

Towards a Macroeconomics of the Just Transition to a Circular Economy

Stabilizing Unstable Economy-Ecology Interactions

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Towards a Climate Catastrophe?

Global greenhouse gas emissions and warming scenarios

Our World
in Data

- Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
- Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.

Annual global greenhouse gas emissions
in gigatonnes of carbon dioxide-equivalents

150 Gt

100 Gt

Greenhouse gas emissions
up to the present

0

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

No climate policies

4.1 – 4.8 °C

→ expected emissions in a baseline scenario if countries had not implemented climate reduction policies.

Current policies

2.7 – 3.1 °C

→ emissions with current climate policies in place result in warming of 2.7 to 3.1°C by 2100.

Pledges & targets (2.4 °C)

→ emissions if all countries delivered on reduction pledges result in warming of 2.4°C by 2100.

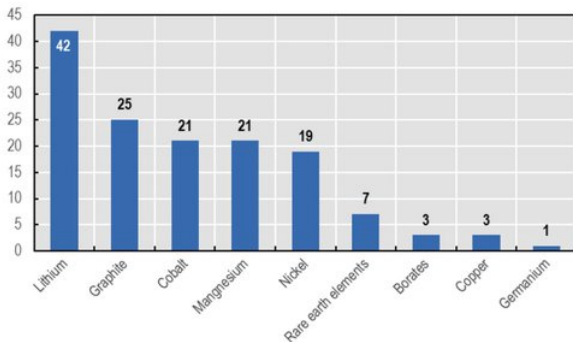
2°C pathways

1.5°C pathways

Demand for Raw Materials by Green Technologies

Figure 1.1. Projected global demand growth for certain raw materials by 2040

Projected increase factor (1= current demand)



Economic Theory in the Face of the Uneven Climate Crisis

- Modelling the Macroeconomics of the Just Transition to a Circular Economy
 - Systematic Literature Review
 - Multi-Country, Multi-Industry ECO-IO-SFC Model
- Network Analysis of the Input-Output Structure of Economic Production
- Ecological Applications of the Bielefeld Disequilibrium Approach
 - Can tax-subsidy mixes accelerate decarbonization while stabilizing key industries?
 - Can price controls stabilize economic fluctuations and economy-ecology interactions?

Systematic Literature Review

Concepts

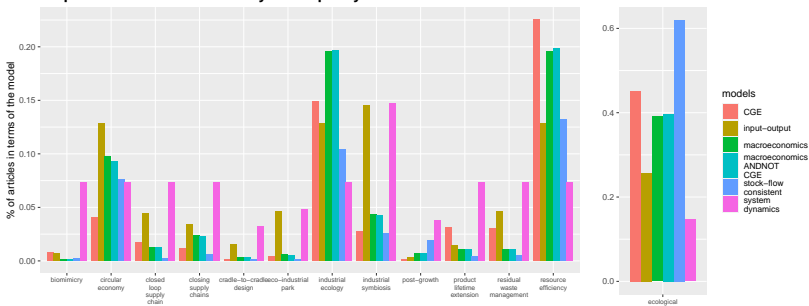
circular economy	closing supply chains	eco-industrial park
ecological	product lifetime extension	cradle-to-cradle design
environmental	resource efficiency	closed loop supply chain
post-growth	industrial symbiosis	biomimicry
residual waste management	industrial ecology	

Models

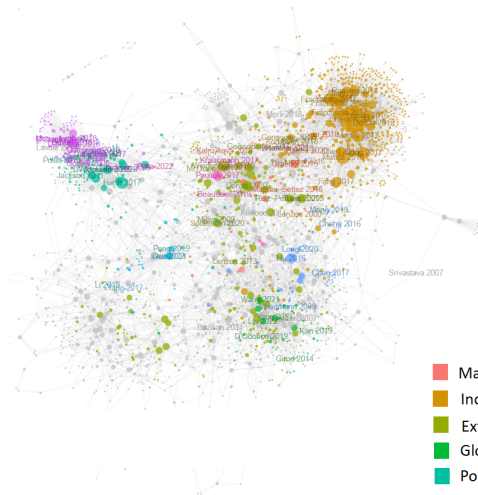
input-output	macroeconomics	system dynamics
stock-flow consistent	macroeconomic model ANDNOT CGE	computational general equilibrium
macroeconomic model	macroeconomics ANDNOT CGE	CGE

Systematic Literature Review

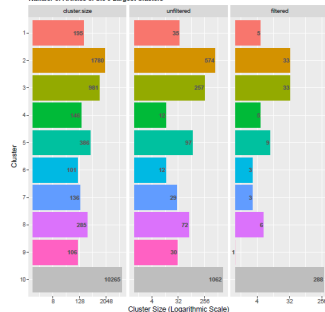
Emphasis on Circular Economy Concepts by Model



Citation Network



Number of Articles of the 9 Largest Clusters



- Material flow analysis
- Industrial symbiosis
- Extended IO
- Global value chain
- Post-growth SFC
- CGE (electric vehicles)
- Carbon footprint analysis
- Post-Keynesian SFC
- IAMs

Main Gaps Identified

- **Modelling of Rebound Effects** Current modeling of changes in demand, and consequently in environmental impacts, associated with changes in prices, employment and disposable income is limited.
- **Transitional Dynamics** Most commonly used input-output analysis is a static method.
- **Limited Coverage of Socio-Economic Aspects Only** employment is considered.
- **Technology Innovation and Diffusion + Assumptions in Changes of Demand** Lower-labor-cost technologies may be preferred.
- **North-South, Core-Periphery Ecological Unequal Exchange**

ECO-IO-SFC Model

- a) Macro frame taken from standard SFC models *Godley and Lavoie 2007*):
 - **Six sectors** households, production firms, government, commercial banks, central bank, foreign sector
 - **Three Assets** cash, bank deposits, and government bills (+ advances)
 - Only **loans to firms** (no personal loans)
 - **Fixed capital**, but no inventories
- b) Simple IO structure: **3/4 industries** (manufacturing, agriculture, services) + *waste recycling*
- c) Identification: literature / reasonable values / neutrality
- d) Solution: numerical simulations (*R* code), 250 periods, 100 iterations

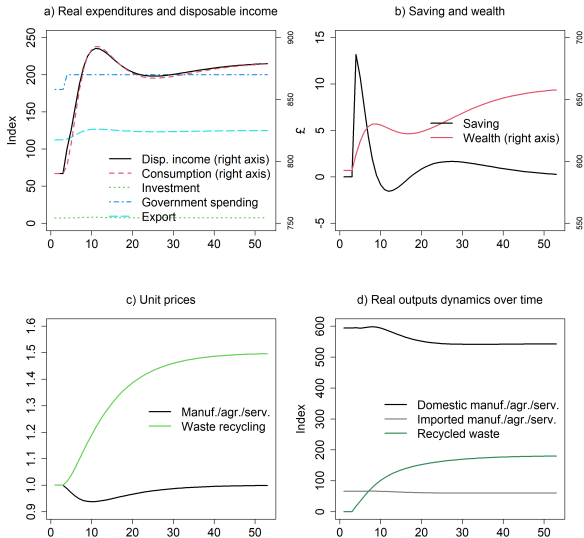
Government-led Transition to a Circular Economy

There is a tendency for current technical coefficients to converge to **target CE values** over time:

$$a_{ij} = a_{ij,-1} + \gamma_A(g) \cdot (a'_{ij,-1} - a_{ij,-1}) \quad (1)$$

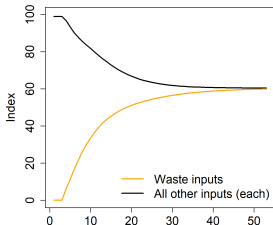
$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & 0 \\ a_{21} & a_{22} & a_{23} & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \rightarrow \begin{pmatrix} a'_{11} \leq a_{11} & a'_{12} \leq a_{12} & a'_{13} \leq a_{13} & a'_{14} \geq 0 \\ a'_{21} \leq a_{21} & a'_{22} \leq a_{22} & a'_{23} \leq a_{23} & a'_{24} \geq 0 \\ a'_{31} \leq a_{31} & a'_{32} \leq a_{32} & a'_{33} \leq a_{33} & a'_{34} \geq 0 \\ a'_{41} \geq 0 & a'_{42} \geq 0 & a'_{43} \geq 0 & 0 \end{pmatrix}$$

CE-oriented government spending

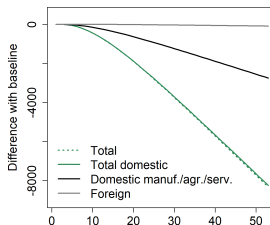


CE-oriented government spending

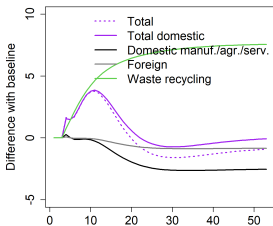
a) Demand for inputs in manufacturing industry



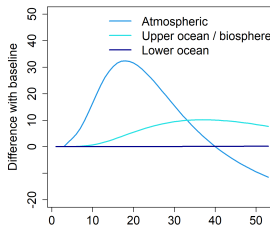
b) Waste production (stock)



c) Annual emissions of CO2

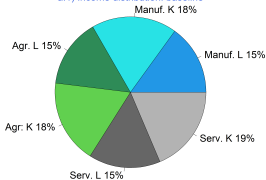


d) CO2 concentration

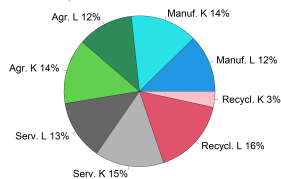


Income Distribution and Gender Segregation

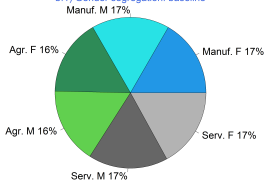
a.1) Income distribution: baseline



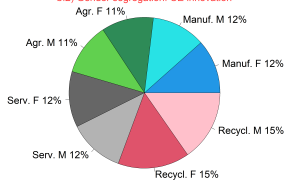
a.2) Income distribution: CE innovation



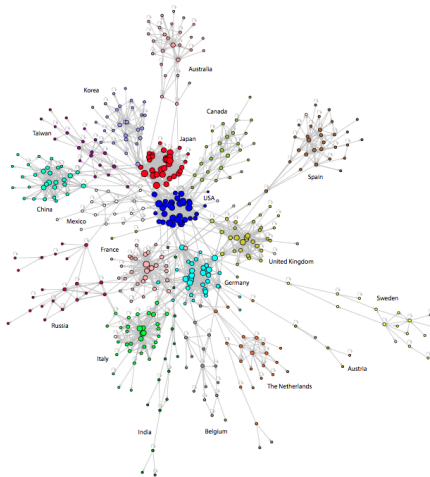
b.1) Gender segregation: baseline



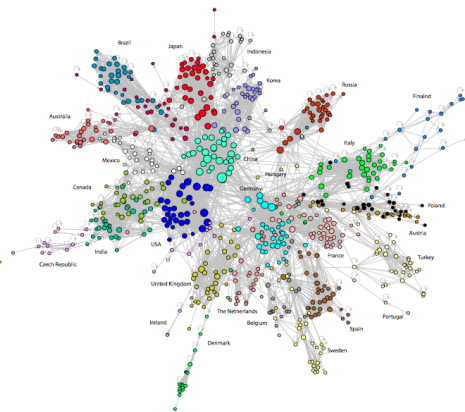
b.2) Gender segregation: CE innovation



Evolution of Globalization [Cerina et al., 2015]

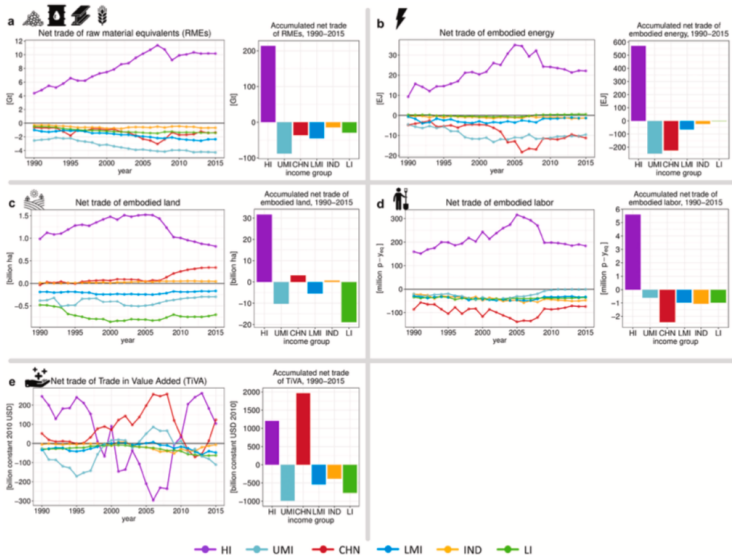


(a)1995

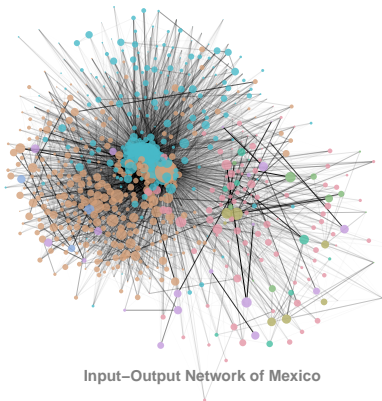


(b)2011

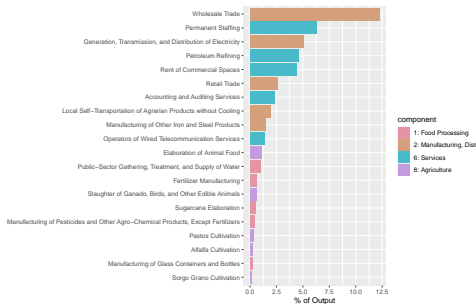
Ecological North-South Unequal Exchange [Dorninger et al., 2021]



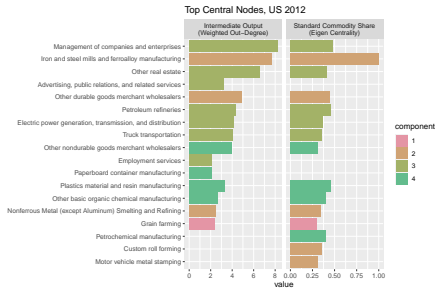
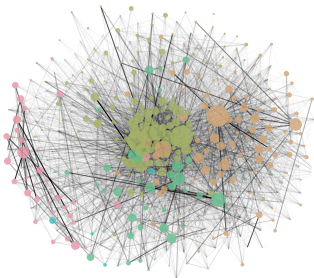
Mexican Economic Structure is Highly Hierarchical



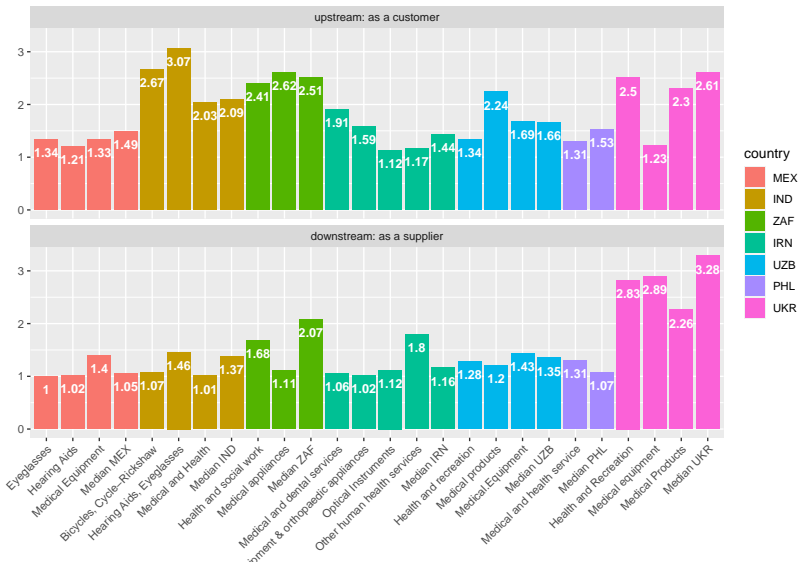
Input-Output Network of Mexico



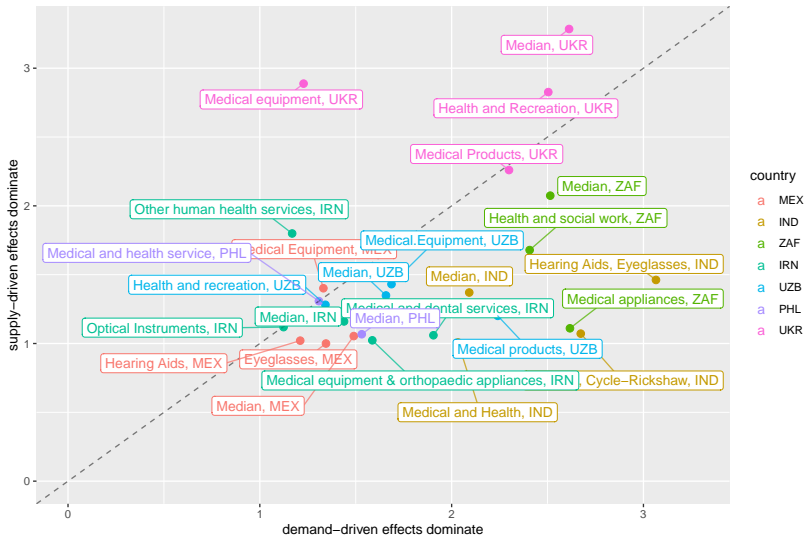
US Economic Structure is Highly Hierarchical



Output Multipliers of Health Industries in the Global South



Spillover Effects: Relative Position over the Value Chain



Dynamical Systems

Exponential Growth in a Limited-Resource World

Model	Dimensions	Topic
Bhaduri-Harris	1	Complex Dynamics of the Simple Ricardian System

Predator-Prey Oscillations with 2+ Dimensions

Model	Dimensions	Topic	Prey	Predator
Goodwin	2	Distribution	employment rate	labor share of income
Flaschel-Semmler	2N	Growth	prices/profits	quantities/capital

The Bielefeld Disequilibrium Approach

■ Cross-Dual Adjustment

■ *Walrasian Law of Excess Demand*

if demand d_i is above (below) supply x_i , price p_i rises (falls)

■ *Classical Law of Excess Profitability*

if price p_i above (below) $cost_i$, quantity x_i rises (falls)

■ Keynesian Dual Adjustment

■ *Oligopolistic Markup Pricing*

if price p_i above (below) $cost_i$, price p_i falls (rises)

■ *Inventory Adjustment*

if demand d_i is above (below) supply x_i , quantity x_i rises (falls)

The Composite Dynamical System

$$\dot{x} = \underbrace{\delta_{xx}\Delta_x}_{\text{Keynesian}} - \underbrace{\delta_{xp}\Delta_p^T}_{\text{classical}} \quad (2)$$

$$\dot{p}^T = \underbrace{\delta_{px}\Delta_x}_{\text{Walrasian}} + \underbrace{\delta_{pp}\Delta_p^T}_{\text{Keynesian}} \quad (3)$$

which can be simplified as:

$$\begin{pmatrix} \dot{x} \\ \dot{p}^T \end{pmatrix} = \begin{pmatrix} \delta_{xx} & -\delta_{xp} \\ \delta_{px} & \delta_{pp} \end{pmatrix} \left\{ \begin{pmatrix} (1+g)A - I \\ [(1+r)A - I]^T \end{pmatrix} \begin{pmatrix} x \\ p^T \end{pmatrix} + \begin{pmatrix} c \\ w^T \end{pmatrix} \right\} \quad (4)$$

with homogeneous solution $y(t) = e^{Qt}y(0)$ where $y = z - z^*$.

Out-of-Equilibrium Imbalances in Quantities and Prices

Supply-demand imbalance column-vector Δx is:

$$\Delta x = \underbrace{Ax + gAx + c}_{\text{demand}} - \underbrace{x}_{\text{supply}} \quad (5)$$

Unit profitability imbalance row-vector Δp is:

$$\Delta p = \underbrace{pA + rpA + w}_{\text{unit cost}} - \underbrace{p}_{\text{unit revenue}} \quad (6)$$

In equilibrium, supply equals demand:

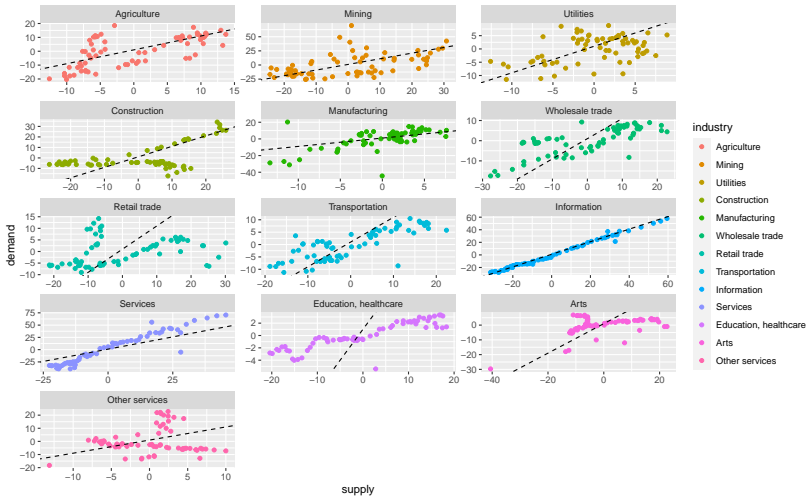
$$\Delta x^* = 0 \quad \rightarrow \quad x^* = [I - (1 + g)A]^{-1}c \quad (7)$$

and profitability is uniform across sectors:

$$\Delta p^* = 0 \quad \rightarrow \quad p^* = w[I - (1 + r)A]^{-1} \quad (8)$$

Empirical Imbalances: Supply-Demand

Supply-Demand Imbalances: Supply vs Demand

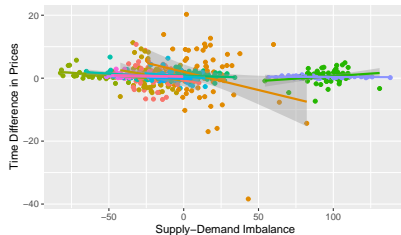


Empirical Imbalances: Composite Adjustments

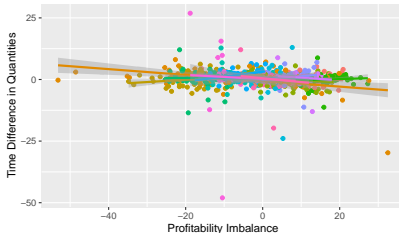
Quantity–Quantity Interaction



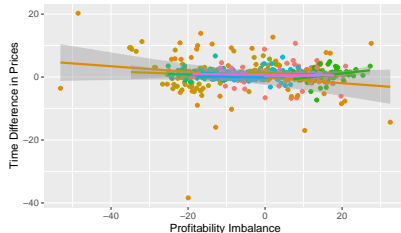
Price–Quantity Interaction (Walrasian)



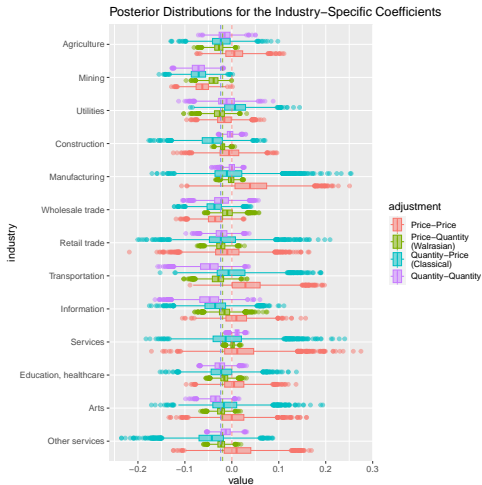
Quantity–Price Interaction (Classical)



Price–Price Interaction

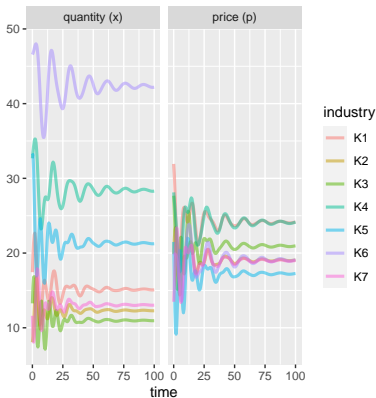


Posterior Distributions of the Industry-Specific Random Effects

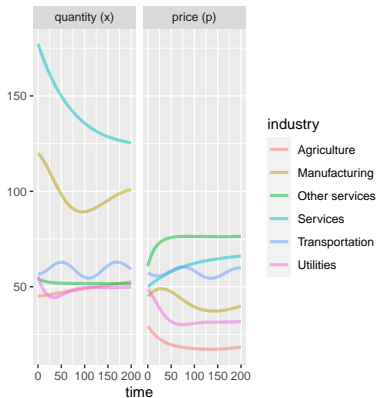


Simulations

Stylized Simulations

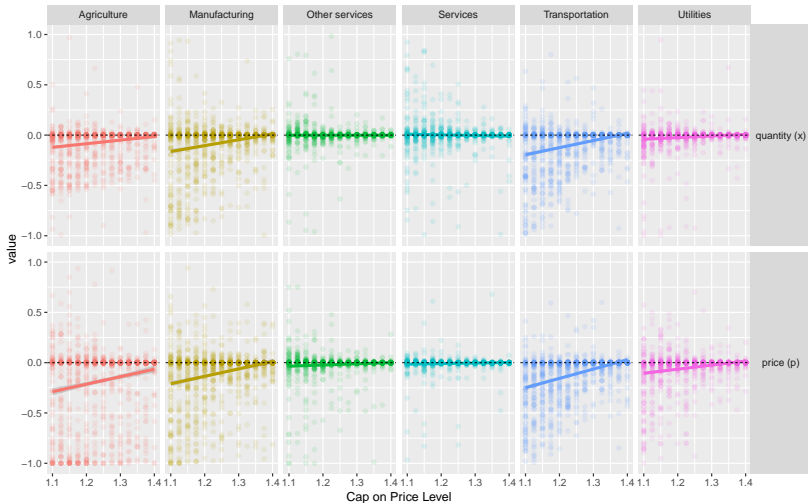


Calibrated Simulations



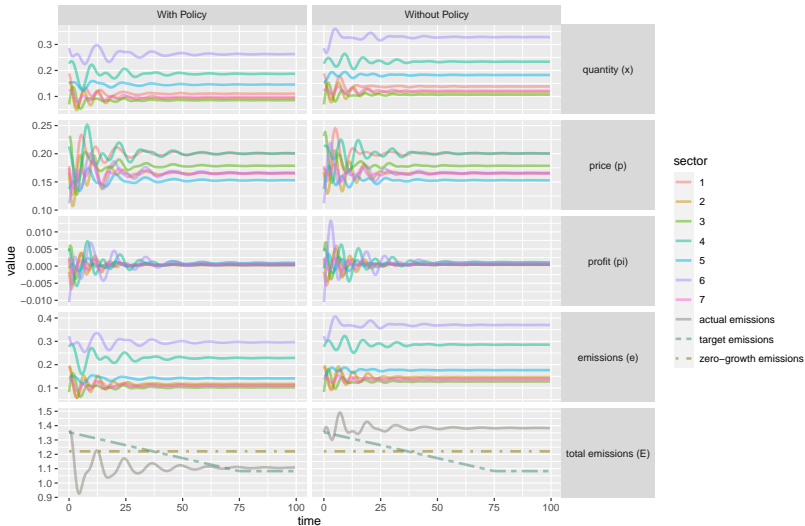
Price Controls Reduce Economic Volatility

Reduction of Variance under a Cap on the Price Level



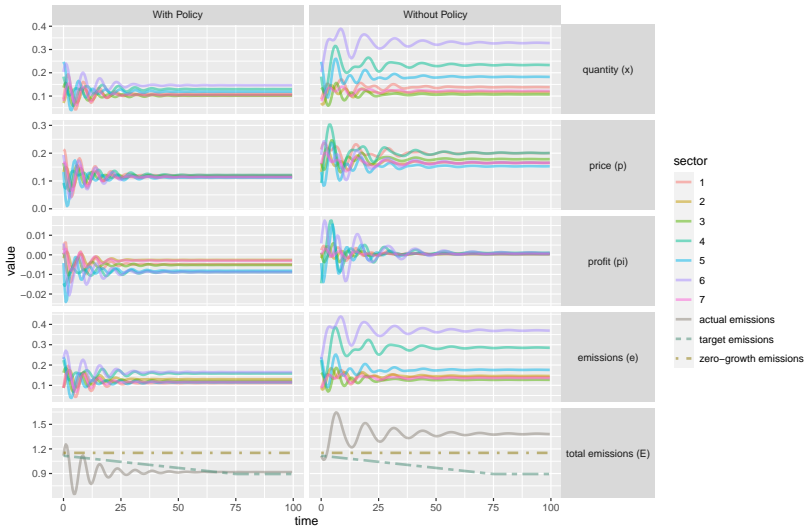
Reduction of Emissions by Rationing

Simulation with Policy of Rationing (Taxes on Consumption)



Reduction of Emissions by Aggregate Productivity Shock

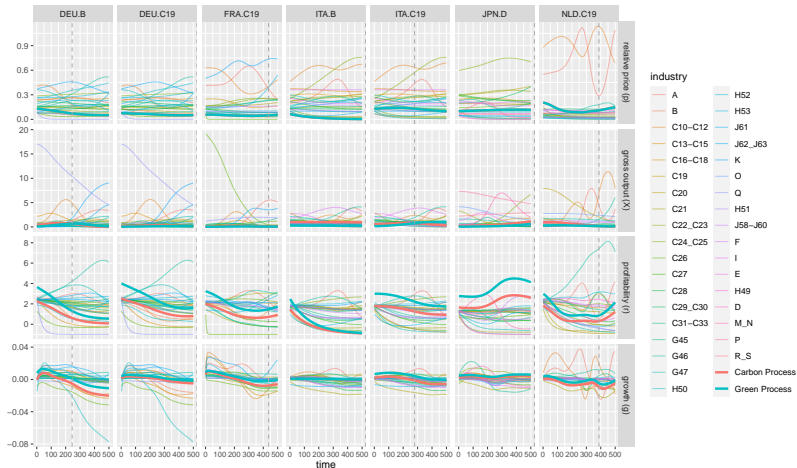
Simulation with Aggregate Productivity Shock



Reduction of Emissions by Process Substitution

Scenario Simulation of the Low-Carbon Transition: No Policy

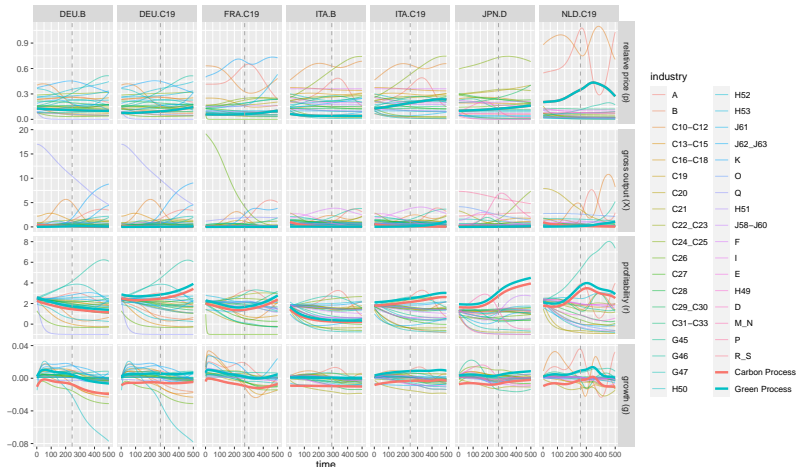
$\theta = 0.7$ $\sigma_0 = 0.25$ $\tau = 0$ $\rho = 0$



Reduction of Emissions by Process Substitution

Scenario Simulation of the Low-Carbon Transition: Only Carbon Pricing 1

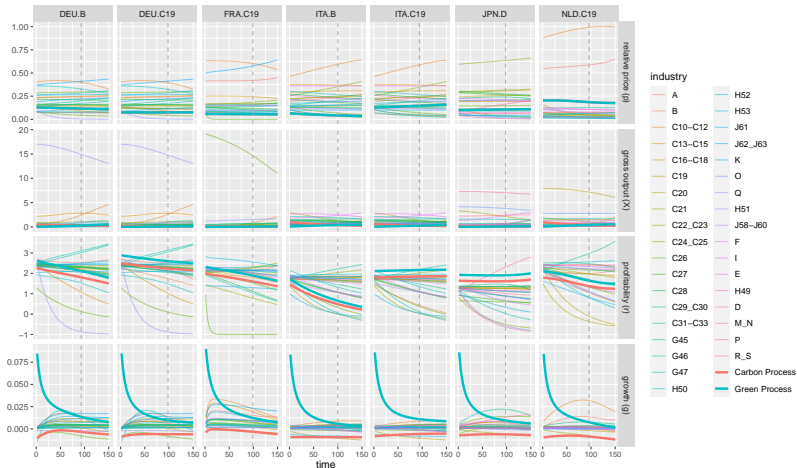
$\theta = 0.9$ $\sigma_0 = 0.055$ $\tau = 0.01$ $\rho = 0$



Reduction of Emissions by Process Substitution

Scenario Simulation of the Low-Carbon Transition: Tax-Subsidy Mix 1

$\theta = 0.9$ $\sigma_0 = 0.055$ $\tau = 0.01$ $\rho = 0.5$



Thank you!

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References I



Cerina, F., Zhu, Z., Chessa, A., and Riccaboni, M. (2015). World input-output network. *PloS one*, 10(7):e0134025.



Dorninger, C., Hornborg, A., Abson, D. J., Von Wehrden, H., Schaffartzik, A., Giljum, S., Engler, J.-O., Feller, R. L., Hubacek, K., and Wieland, H. (2021). Global patterns of ecologically unequal exchange: Implications for sustainability in the 21st century. *Ecological economics*, 179:106824.