ Government demands
- ✓ Zero pure profits
- ✓ Indirect tax equations
- ✓ Market-clearing
- ✓ Regional and national macroeconomic variables and price indexes
- ✓ Capital accumulation and investment
- ✓ Regional population and labor market

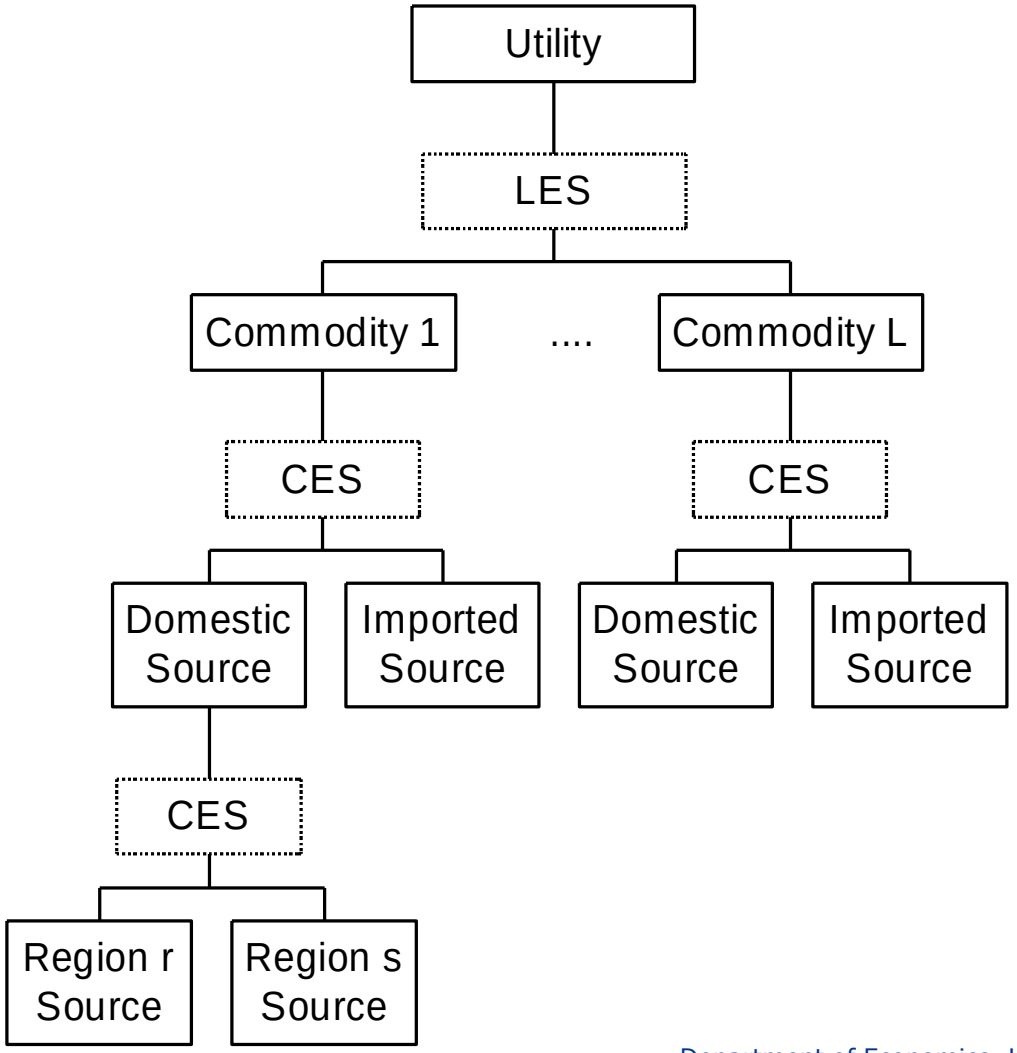
Production nest



Investment demand



Household demand

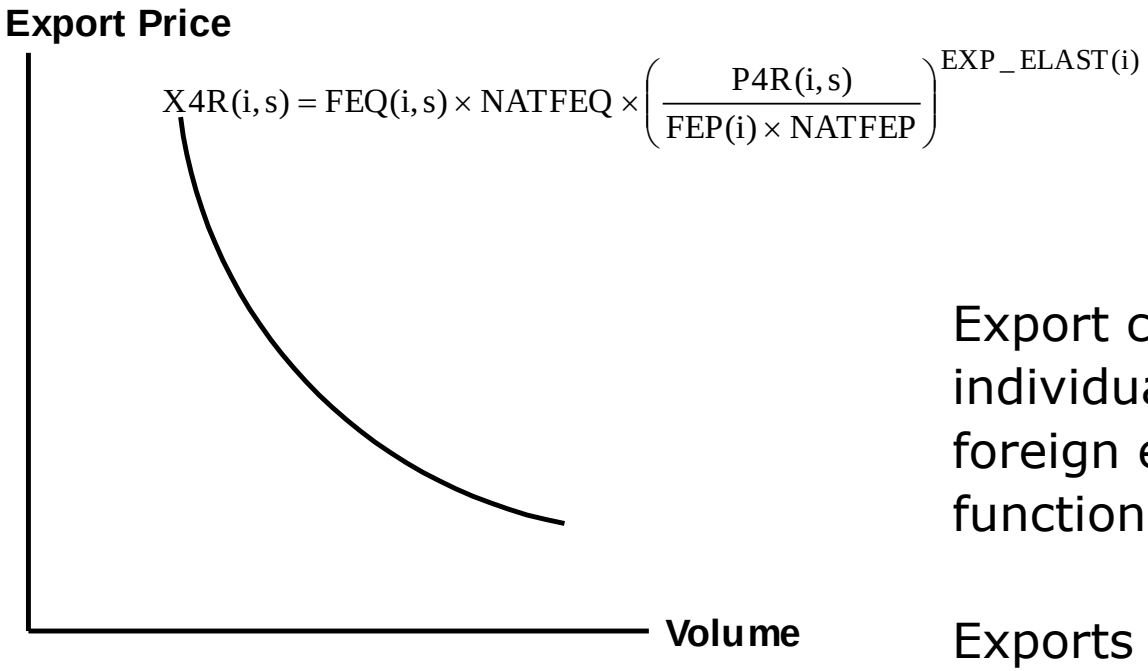


Household demand

Each regional household determines optimal consumption bundle by maximizing a Stone-Geary utility function subject to a budget constraint

A Keynesian-type consumption function determines aggregate regional household expenditure

Foreign export demand



Export commodities face individual downward-sloping foreign export demand functions

Exports of product i from source s are distinguished from exports of i from source r (r not equal s)

Government demand

Recognise regional governments and central government demands for goods and services for current consumption

Default:

- aggregate regional government demand in region q moves with regional government revenue, with structure of demand exogenous
- aggregate central government demand in region q moves with national government revenue, with structure of demand exogenous

Zero pure profits

Critical assumptions

- no pure profits in the production or distribution of commodities
- price received by the producer is uniform across all customers

Zero pure profits in current production imposed by setting unit prices received by producers equal to unit costs

Zero pure profits in distribution imposed by setting the prices paid by users equal to producer price plus commodity tax plus margins

Indirect taxes

Equations have been added to enable flexible handling of indirect taxes on all flows of goods and services

Equations allow for variations in tax rates across commodities, their sources and destinations

Market-clearing

Equations that impose market clearing (demand equals supply) for:

- domestically produced margin and non-margin commodities
- imported commodities

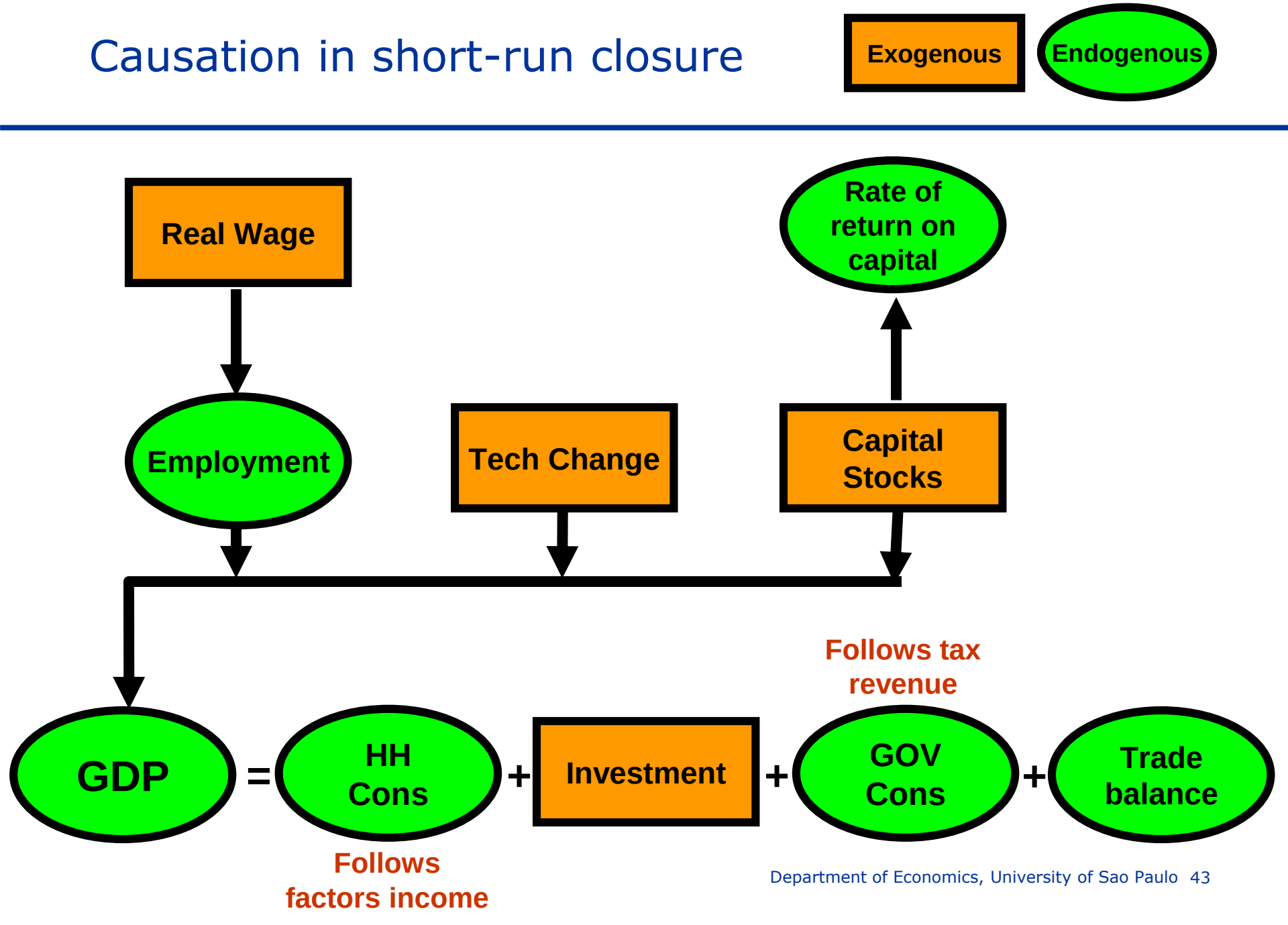
Macro aggregates

Wide range of national and regional macro variables defined…

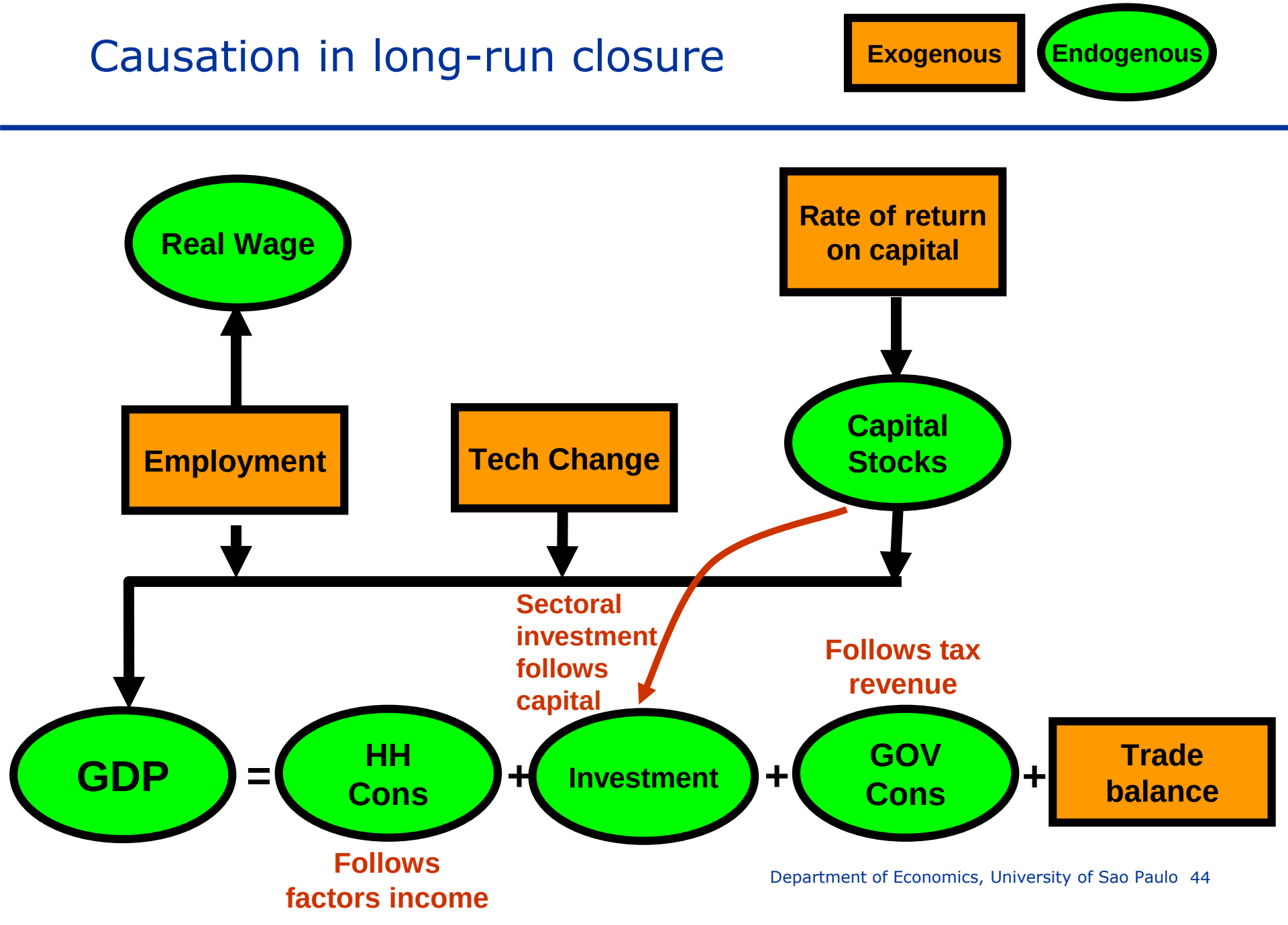
Two concepts of the real wage rate:

- consumer real wage rate (PLAB/CPI)
- producer real wage rate (PLAB/PGDP)

Causation in short-run closure



Causation in long-run closure



Investment "dynamics"

Capital, investment and expected rates of return

$$K_{j,q}(t+1) = (1 - DEP_{j,q}) \times K_{j,q}(t) + Y_{j,q}(t)$$

Given starting point for capital (t=0) and an explanation of investment, we can trace out time path for capital

Investment "dynamics"

Investment explained by assuming that:

$$\frac{K_{j,q}(t+1)}{K_{j,q}(t)} - 1 = F^{t}_{j,q}[EROR_{j,q}(t)]$$

Growth in capital related to expected rate of return

- In BM-CH ICGE only assume static expectations, though rational is possible

Rates of return and investment

For static expectations case, the actual rate of return is:

$$RO_t(j,q) = \frac{P_t(j,q)}{\Pi_t(j,q)} - D(j,q)$$

$$ro(j,q) = p_t(j,q) - \pi_t(j,q)$$

$$ro(j,q) = QCOEF\ (j,q)\left[p_t(j,q) - \pi_t(j,q)\right]$$

QCOEF: relationship between gross and net rates of return (> 1)

Rates of return and investment

In long-run comparative-static simulations:

- aggregate capital adjusts to maintain R_{INT} (*natr_tot*)
- capital allocated in line with equation **E_f_rate_xx**
  - industries with relatively large increases in capital require relatively high rates of return
  - industries with relatively small increases in capital require relatively low rates of return
- industry investment determined by fixed ratios of investment to capital (equation **E_y**)

Rates of return and investment

Equalization in the rates of return

$$\left(\frac{K(j,q)}{K(q)}\right)^{-\beta(j,q)} RO(j,q) = R_{\text{int}}$$

$$ro(j,q) - r_{\text{int}} = \beta_t(j,q)\left[k(j,q) - k(q)\right] + f\_rate(j,q)$$

beta: risk/return ratio

Short-run: *f_rate* endogenous, *k* exogenous

Long-run: *f_rate* exogenous, *k* endogenous

Investment "dynamics"

Growth rate of capital stocks and investment in the short-run:

$k_{t+1}(j,q) - k_t(j,q) = 0$ % change in capital stocks

$y_t(j,q) = 0$ % change in investment

Investment "dynamics"

Growth rate of capital stocks and investment in the long-run:

$$\frac{K_{j,q}(t+1)}{K_{j,q}(t)} = \left(\frac{K_{j,q}(t)}{K_{j,q}(0)} \right)^{1/T}$$

$$k_{t+1}(j,q) = \left(1 + \frac{1}{T} \right) k_t(j,q)$$

Investment in the short run

Fixed capital stocks in the base year values:

- *curcap(j,q)* exogenous (=0)
- relationship between sectoral rates of return, *r0(j,q)*, and reference interest rate, *natr_tot*, is endogenous (*f_rate_xx(j,q)* endogenous)

Percentage change in sectoral investment, *y(j,q)* is zero; this can be guaranteed by setting the shift term, *delf_rate(j,q)*, exogenous and zero

By hypothesis, not only the capital stocks are fixed but also firms' investment plans

Investment in the short run

```
E_r0 # Definition of rates of return to capital #
r0(j,q) = QCOEF(j,q)*(p1cap(j,q) - pi(j,q));

E_f_rate_xx # Capital growth rates related to rates of
return #
(r0(j,q) - natr_tot) = BETA_R(j,q)*[curcap(j,q) -
kt(q)] + f_rate_xx(j,q);

E_curcapT1 # Capital stock in period T+1 #
  curcap_t1(j,q) - curcap(j,q) =0;

E_yT # Investment in period T #
curcap(j,q) - y(j,q)- 100*delf_rate(j,q)=0;
```

endog. exog.

Investment in the long run

Capital stocks endogenously determined:

- *curcap(j,q)* endogenous
- relationship between sectoral rates of return, *r0(j,q)*, and reference interest rate, *natr_tot*, is given (*f_rate_xx(j,q)* exogenous)

Percentage change in sectoral investment, *y(j,q)* is endogenous

Firms' investment plans are carried out, reestablishing returns differentials in the base year

Rate of capital accumulation, but **not the level** of capital stock, remains constant

Investment in the long run

```
E_r0 # Definition of rates of return to capital #
r0(j,q) = QCOEF(j,q)*(p1cap(j,q) - pi(j,q));

E_f_rate_xx # Capital growth rates related to rates of
return #
(r0(j,q) - natr_tot) = BETA_R(j,q)*[curcap(j,q) - kt(q)] +
f_rate_xx(j,q);

E_curcapT1 # Capital stock in period T+1 #
curcap_t1(j,q) - K_TERM*curcap(j,q)=0;

E_yT # Investment in period T #
VALK_T1(j,q)*curcap_t1(j,q)= VALKT(j,q)*DEP(j)*curcap(j,q)
+(INVEST(j,q))*y(j,q)-100*(VALK_0(j,q)*(1-DEP(j))
```

endog. exog.

$(DEP(j) = 0.96)$

Regional population and labor market

Critical variables:

- regional population
- regional migration
- regional unemployment
- regional participation rates
- regional wage relativities

Various closures

Regional population and labor market

(1) Fixed
- wage relativities (determining employment by region), participation and unemployment rates (determining population by region)

(1) Endogenous
- regional migration

(2) Fixed
- **regional migration, participation rates, wage relativities**

(2) Endogenous
- **unemployment rates**

(3) Fixed
- regional migration, participation and unemployment rates

(3) Endogenous
- wage relativities

Labor market in the short-run

```
E_wage_diff # Region real-wage diff
#(all,q,REGDEST)

wage_diff(q) = pwage(q) - natxi3 - natrealwage;

E_del_labsup # P-point changes in regional
unemployment rates #(all,q,REGDEST)

C_labsup(q)*del_unr(q)=C_EMPLOY(q)*(labsup(q)-
                                    employ(q));
```

del_unr(q) # Percentage-point changes in regional unemployment rate #;

endog. exog.

Labor market in the long-run

```
E_wage_diff # Region real-wage diff
#(all,q,REGDEST)

wage_diff(q) = pwage(q) - natxi3 - natrealwage;

E_del_labsup # P-point changes in regional
unemployment rates #(all,q,REGDEST)

C_labsup(q)*del_unr(q)=C_EMPLOY(q)*(labsup(q)-
                                    employ(q));
```

del_unr(q) # Percentage-point changes in regional unemployment rate #;

endog. exog.

Closures

Each equation explains a variable

More variables than equations

Endogenous variables: explained by model

Exogenous variables: set by user

Closure: choice of exogenous variables

Many possible closures

Number of endogenous variables = Number of equations

Length of run, T

T is related to our choice of closure

With short-run closure we assume that:

- T is long enough for price changes to be transmitted throughout the economy, and for price-induced substitution to take place
- T is not long enough for investment decisions to greatly affect the useful size of sectoral capital stocks [new buildings and equipment take time to produce and install]

T might be 2 years. So results mean:

- A 10% consumption increase might lead to employment in 2 years time being 1.2% higher than it would be (in 2 years time) if the consumption increase did not occur.

Different closures

Many closures might be used for different purposes

No unique natural or correct closure

Must be at least one exogenous variable measured in local currency units

Normally just one — called the *numéraire*

Often the exchange rate, *natphi*, or *natxi3*, the CPI.

Some quantity variables must be exogenous, such as:

- primary factor endowments
- final demand aggregates

In honor of those that made this gathering possible!

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