Sectoral Transition Risk in an Environmentally Extended Production Network Model

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Office of the Comptroller of the Currency

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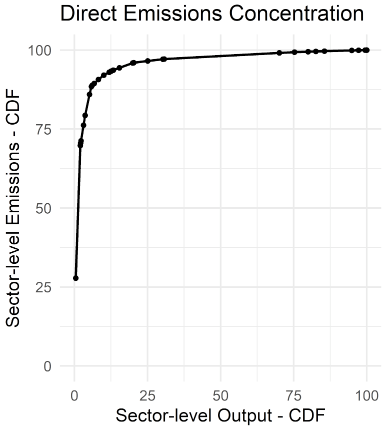
Disclaimer: The views expressed in this paper are those of the author alone and do not necessarily reflect those of the Office of the Comptroller of the Currency or the US Department of the Treasury. All errors are my own.

Motivation

How do we characterize sector-level transition risk?

- Emissions are concentrated in several low-output sectors.
- Q: What is the relative scale of
  - **Direct effects?:** Carbon tax on scope 1
  - **Indirect effects?:** Supply chain - scope 2, scope 3.
  - see figure



Source: EXIOBASE 3: US data.

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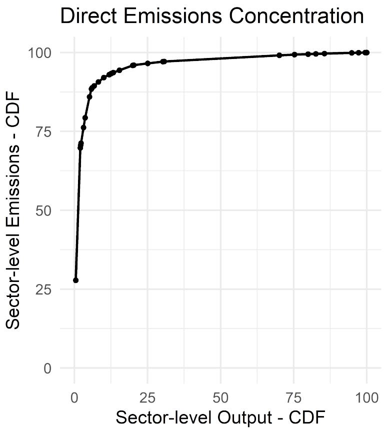

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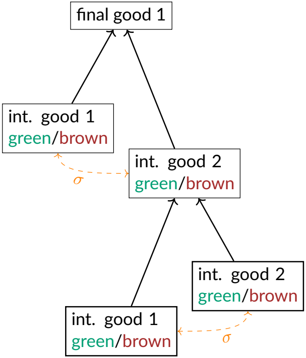
Introducing: Production Network Models

- Pioneered by Long and Plosser (1983).
- Applied to carbon tax setting by McKibbin et al. (2018), Devulder and Lisack (2020), etc.
  - CES production: elasticity σ
- Usually, base structure calibrated on World Input-Output Database.
  - **Issue:** Sector categorization combines green and fossil-fuel energy.



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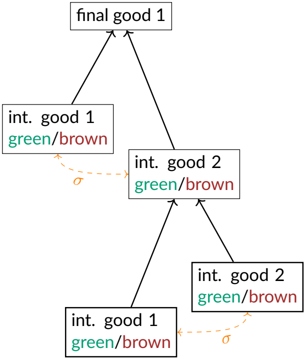

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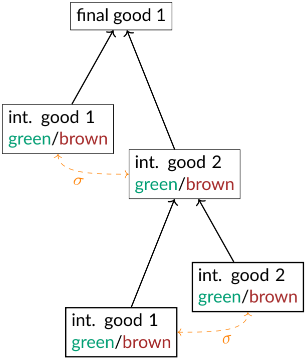
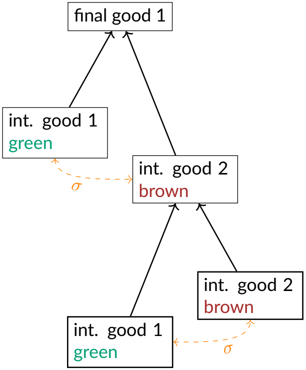


This Paper:

- Uses EXIOBASE *environmentally augmented* I/O tables.
  - Divides green vs non-green.

Results

- Decline for fossil-fuel linked industries. Increase for green energy linked industries, depends on energy EOS σ
- Subsidy on green may be less efficient than carbon tax.
- Provide conditions when scope 3 approximates transition risk.



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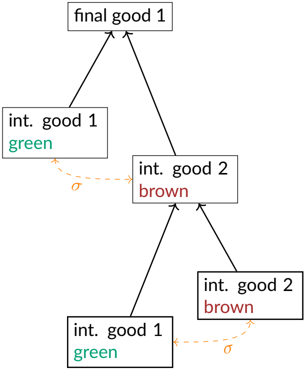
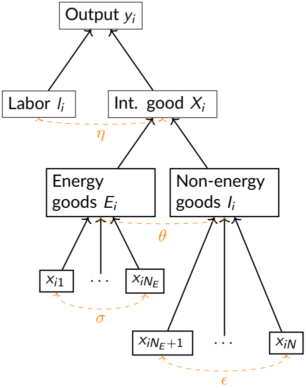


Model

Model: Overview

- **Producers of good i:** maximize profit. Choose output y_i, labor demand l_i, and intermediate good demand x_{ij} - given production carbon tax τ_i, wages w, and goods prices p_i.
    - Nested CES structure - see diagram.



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- Two countries: US and ROW.

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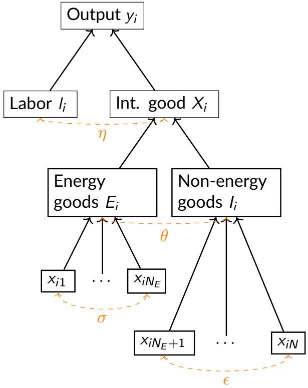

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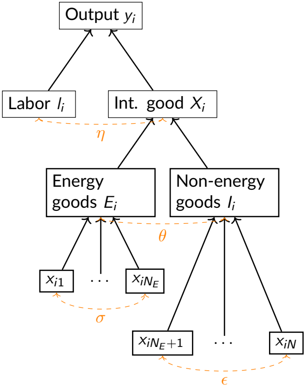

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Model: Input-Output Structure

Amount produced

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{pmatrix} = \begin{pmatrix} F_1(x_{11}, x_{12}, \cdots, x_{1N}) \\ F_2(x_{21}, x_{22}, \cdots, x_{2N}) \\ \vdots \\ F_N(x_{N1}, x_{N2}, \cdots, x_{NN}) \end{pmatrix}$$

Amount produced   Intermediate inputs   Final consumption

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{pmatrix} = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1N} \\ x_{21} & x_{22} & \cdots & x_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ x_{N1} & x_{N2} & \cdots & x_{NN} \end{pmatrix}^{\intercal} \begin{pmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{pmatrix} + \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_N \end{pmatrix}$$

Figure: Input-output structure visualization

Model: Calibration - I

According to equilibrium conditions,

$$x_{ij}^{\text{base}} = \alpha_{ij} F_i^{\text{base}} \tag{1}$$

Where α_{ij} are CES share parameters.
Set

$$\hat{x}_{ij} := \frac{x_{ij}^{\text{base}}}{F_i^{\text{base}}} = \alpha_{ij} \tag{2}$$

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$$DY \sim F_i^{-1}(Y) = X \quad (3)$$

Equation (2) implies that the direct requirements matrix is approximated in the model baseline factor shares/CES share parameters.

$$D^{model} \sim \hat{X} = A \quad (4)$$

And so these parameters are set through I/O table.

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Data

Data

- **Need:**
  - Input/Output tables with separate green and non-green sectors.
  - Integrated emissions
- EXIOBASE3 (see Stadler et al (2018)) is **designed** to study environmental impact.
  - 163 industry by 200 product classification for 44 countries.
  - Includes full categorization of green energy sectors.
  - Reconciled estimates from primary sources.
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Emissions

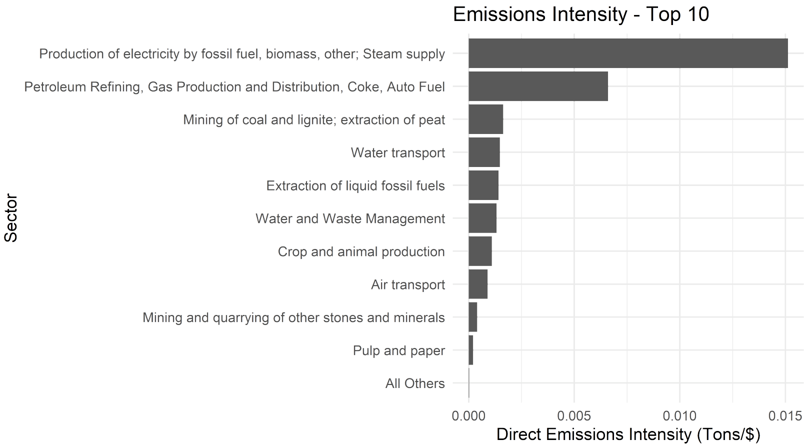
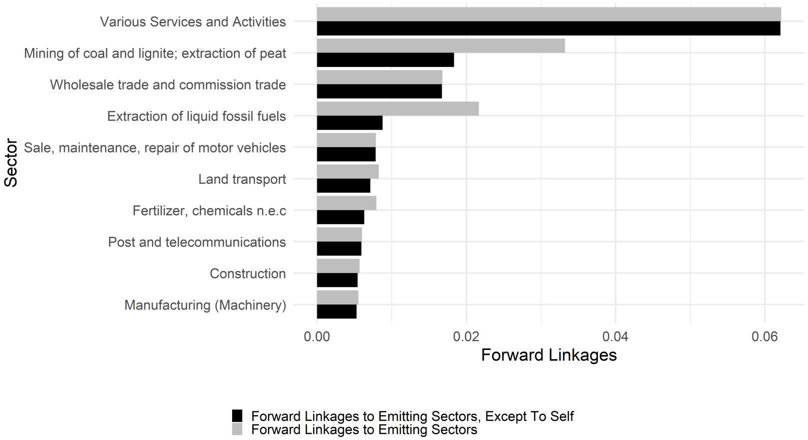


Figure: *Source:* EXIOBASE3

Forward Linkages to Emitting Sectors (Minus Self)
Top 10



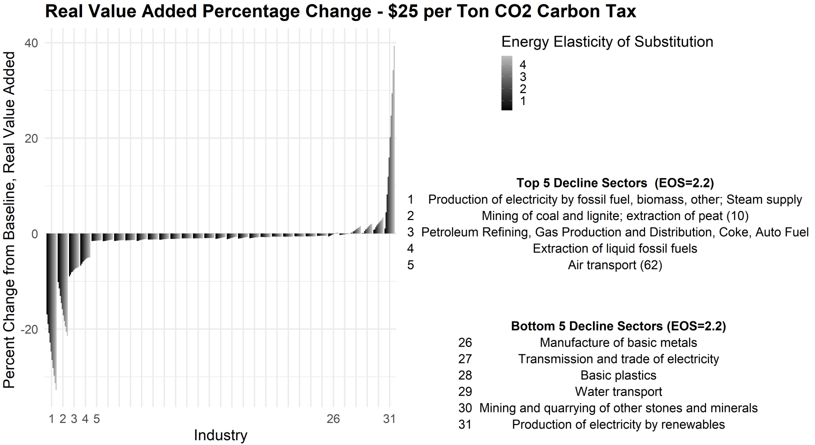
Other Parameters

Parameter	Description	Estimate
σ	**Producer:** Energy EOS	$0.2 - 4.7$
ϵ	**Producer:** Non-Energy EOS	0.1
η	**Producer:** Energy - non-Energy EOS	0.1
θ	**Producer:** Value Added - Int. Goods EOS	0.1
ρ	**Consumer:** EOS	0.8
ϕ	**Consumer:** Coefficient of Risk Aversion	2.0

Results

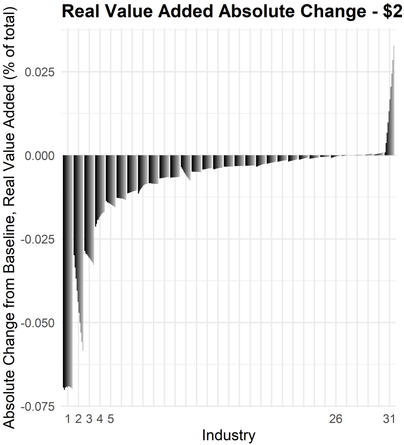
Real Value Added Percentage Change

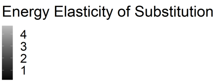
Varying energy EOS σ



Real Value Added Absolute Change

Varying energy EOS σ





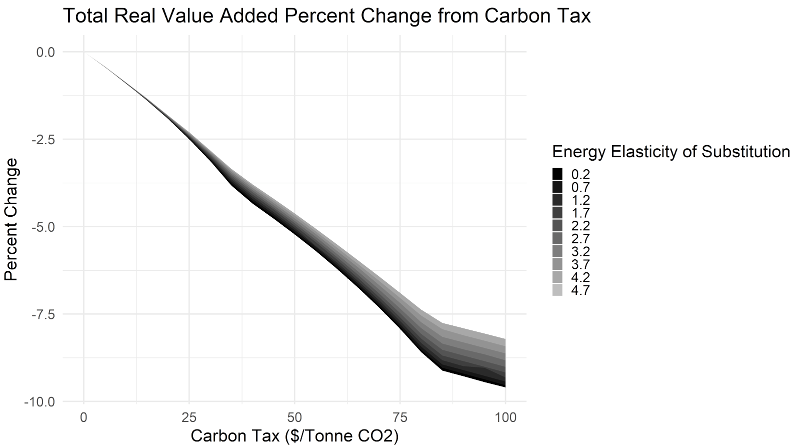
Top 5 Decline Sectors (EOS=2.2)

1 Various Services and Activities
2 Production of electricity by fossil fuel, biomass, other; Steam supply
3 Real estate activities (70)
4 Petroleum Refining, Gas Production and Distribution, Coke, Auto Fuel
5 Hotels and restaurants (55)

Bottom 5 Decline Sectors (EOS=2.2)

26 Transmission and trade of electricity
27 Manufacture of basic metals
28 Basic plastics
29 Water transport
30 Mining and quarrying of other stones and minerals
31 Production of electricity by renewables

Aggregate Output
Varying energy EOS σ



Direct vs Indirect Sector-Level Decomposition

- **Question:** What is the relative importance of direct vs indirect effects?
- **Approach:** "Leave one covariate out" (LOCO)-style analysis
  1. Calculate effect on sector *i* when only taxing sector *i*.
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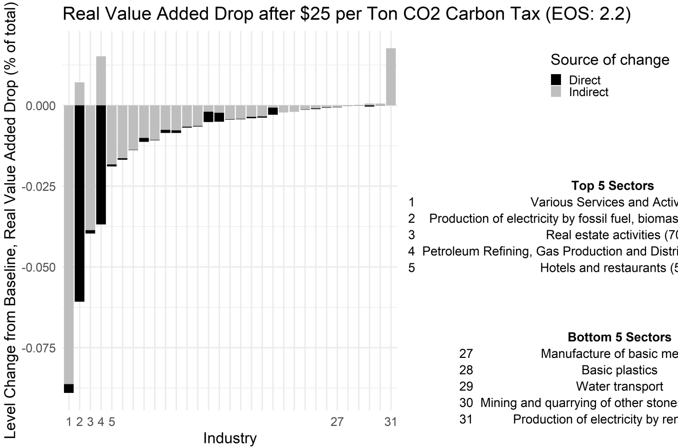
Aggregate Real Value Added Change

Direct vs Indirect Sector-Level Decomposition



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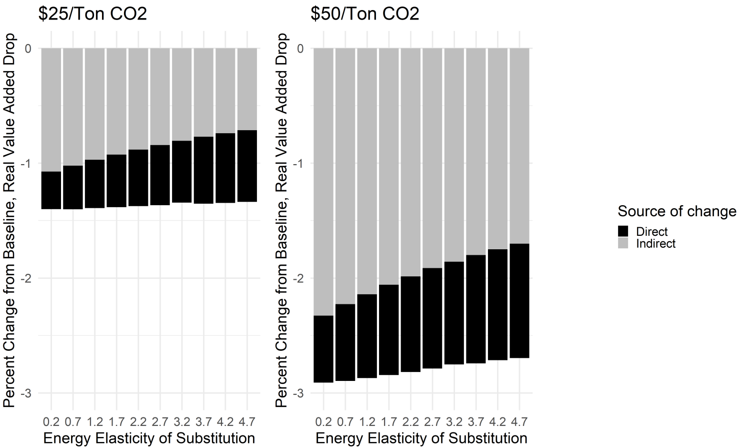
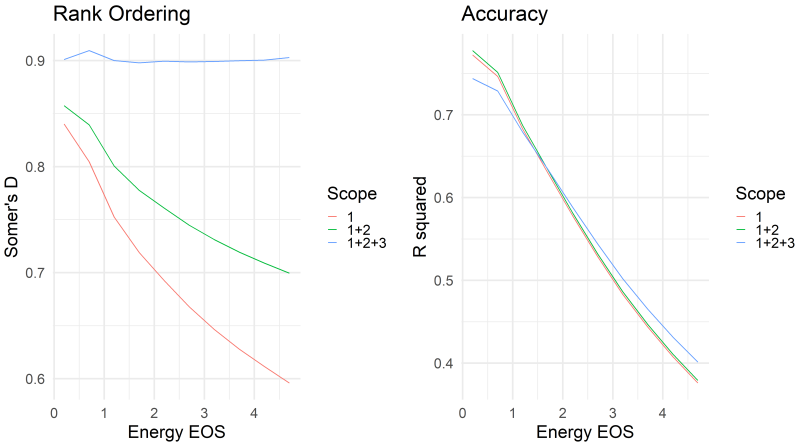
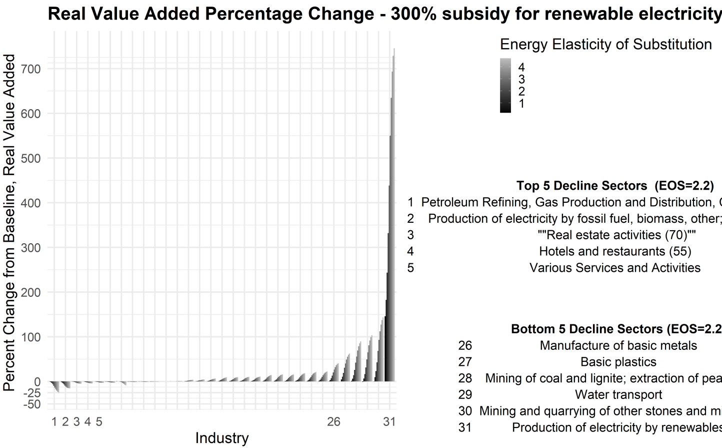


Real Value Added Percentage Change

Scope 1+2+3 Linear Approximation



Real Value Added Percentage Change
Renewable Subsidy



Top 5 Decline Sectors (EOS=2.2)

1 Petroleum Refining, Gas Production and Distribution, Coke, Auto Fuel
2 Production of electricity by fossil fuel, biomass, other; Steam supply
3 ""Real estate activities (70)""
4 Hotels and restaurants (55)
5 Various Services and Activities

Bottom 5 Decline Sectors (EOS=2.2)

26 Manufacture of basic metals
27 Basic plastics
28 Mining of coal and lignite; extraction of peat (10)
29 Water transport
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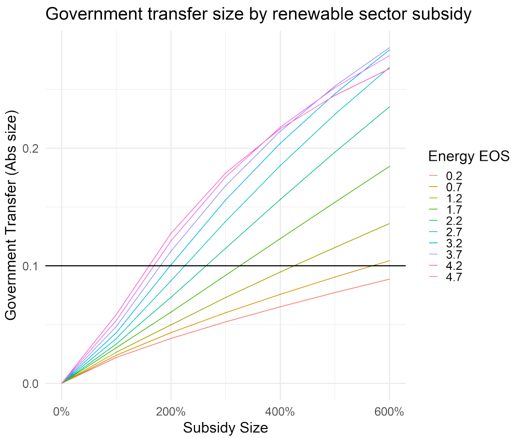
31 Production of electricity by renewables

Government Transfer Comparison
Renewable Subsidy



- Transfer with $25 carbon tax ≈ 0.1
- Transfer with high EOS subsidy tends to be higher.
- I.e. subsidy is less efficient in emissions reduction?

Discussion

- Sector-level dynamics highly dependent on energy EOS
  - 18% – 32% drop in response to 25$ carbon tax in fossil-fuel electricity.
  - 5% – 40% increase in response to 25$ carbon tax in renewable electricity.
  - Richer elasticity structures may produce more variation.
- Largest *absolute* losses are driven by *indirect* effects in large low-emissions sectors.
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Work in progress

- Next step: estimating sector-specific EOS parameters
  - Data needs: Sector specific input prices over time + factor shares.
  - Currently using EU KLEMS + EXIOBASE + misc. data sources for renewables.

- Alternate IO table calibration - local models?
  - USEEIO, State USEEIO.
  - This provides an understanding of *local* sectoral impacts and flows.

Appendix

Indirect vs Direct Effects

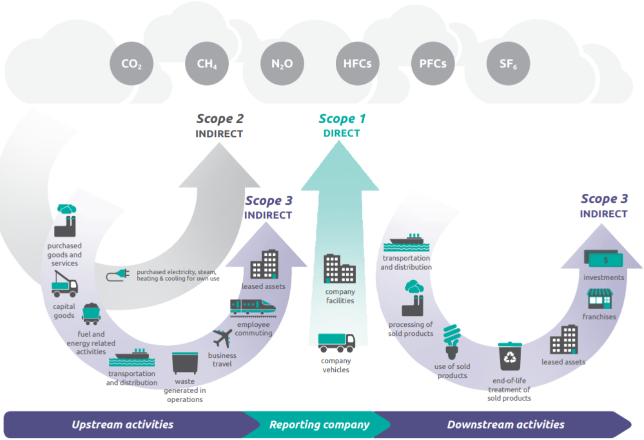

Figure: *Source*: Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard

Campiglio, Emannuele, Hubert Massoni, and Stefan Trsek (2022), "The network effects of carbon pricing." *Working Paper*.

Devulder, Antoine and Noemie Lisack (2020), "Carbon tax in a production netwok: propagation and sectoral incidence." *Bank of France Working Paper*, 760.

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Stadler, K., R. Wood, T. Bulavskaya, C.-J. Södersten, M. Simas, S. Schmidt, A. Usubiaga, J. Acosta-Fernández, J. Kuenen, M. Bruckner, S. Giljum, S. Lutter, S. Merciai, J.H. Schmidt, M.C. Theurl, C. Plutzar, T. Kastner, N. Eisenmenger, K.-H. Erb, A. de Koning, and A. Tukker (2018), "EXIOBASE 3: Developing a time series of detailed environmentally extended multi-regional input-output tables." *Journal of*