Towards a Macroeconomics of the Just Transition to a Circular Economy

Stabilizing Unstable Economy-Ecology Interactions

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Levy Economics Institute at Bard College
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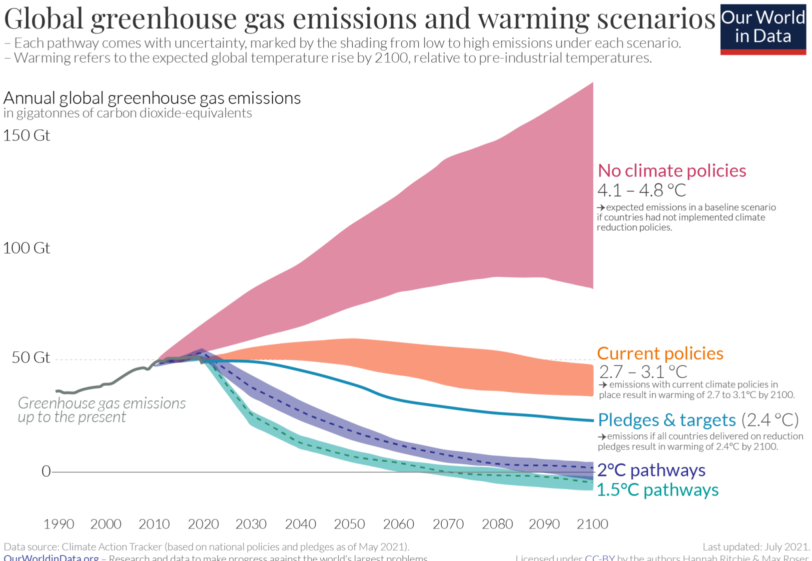
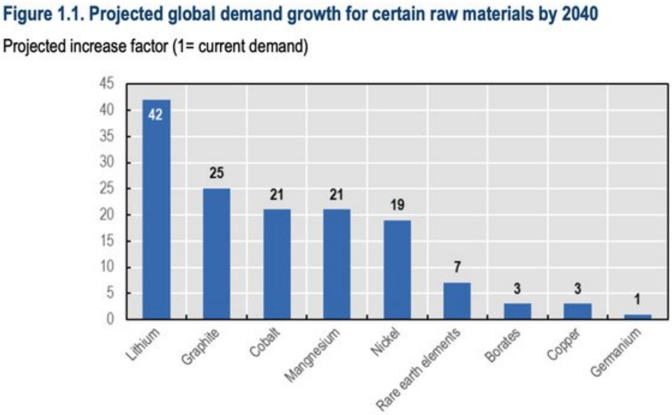
Towards a Climate Catastrophe?



Demand for Raw Materials by Green Technologies



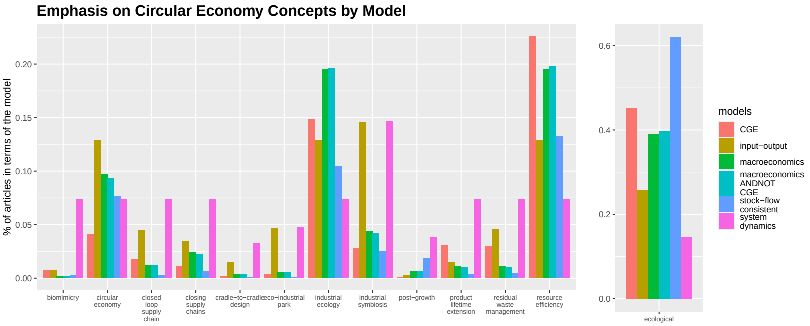
Economic Theory in the Face of the Uneven Climate Crisis

- 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?

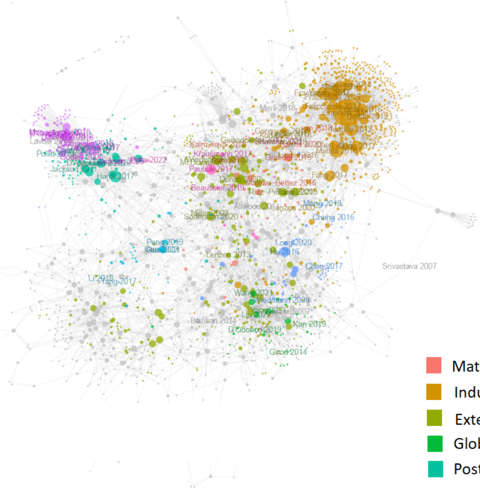
Systematic Literature Review

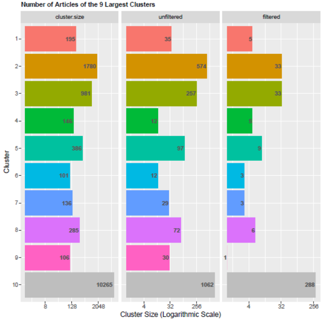
Concepts		
circular economy	closing supply chains	eco-industrial park
ecological	product lifetime extension	cradle-to-cradle design
environmental	resource efficiency	closed loop supply chain
post-growth	industrial symbiosis	biomimicry
residual waste management	industrial ecology	
Models		
input-output	macroeconomics	system dynamics
stock-flow consistent	macroeconomic model ANDNOT CGE	computational general equilibrium
macroeconomic model	macroeconomics ANDNOT CGE	CGE

Systematic Literature Review



Citation Network





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

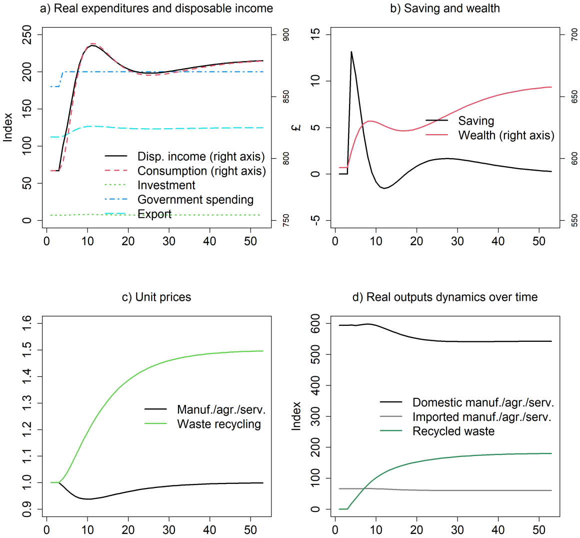
Government-led Transition to a Circular Economy

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

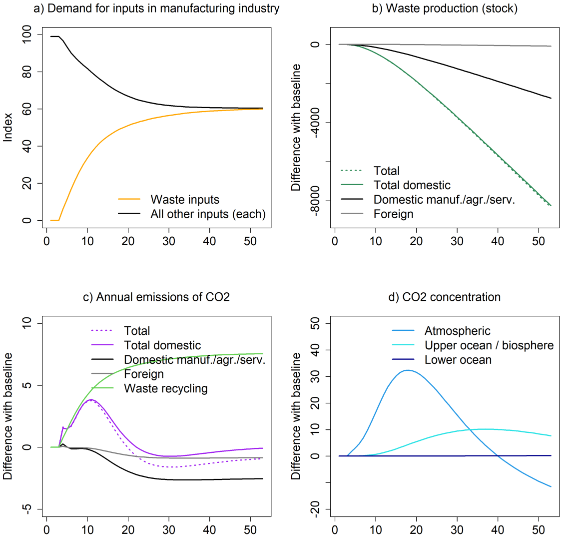
$$a_{ij} = a_{ij,-1} + \gamma_A(g) \cdot (a'_{ij,-1} - a_{ij,-1}) \tag{1}$$

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

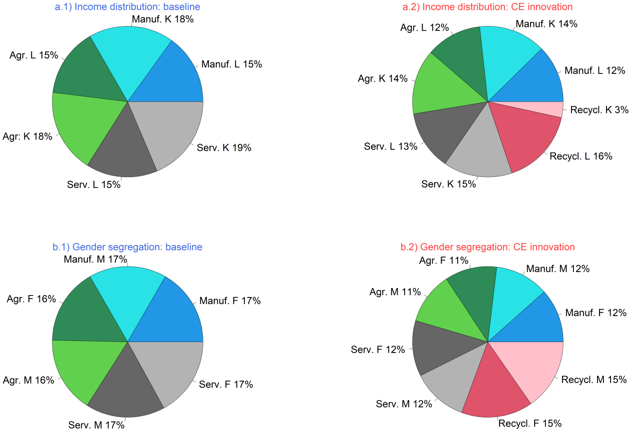
CE-oriented government spending



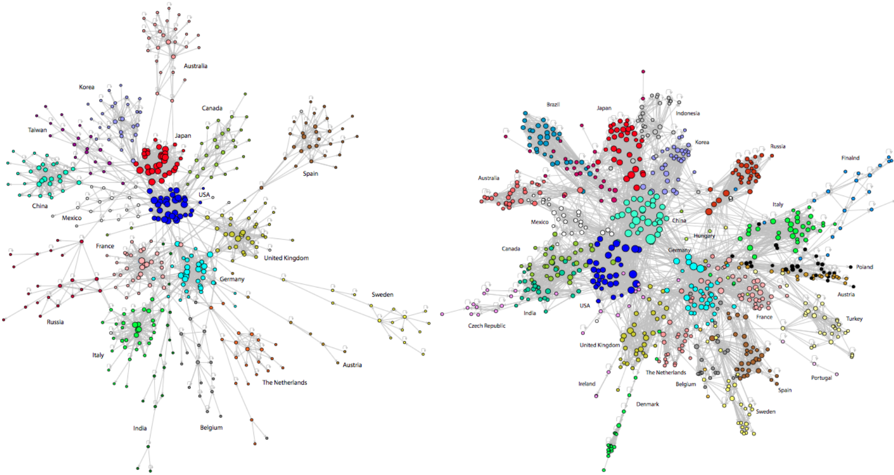
CE-oriented government spending



Income Distribution and Gender Segregation



Evolution of Globalization [Cerina et al., 2015]



(a)1995 (b)2011

Self-Reproducing (Industrial) Ecosystems

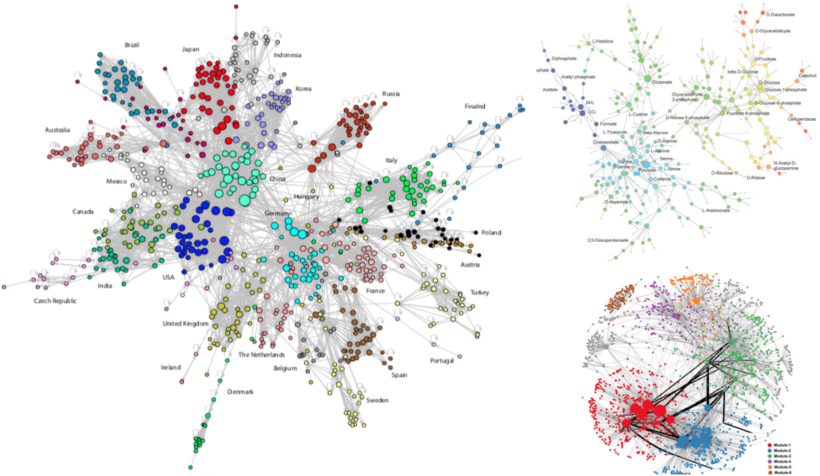
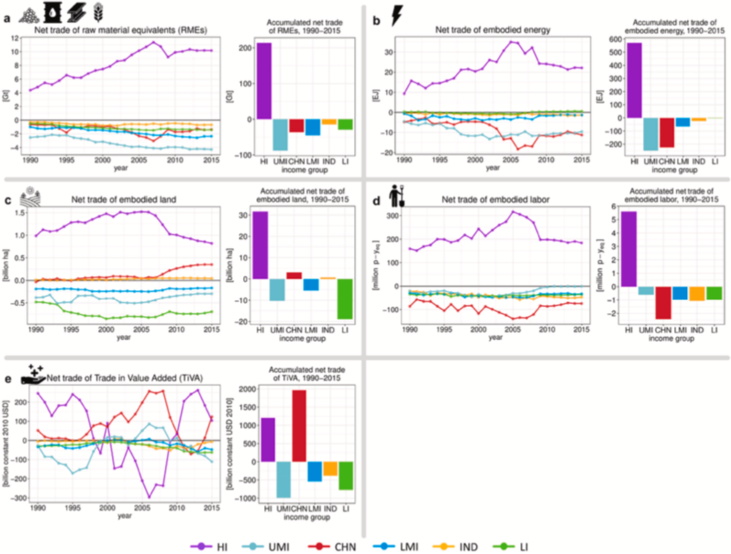
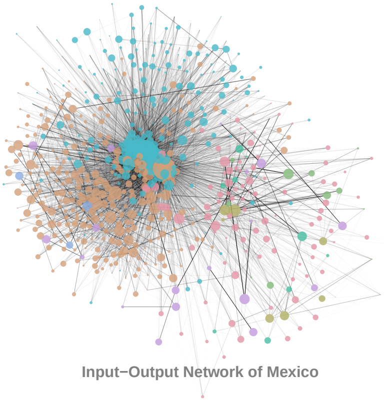


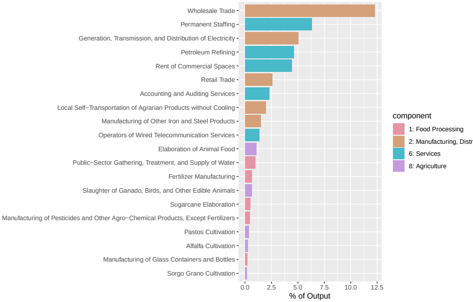
Figure: The World Input-Output Network (left), a metabolic network (top-right), and a gene regulation network (bottom-right)

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

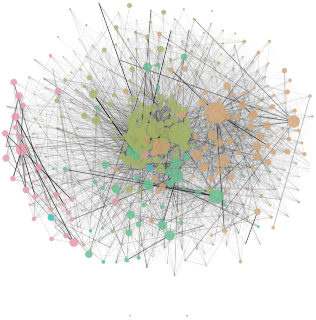


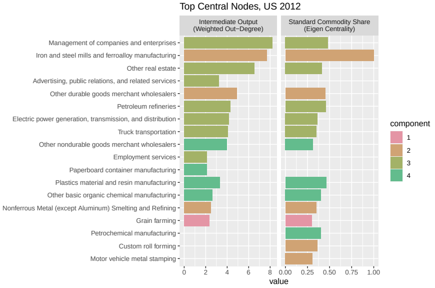
Mexican Economic Structure is Highly Hierarchical



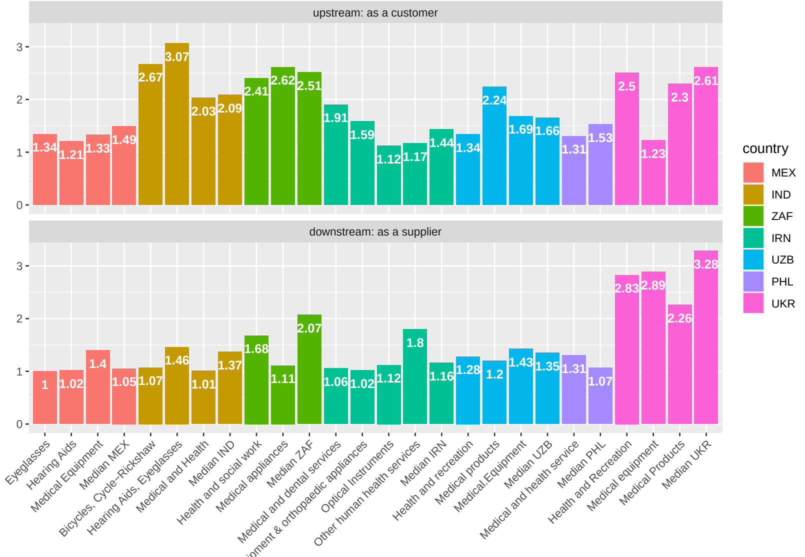


US Economic Structure is Highly Hierarchical

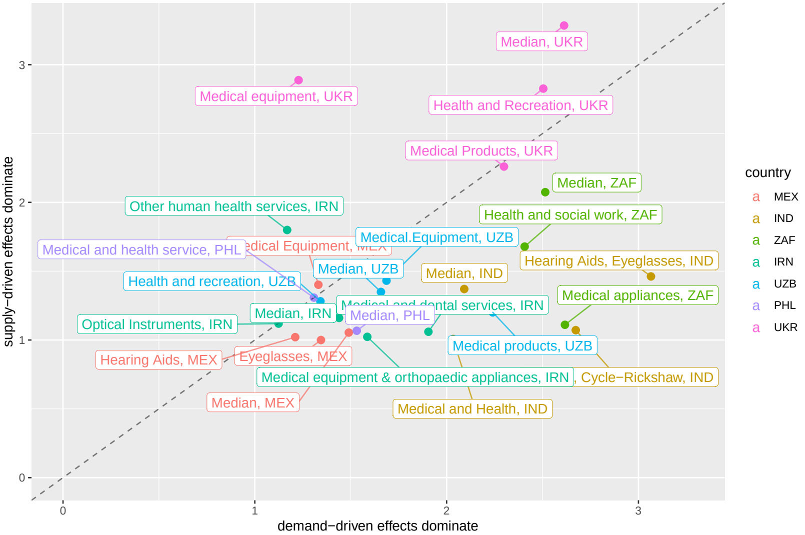




Output Multipliers of Health Industries in the Global South



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

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

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

which can be simplified as:

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

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 Δ_p is:

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

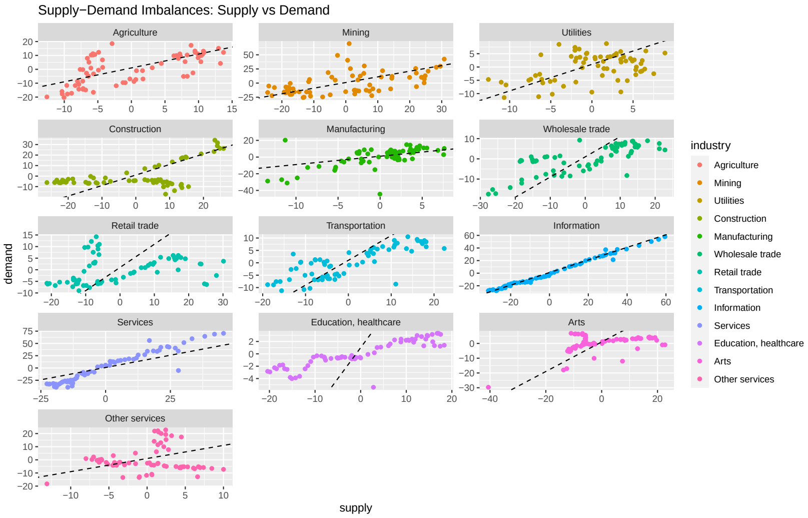
In equilibrium, supply equals demand:

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

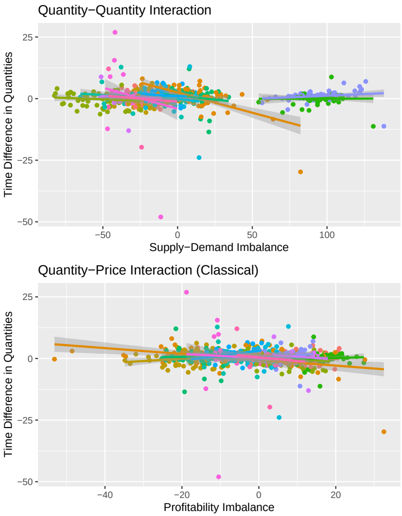
and profitability is uniform across sectors:

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

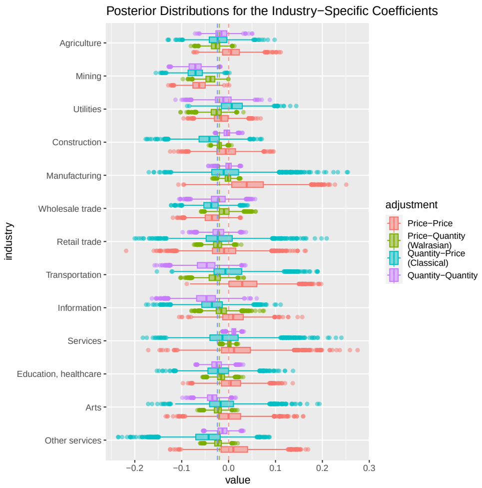
Empirical Imbalances: Supply-Demand



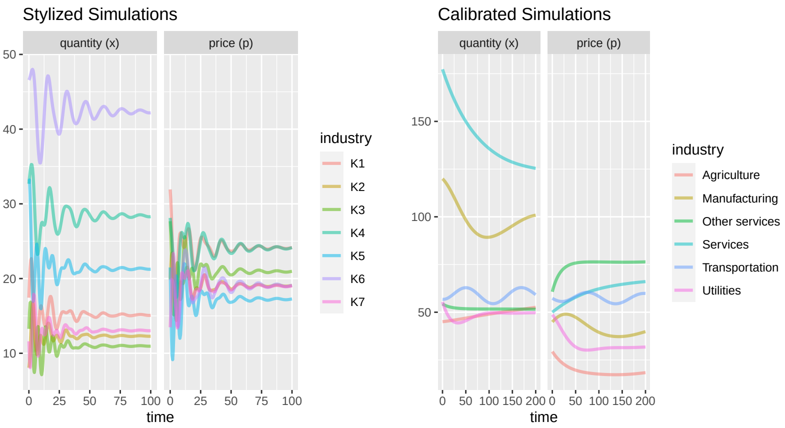
Empirical Imbalances: Composite Adjustments



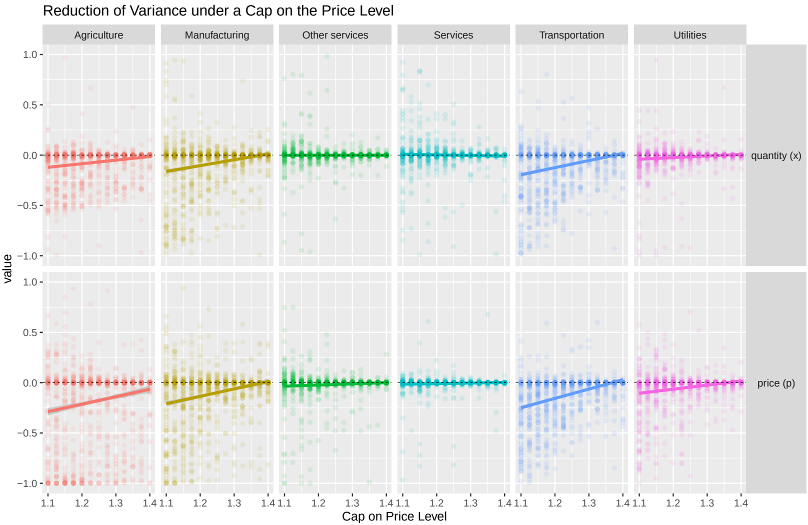
Posterior Distributions of the Industry-Specific Random Effects



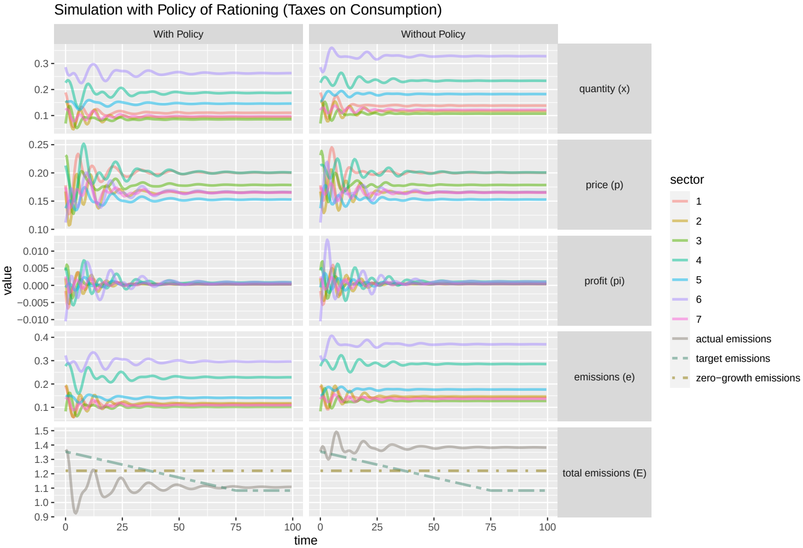
Simulations



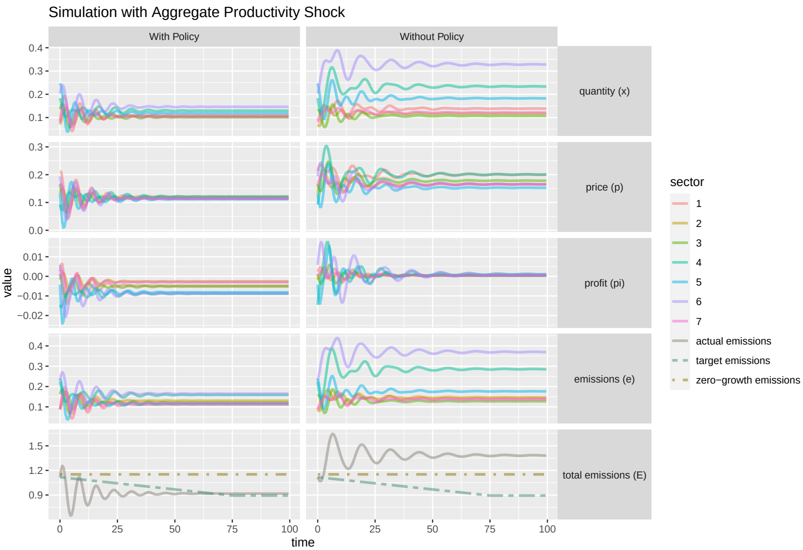
Price Controls Reduce Economic Volatility



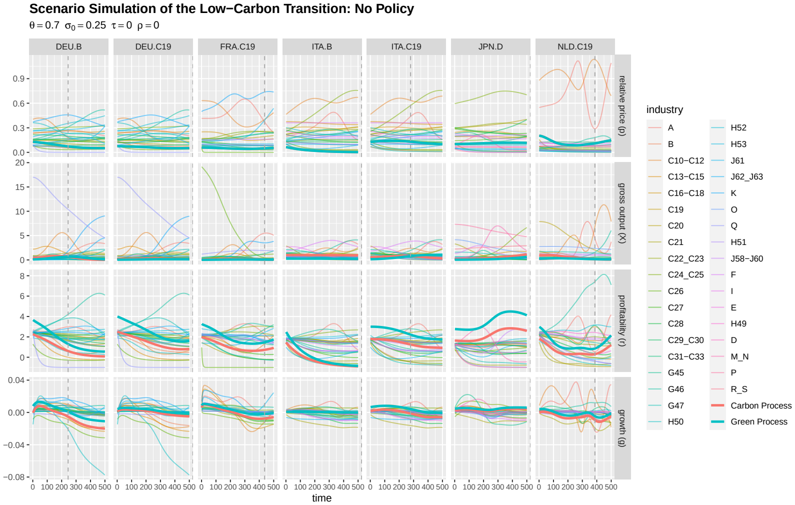
Reduction of Emissions by Rationing



Reduction of Emissions by Aggregate Productivity Shock



Reduction of Emissions by Process Substitution



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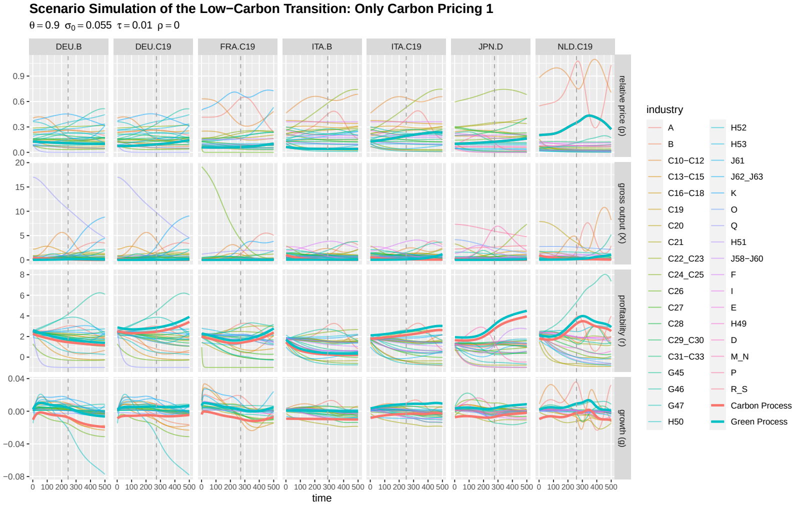
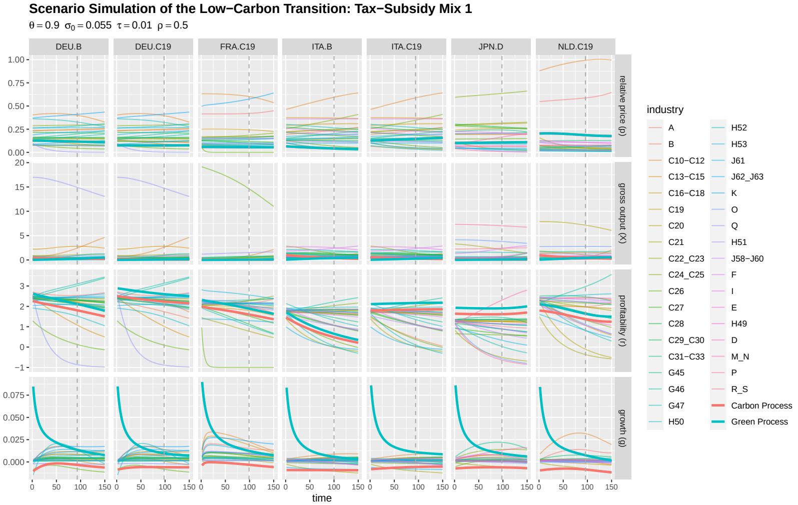


Reduction of Emissions by Process Substitution



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.