The (Dis-)Equalizing Effects of Production Networks

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Poor Households and the Weight of Inflation

Jan Schulz[1] **Leonhard Ipsen**[1,2]

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Who is most exposed to inflation?

- The wealthy?
- The poor?
- The low-incomes?
- The non-professors?

Income-dependent Inflation Inequality

- Inconclusive: magnitude and direction
  (Claeys and Guetta-Jeanrenaud, 2022; Crawford and Oldfield, 2002; Garcimartín et al. 2021; Hobijn and Lagakos, 2005; Strasser et al., 2023)
- Inconclusive: higher inflation rates = higher inflation inequality?
  (Claeys and Guetta-Jeanrenaud, 2022; Crawford and Oldfield, 2002; Hobijn and Lagakos, 2005)
- Low persistency
  (Hobijn and Lagakos, 2005; Strasser et al., 2023)
- Meanwhile: poorer HH *consistently* indicate to be most exposed
  (Easterly and Fischer, 2001; Stantcheva, 2024)

How can we explain this inflation-inequality puzzle?

I. The Role of Sectoral Asymmetries for Inflation Inequality

The (Dis-) Equalizing Effects of Production Networks

'Systemically Significant Prices'

(Weber et al. 2024)

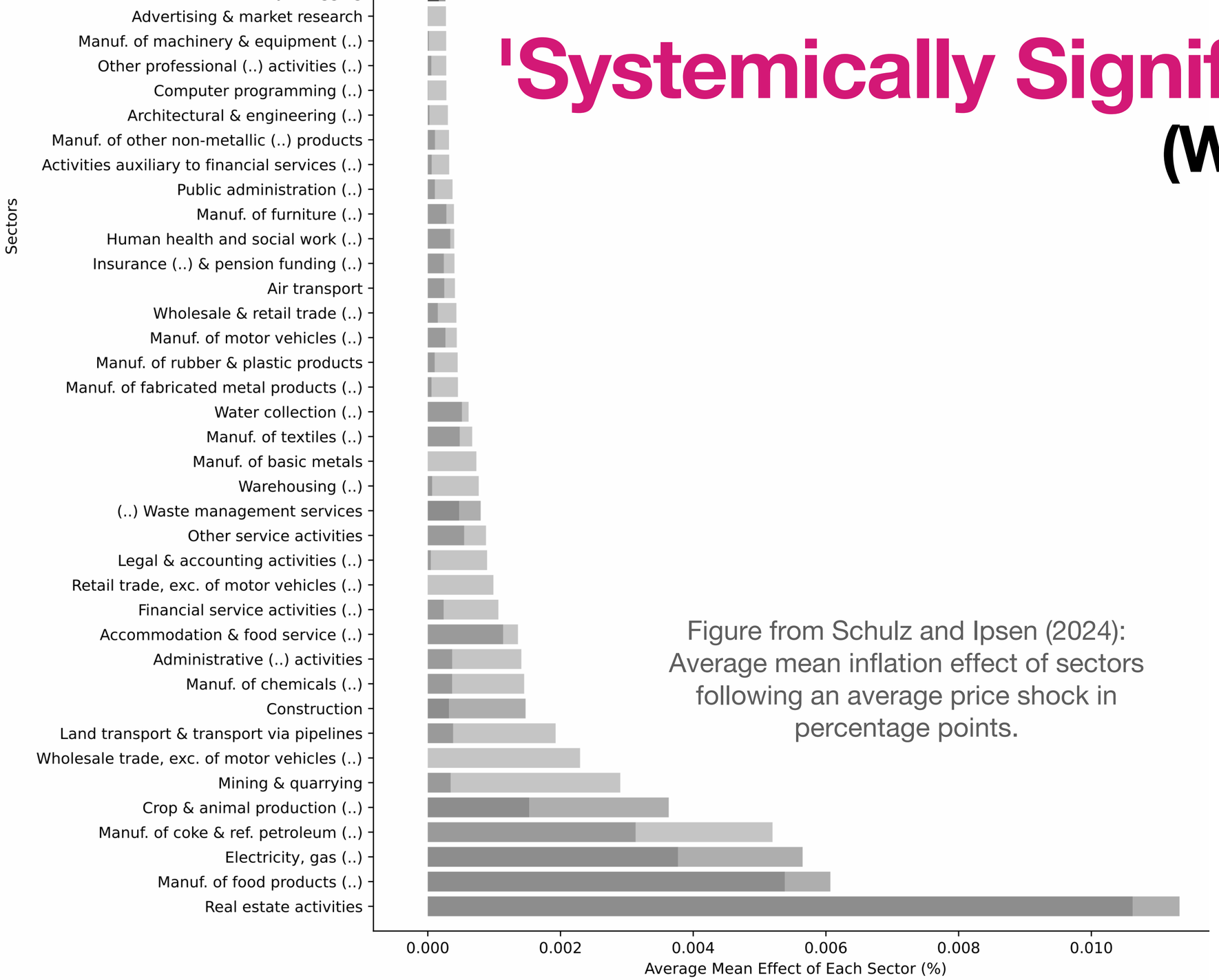


Figure from Schulz and Ipsen (2024): Average mean inflation effect of sectors following an average price shock in percentage points.

Data

World Input Output Database (WIOD)

- Sector level data for 43 countries with 56 sectors each (2000 - 2014; > 85% GDP)

Classification of individual consumption by purpose (COICOP)

- Eurostat: 21 EU countries, 5 quintiles each (2020)
- Merged with WIOD data (Cai and Vandyck, 2020)

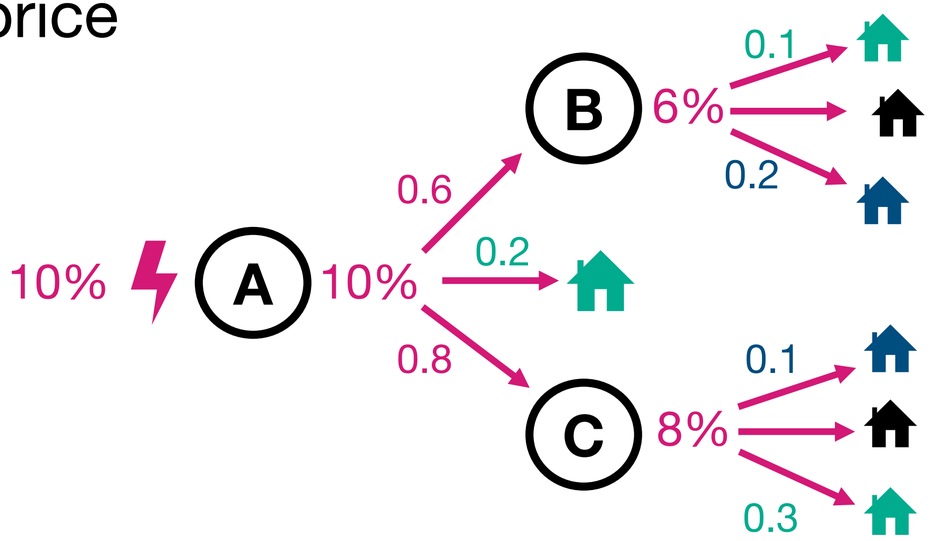
Average income for each quintile

- Eurostat: 21 EU countries (2020)

Approach: Leontief Price Model

Each sector is exposed to its average input price shock between 2000 - 2014.

Shocks propagate downstream and linearly



Sector level consumption shares of
5 income groups in 21 EU countries

Consumption shares are heterogenous for countries and income quintiles.
Thus exposure to individual sectors is asymmetric!

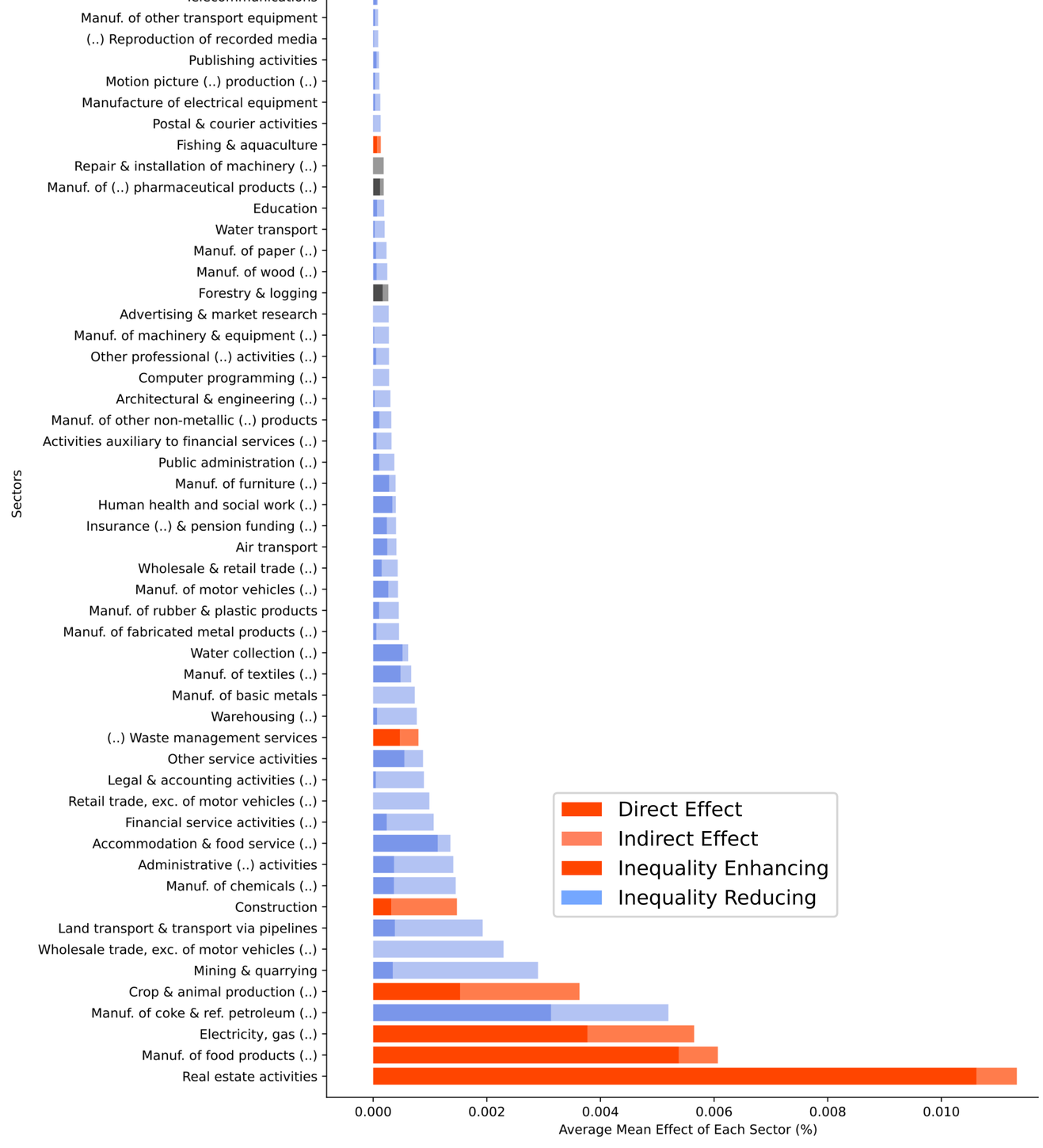
Regression

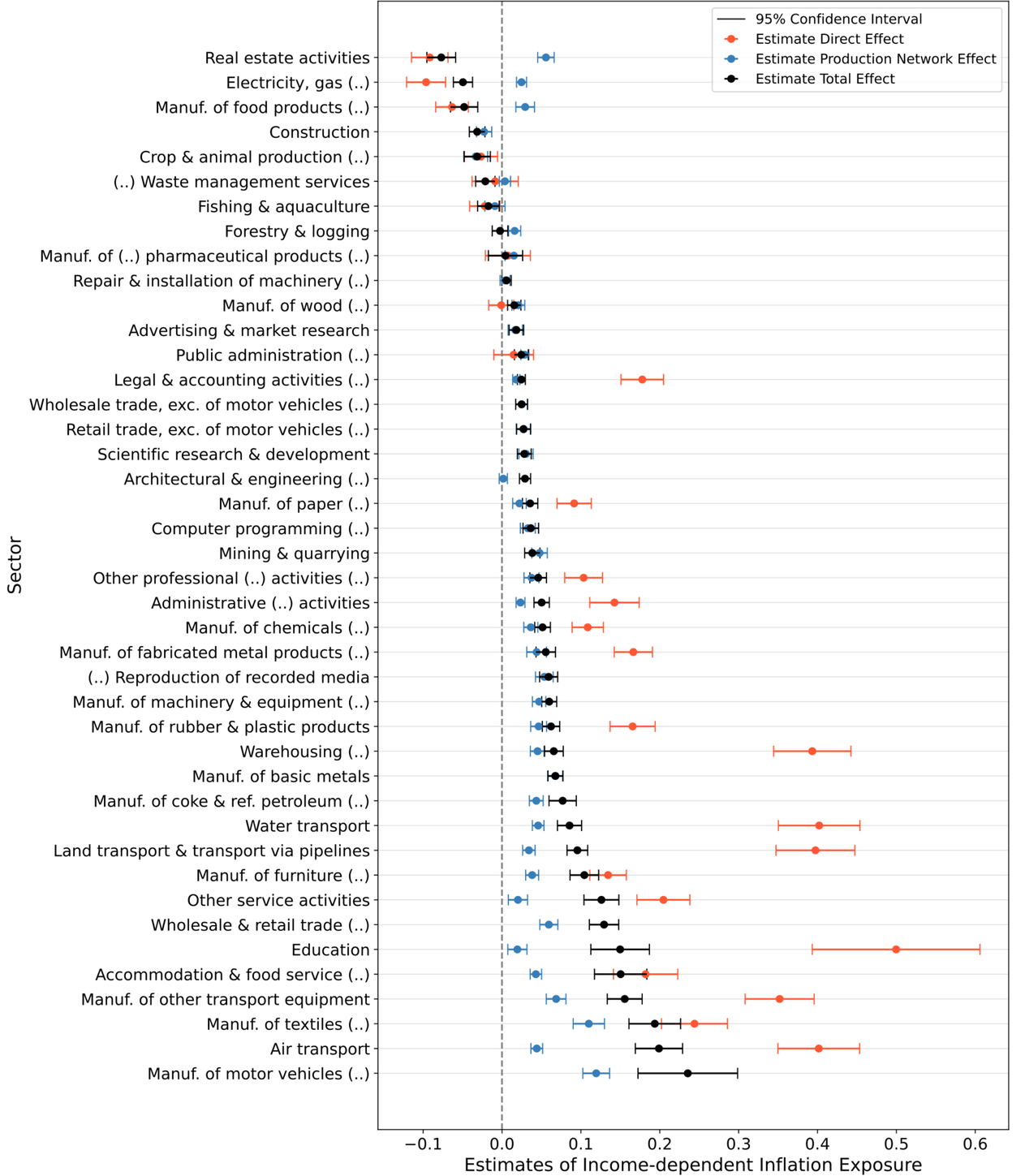
$$log(E)_{j,c,q} = \beta_{0,j} + \beta_{1,j} log(Y_{c,q}) + \delta_c + \epsilon_{j,c,q}$$

- Elasticity estimates for direct, indirect and total effect of sector class j
- $Y_{c,q}$ is average absolute income of quintile q in country c
- δ_c is a country dummy variable for Fixed Effects
- $\epsilon_{j,c,q}$ is an error term

The (Dis-) Equalizing Effects of Production Networks

Working Paper
Ipsen & Schulz 2024


Sectors
Manuf. of other transport equipment
(..) Reproduction of recorded media
Publishing activities
Motion picture (..) production (..)
Manufacture of electrical equipment
Postal & courier activities
Fishing & aquaculture
Repair & installation of machinery (..)
Manuf. of (..) pharmaceutical products (..)
Education
Water transport
Manuf. of paper (..)
Manuf. of wood (..)
Forestry & logging
Advertising & market research
Manuf. of machinery & equipment (..)
Other professional (..) activities (..)
Computer programming (..)
Architectural & engineering (..)
Manuf. of other non-metallic (..) products
Activities auxiliary to financial services (..)
Public administration (..)
Manuf. of furniture (..)
Human health and social work (..)
Insurance (..) & pension funding (..)
Air transport
Wholesale & retail trade (..)
Manuf. of motor vehicles (..)
Manuf. of rubber & plastic products
Manuf. of fabricated metal products (..)
Water collection (..)
Manuf. of textiles (..)
Manuf. of basic metals
Warehousing (..)
(..) Waste management services
Other service activities
Legal & accounting activities (..)
Retail trade, exc. of motor vehicles (..)
Financial service activities (..)
Accommodation & food service (..)
Administrative (..) activities
Manuf. of chemicals (..)
Construction
Land transport & transport via pipelines
Wholesale trade, exc. of motor vehicles (..)
Mining & quarrying
Crop & animal production (..)
Manuf. of coke & ref. petroleum (..)
Electricity, gas (..)
Manuf. of food products (..)
Real estate activities
Direct Effect
Indirect Effect
Inequality Enhancing
Inequality Reducing
0.000
0.002
0.004
0.006
0.008
0.010
Average Mean Effect of Each Sector (%)


Sector
95% Confidence Interval
Estimate Direct Effect
Estimate Production Network Effect
Estimate Total Effect
Real estate activities
Electricity, gas (..)
Manuf. of food products (..)
Construction
Crop & animal production (..)
(..) Waste management services
Fishing & aquaculture
Forestry & logging
Manuf. of (..) pharmaceutical products (..)
Repair & installation of machinery (..)
Manuf. of wood (..)
Advertising & market research
Public administration (..)
Legal & accounting activities (..)
Wholesale trade, exc. of motor vehicles (..)
Retail trade, exc. of motor vehicles (..)
Scientific research & development
Architectural & engineering (..)
Manuf. of paper (..)
Computer programming (..)
Mining & quarrying
Other professional (..) activities (..)
Administrative (..) activities
Manuf. of chemicals (..)
Manuf. of fabricated metal products (..)
(..) Reproduction of recorded media
Manuf. of machinery & equipment (..)
Manuf. of rubber & plastic products
Warehousing (..)
Manuf. of basic metals
Manuf. of coke & ref. petroleum (..)
Water transport
Land transport & transport via pipelines
Manuf. of furniture (..)
Other service activities
Wholesale & retail trade (..)
Education
Accommodation & food service (..)
Manuf. of other transport equipment
Manuf. of textiles (..)
Air transport
Manuf. of motor vehicles (..)
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Estimates of Income-dependent Inflation Exposure

I. The Role of Sectoral Asymmetries for Inflation Inequality

The (Dis-) Equalizing Effects of Production Networks

II. Income-weighted Price Shock Effects

Poor Households and the Weight of Inflation

The Weight of Inflation

$$U(\gamma; Y, \alpha, p) = \left(\gamma \cdot \frac{Y}{p}\right)^{\alpha} \cdot \left((1-\gamma)\frac{Y}{p}\right)^{1-\alpha}$$

$$\frac{\partial U}{\partial \gamma} \stackrel{!}{=} 0 \Rightarrow \gamma^* = \alpha$$

$(\ldots)$ $(\ldots)$

$$-\frac{\Delta u^*}{u} = \alpha \cdot \Delta p \quad \text{or} \quad -\frac{\Delta u^*}{u} = \Delta p$$

Y = available current income

p = price level

γ= average propensity to consume

α= weight on current consumption

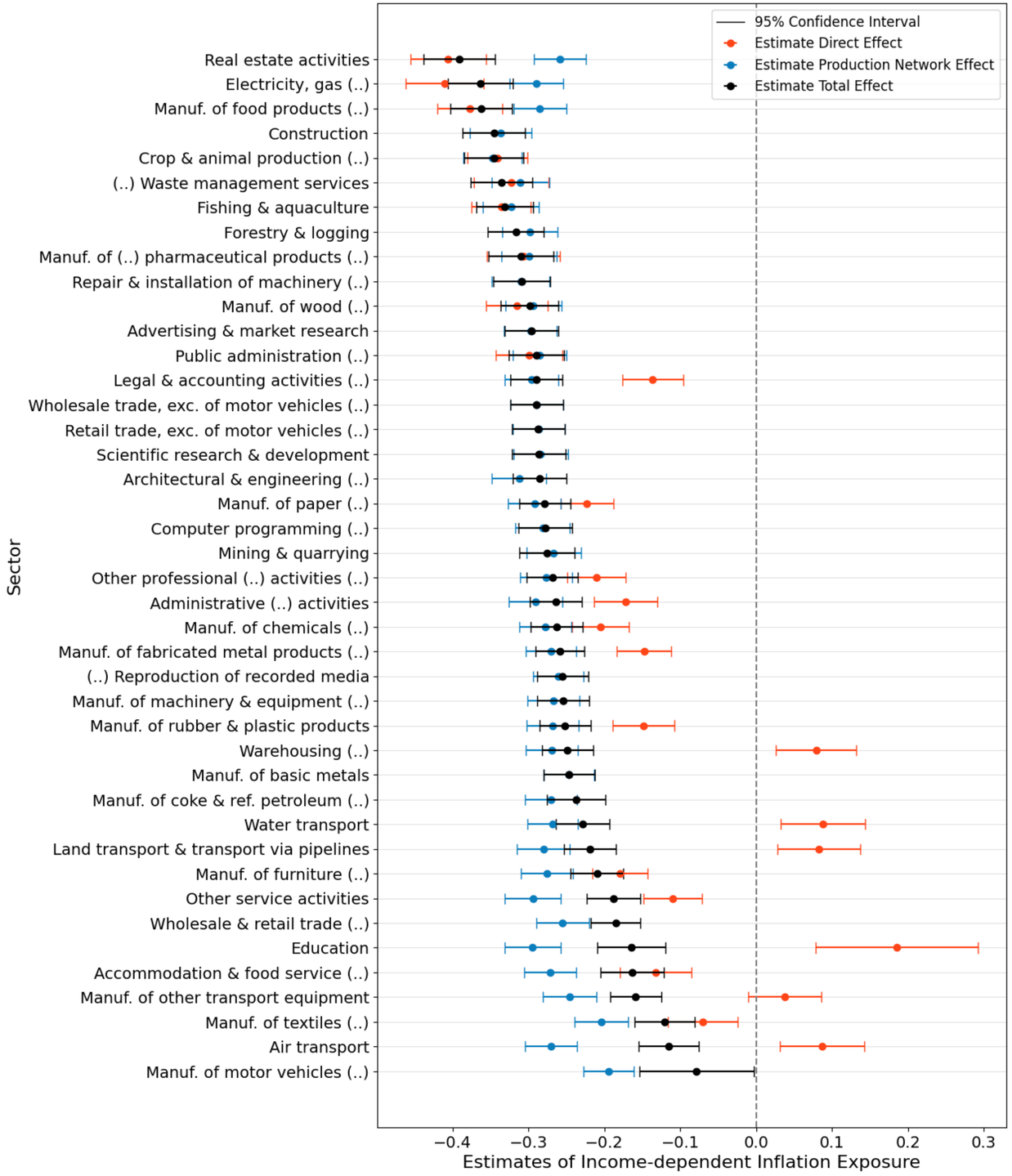
Introducing Average Propensity to Consume

$$Expenditure\ Weights \times APC = \left(\frac{Expenditure_i}{Total\ Expenditures}\right) \times \left(\frac{Total\ Expenditures}{Income}\right) = \frac{Expenditure_i}{Income}$$

GEO	Q1 (%)	Q2 (%)	Q3 (%)	Q4 (%)	Q5 (%)
Austria	129.8	97.9	85	75.9	59
Belgium	118.9	92.1	74	63.3	50
Bulgaria	113.9	89.6	75	62.2	44.1
Croatia	121	107.7	88.4	80	63
Cyprus	89.3	87	86.5	83	65.2
Denmark	118	85.6	74.8	62.3	47
Estonia	108.3	81.9	70	54	45.3
France	114	84.9	78.7	72	55
Germany	143	91.6	84	77.5	63.4
Greece	168	110.4	101.5	88.6	72
Hungary	113.4	94.8	83.3	74.8	66.2
Latvia	114	88.7	78	72.4	56.9
Lithuania	110.7	82.1	69.5	51.8	39.4
Luxembourg	112.9	86.8	80	63.8	52.8
Malta	136.2	94.6	87.6	74.4	53.9
Netherlands	148.2	104.3	83.6	68	52.9
Poland	104.1	60.6	54	47.2	38.8
Romania	195	126.6	104.1	86	66
Slovakia	103	89.2	79.6	71.3	55
Slovenia	117	95.7	87	78.2	64
Spain	129	90.6	76	65.8	51

Income-weighted Price Shock Effects

& The Role of Sectoral Asymmetries for Inflation Inequality



Take Aways

- Sectoral asymmetries in the global production network matter for inflation inequality
- Direction, magnitude & persistence of inflation inequality likely dependent on sector of origin
- Focus on expenditure weights might mask substantial source of inflation inequality
- Income-weighting price shock effects could explain why poorer households consistently feel most exposed to inflation

Working Paper
Ipsen[1,2] & Schulz[1]
(2024)

JanSG

janschulz91

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Appendix

Utility Maximization under (Bounded) Rationality

$$U(\gamma; Y, \alpha, p) = \left(\gamma \cdot \frac{Y}{p}\right)^{\alpha} \cdot ((1-\gamma)Y)^{1-\alpha}$$

$$U(\gamma; Y, \alpha, p) = \left(\gamma \cdot \frac{Y}{p}\right)^{\alpha} \cdot \left((1-\gamma)\frac{Y}{p}\right)^{1-\alpha}$$

By the FOC, the optimal propensity to consume γ^* is given by,

$$\frac{\partial U}{\partial \gamma} \stackrel{!}{=} 0 \Rightarrow \gamma^* = \alpha$$

$$\frac{\partial U}{\partial \gamma} \stackrel{!}{=} 0 \Rightarrow \gamma^* = \alpha$$

Optimizing gives the utility function for γ^*

$$U^*(Y, \alpha, p) = \left(\alpha \frac{Y}{p}\right)^{\alpha} \cdot ((1-\alpha)Y)^{1-\alpha}.$$

$$U^*(Y, \alpha, p) = \left(\alpha \frac{Y}{p}\right)^{\alpha} \cdot \left((1-\alpha)\frac{Y}{p}\right)^{1-\alpha}.$$

Taking the logarithmic derivative and approximating by the discrete growth rate in utility over the discrete growth rate in the price level yields

$$\frac{d\log U^*}{d\log p} = -\frac{\alpha}{p} \approx \frac{\Delta u^*/u^*}{\Delta p/p}.$$

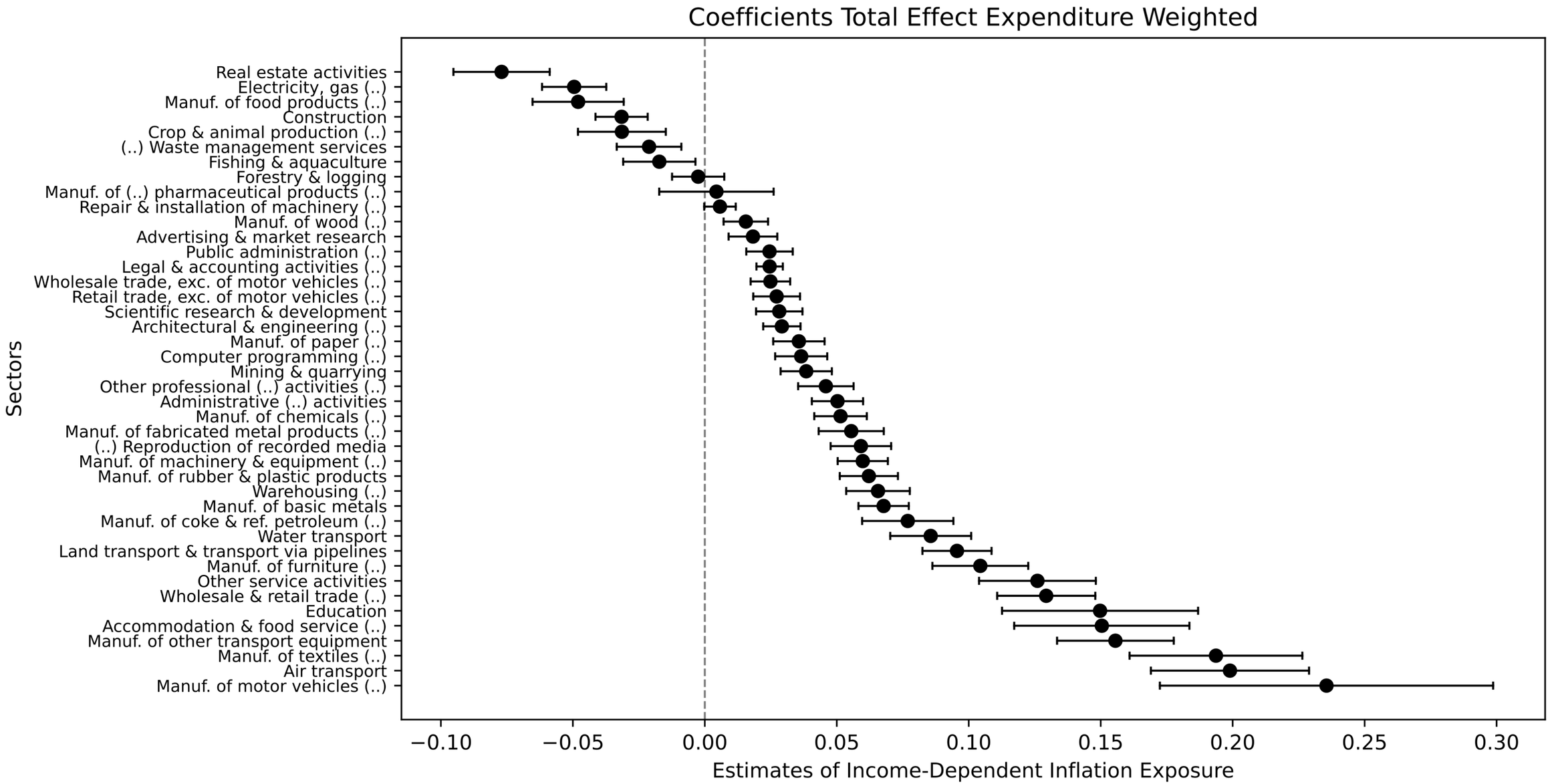
$$\frac{d\log U^*}{d\log p} = -\frac{1}{p} \approx \frac{\Delta u^*/u^*}{\Delta p/p}.$$

Normalizing initial price level to unity, the marginal growth rate of utility in response to a price shock Δp as

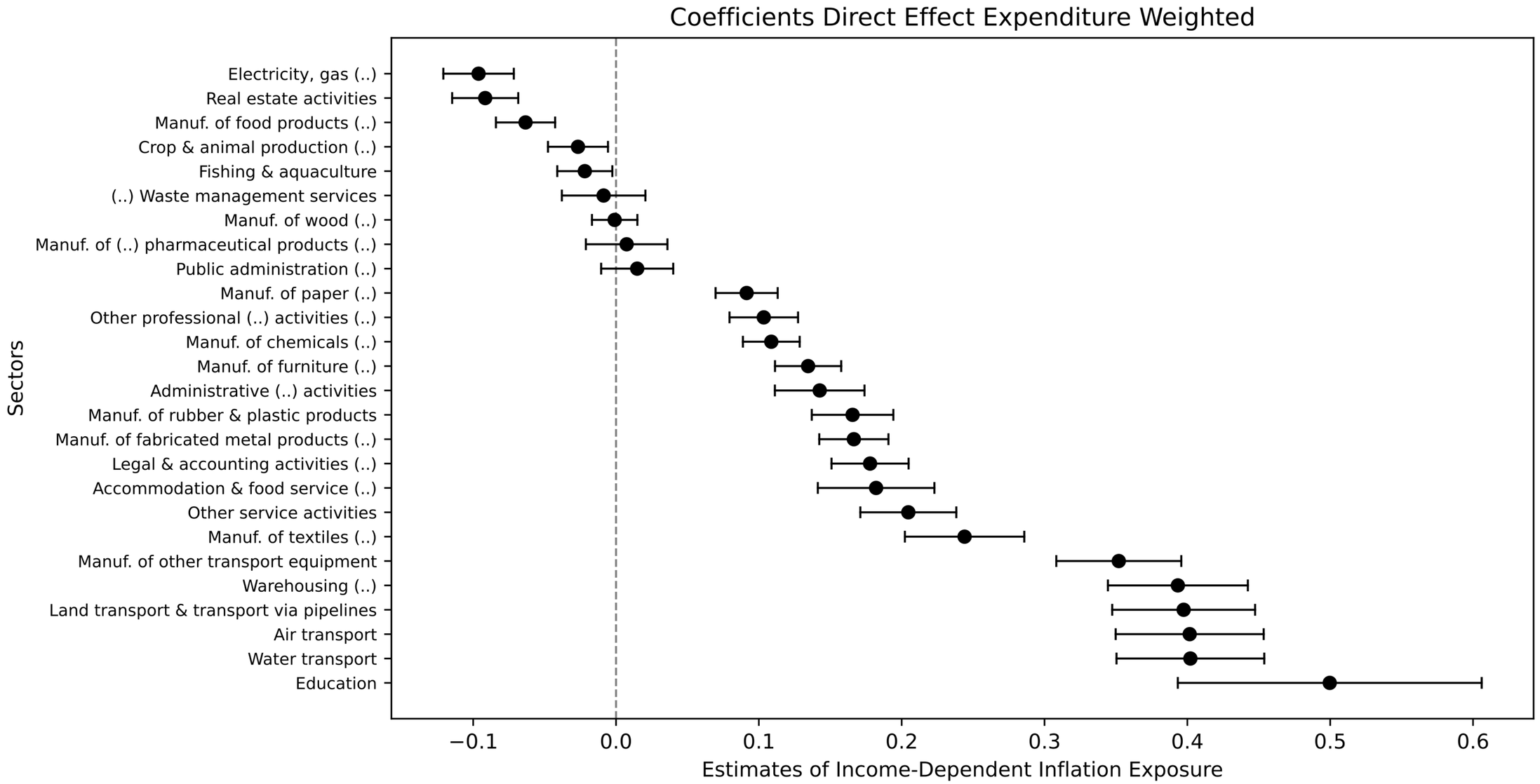
$$\frac{\Delta u^*/u}{\Delta p} = -\alpha \Leftrightarrow -\frac{\Delta u^*}{u} = \alpha \cdot \Delta p.$$

$$\frac{\Delta u^*/u}{\Delta p} = -1 \Leftrightarrow -\frac{\Delta u^*}{u} = \Delta p.$$

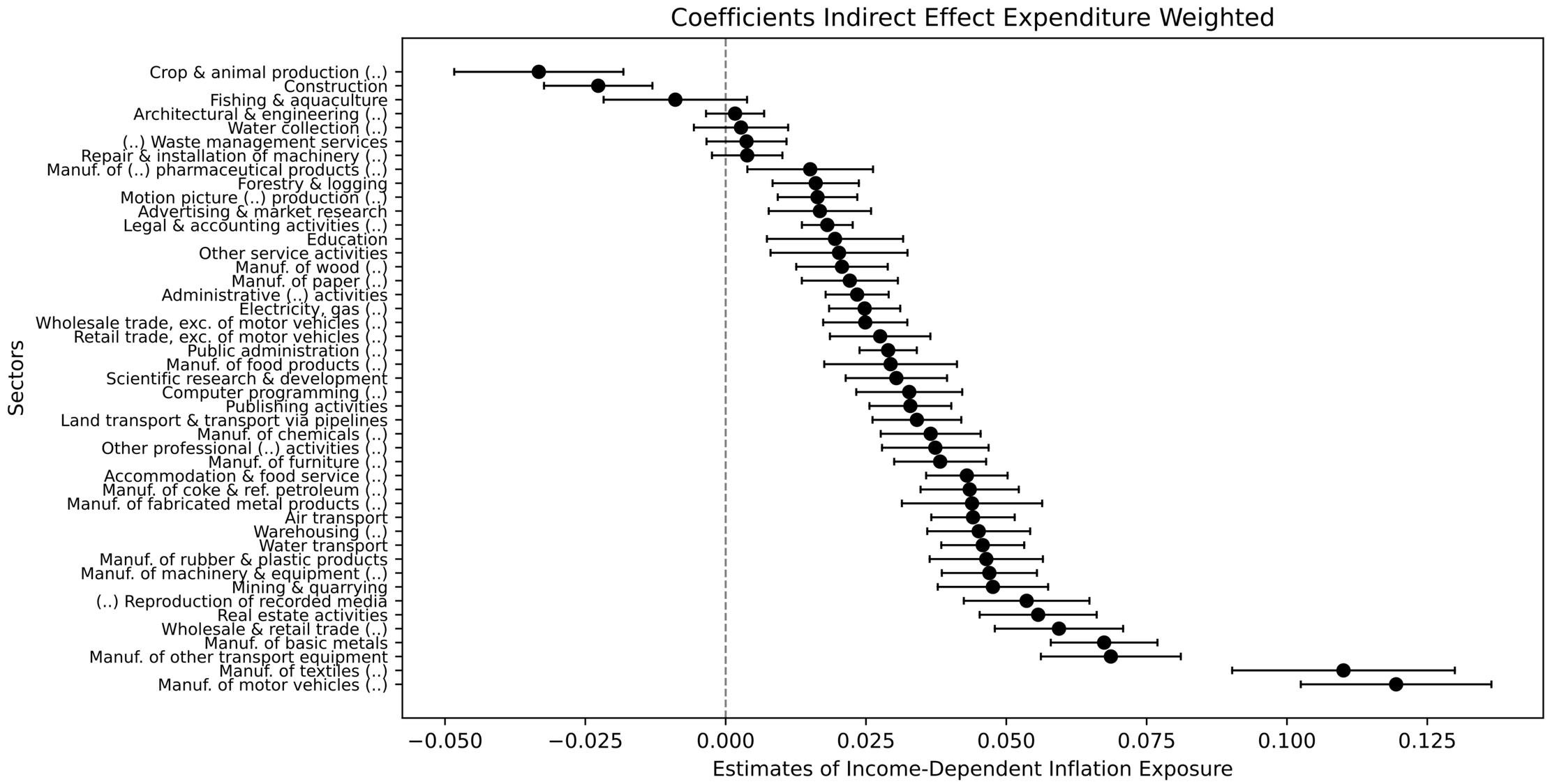
Total Effect



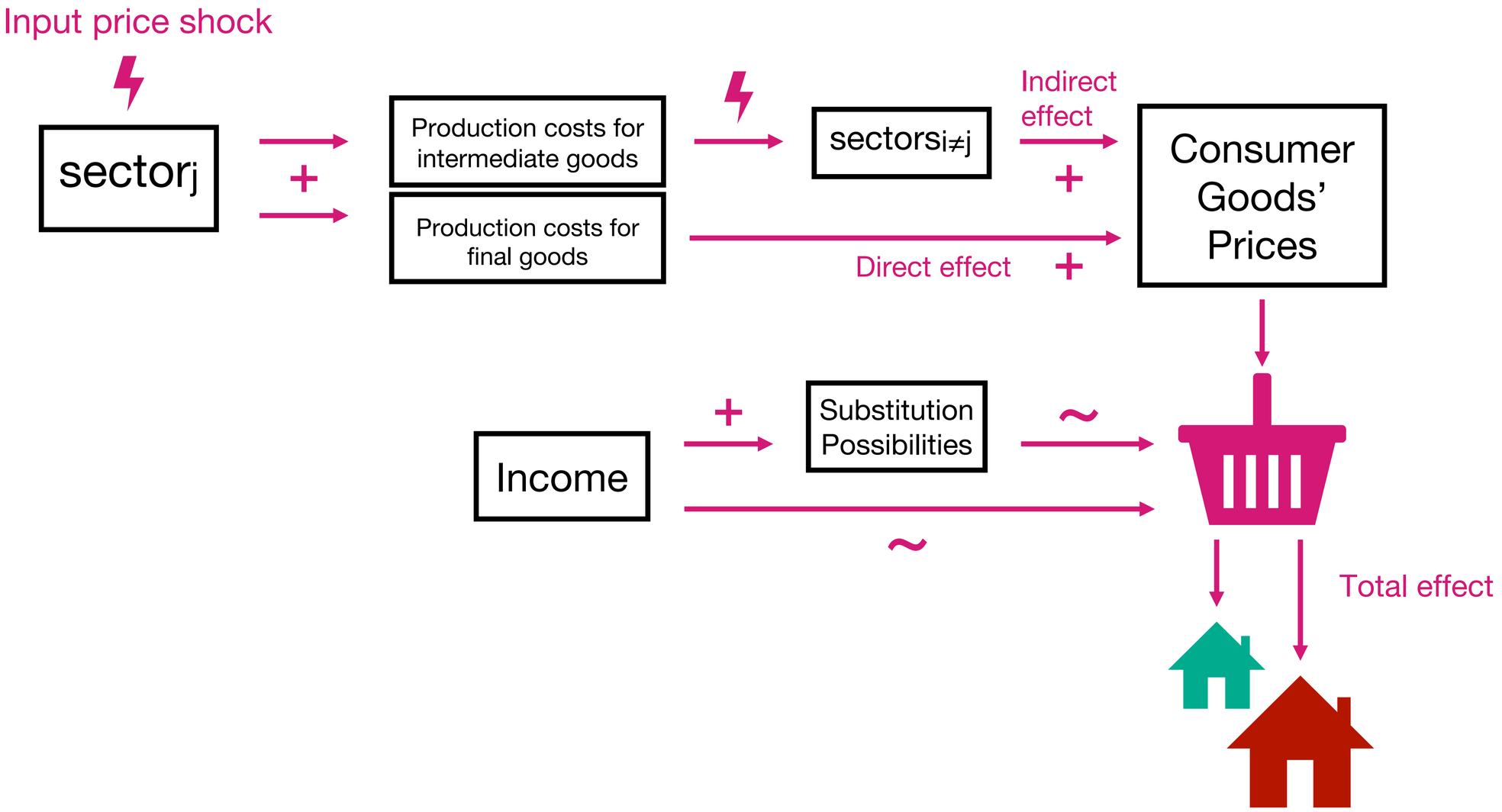
Direct Effect



Indirect Effect



Sectoral Asymmetries & Inflation Inequality

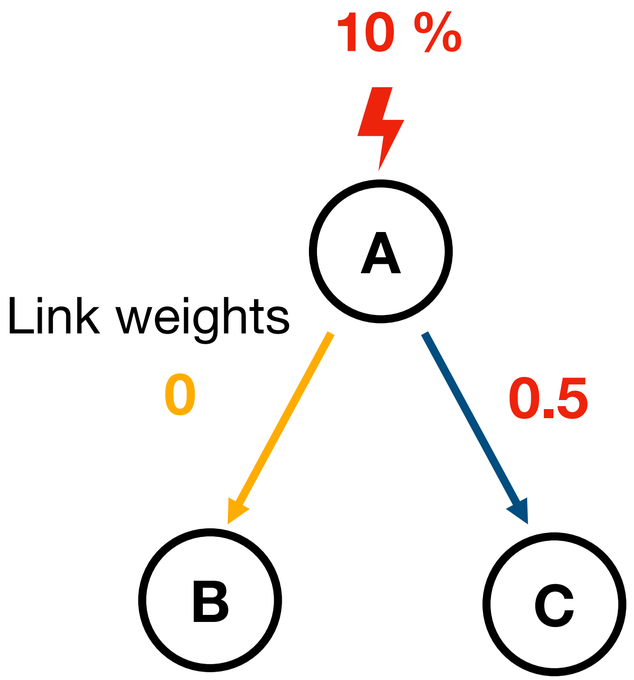


Limitations

- no substitution effects
  - in the network (1:1 supported by Duprez and Magerman, 2018)
  - in products
  - in consumption shares
- Sector level data
- no wealth and debt effect

Inequality reducing effect

Input price Shock



Consumption Shares

$$C_{LI} = \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} 0.2 \\ 0.8 \\ 0 \end{bmatrix}$$

$$C_{HI} = \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} 0.2 \\ 0 \\ 0.8 \end{bmatrix}$$

Effect

$direct^{LI}$ = 0.1 x 0.2 = 0.02

$indirect^{LI}$ = 0.1 x 0 x 0.8 = 0

$total^{LI}$ = 0.02 + 0 = 0.02

$direct^{HI}$ = 0.1 x 0.2 = 0.02

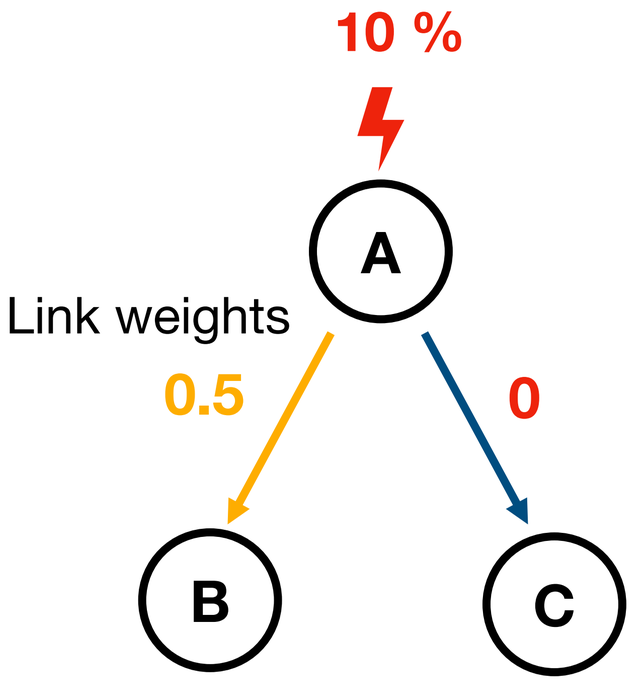
$indirect^{HI}$ = 0.1 x 0.5 x 0.8 = 0.04

$total^{HI}$ = 0.02 + 0.04 = 0.06

$$total^{LI} < total^{HI}$$

Inequality enhancing effect

Input price Shock



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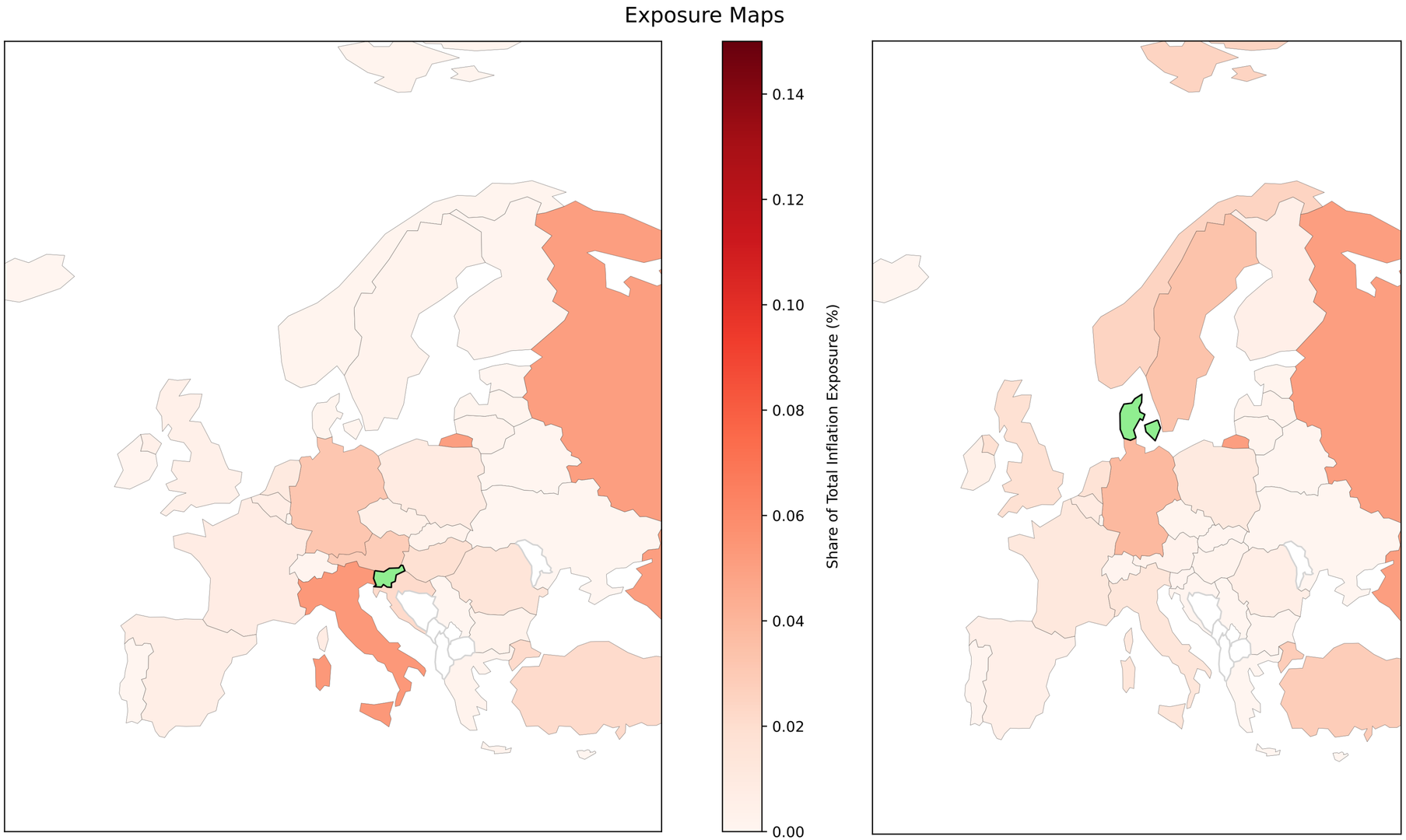
$total^{HI}$ = 0.02 + 0 = 0.02

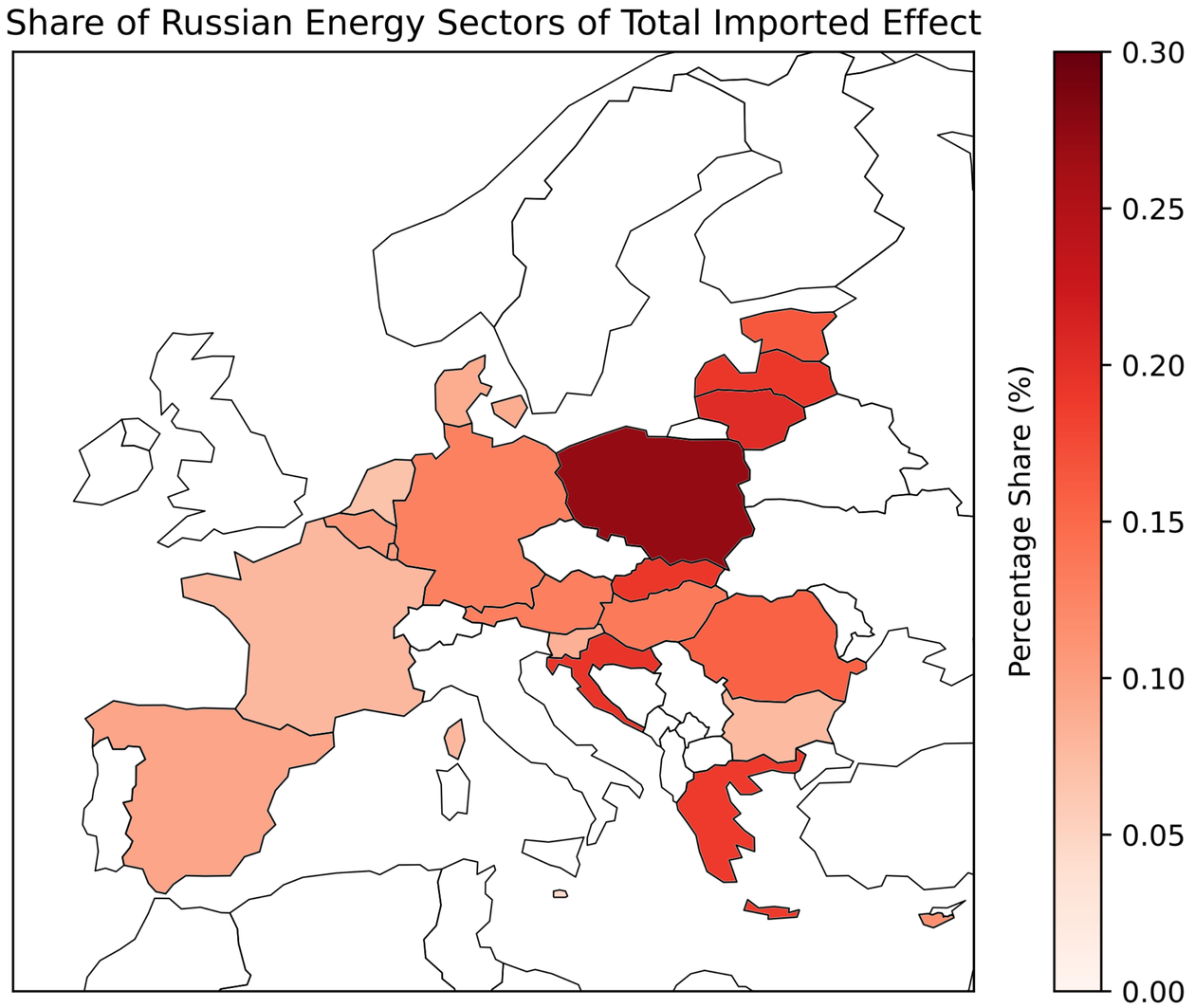
$$total^{LI} > total^{HI}$$

Country-level Analysis: Slovenia and Denmark



Share of total inflation exposure by country for Slovenia (right) and Denmark (left)

Country-level Analysis: Russia's Energy



Share of Russian energy sectors in total imported inflation exposure by country

Take Aways

- **Production networks matter for inflation:** Systemically Significant Prices
- **Production networks matter for inflation inequality**
  - **Inequality Enhancing Prices:**
    We find one relevant channel for inflation inequality. We can identify the sectors to which a price shock is inequality enhancing. One would fail to identify all relevant sectors by focusing only on consumption share differences.
  - **Significant overlap of SSP and IEP**
  - **Mostly homogenizing effect** — however important exception!
- **APC dominant factor for realized inflation inequality:**
  Every price shock becomes an IEP when considering APC

Next Steps / Projects

- Social welfare bias? Food stamps etc.
- Income dependent exposure to Russia?
- How large are the international differences in income dependent exposure?
- Monetary Policy, Production Networks and Inequality (Dix, Schulz, Ipsen)
- Propagation Mechanism of Inflation Shocks in Production Networks (Schulz, Rochowicz, Ipsen)

Working Paper

Ipsen[1,2], Aminian[1,2] & Schulz[1] (2023)

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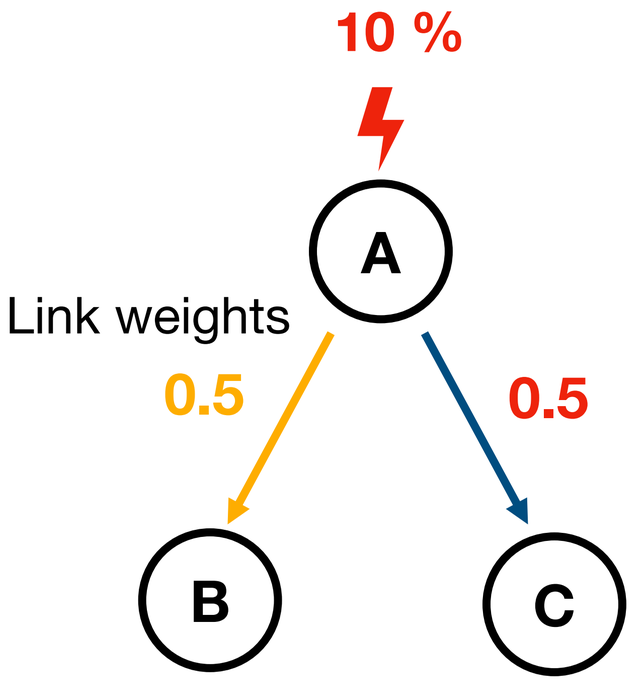
Neutral effect

Input price Shock



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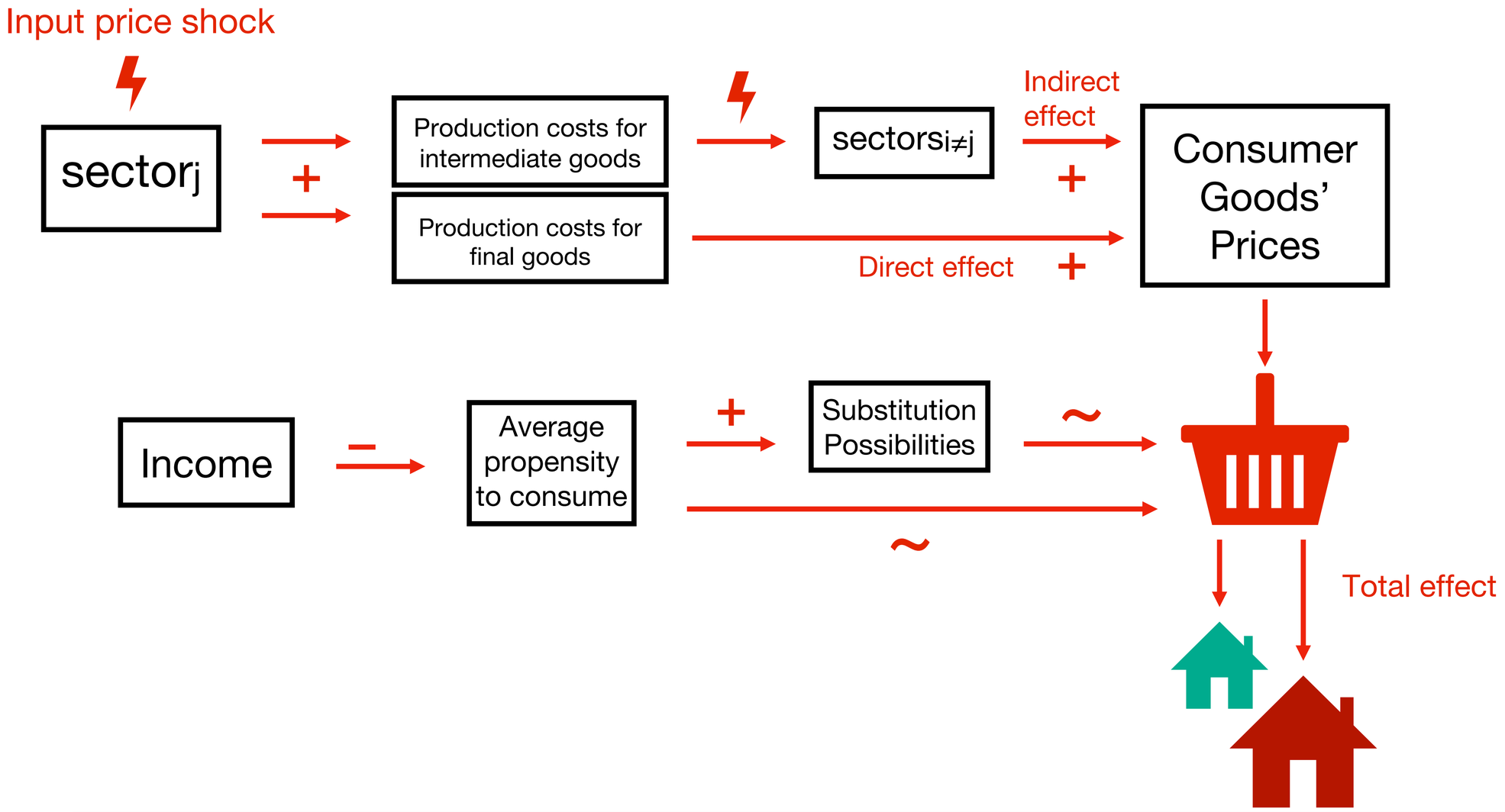
$total^{HI}$ = 0.02 + 0.04 = 0.06

$$total^{LI} = total^{HI}$$

Causal Flow: Realized Inflation Inequality



Leontief Price Model

$$P_j = a_{1j}P_1 + \ldots + a_{ij}P_i + \ldots + a_{nj}P_n + V_j$$

$$P_j = Price\ of\ sector_j\ output$$

$$V_j = Value\ Added\ of\ sector_j$$

$$a_{ij} = \frac{Value\ of\ output\ from\ sector_i\ to\ sector_j}{Value\ of\ sector_j o utput}$$

Leontief Price Model

For n sectors

$$\begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{bmatrix} = \begin{bmatrix} a_{11}a_{21} & \cdots a_{n1} \\ a_{12}a_{22} & \cdots a_{n2} \\ \vdots \ \vdots & \ddots \ \vdots \\ a_{1n}a_{2n} & \cdots a_{nn} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}$$

Simulate downstream shocks: need inverse of A

$$P = A' P + v \, .$$

Singling out sector that experiences shock splits this into

$$\begin{bmatrix} P_X \\ P_E \end{bmatrix} = \begin{bmatrix} A'_{XX}A'_{EX} \\ A'_{XE}A'_{EE} \end{bmatrix} \begin{bmatrix} P_X \\ P_E \end{bmatrix} + \begin{bmatrix} v_X \\ v_E \end{bmatrix}$$

with P_X as the price vector of the shocked sector and P_E as the price vectors of the remaining endogenous sectors.

Derivation Price Model

Following Weber et al. 2022

$$\begin{bmatrix} P_X \\ P_E \end{bmatrix} = \begin{bmatrix} A'_{XX} & A'_{EX} \\ A'_{XE} & A'_{EE} \end{bmatrix} \begin{bmatrix} P_X \\ P_E \end{bmatrix} + \begin{bmatrix} v_X \\ v_E \end{bmatrix}$$

- A'_{XX} is an $x \times x$ matrix, containing the direct input requirements of ex. industries from ex. industries.
- A'_{EX} is an $x \times e$ matrix, containing the direct input requirements of the ex. industries (rows) from the endogenous industries (columns).
- A'_{XE} is an $e \times x$ matrix, containing the direct input requirements of the end. industries (rows) from the ex. industries (columns).
- A'_{EE} is an $e \times e$ matrix containing the direct input requirements of end. industries (rows) from end. industries (rows)

Leontief Price Model

Since P_X is determined by the exogenous shock, we are only interested in

$$P_E = A'_{XE} P_X + A'_{EE} P_E + v_E \,.$$

$A'_{XE} P_X$ captures how the prices in the endogenous sectors depend on the price of the exogenous sector. $A'_{EE} P_E$ captures how the prices in the endogenous sectors depend on each other. If we solve for P_E, we get

$$P_E = (I - A'_{EE})^{-1} A'_{XE} P_X + (I - A'_{EE})^{-1} v_E \,.$$

Assuming no substitution, the quantity of inputs remains unchanged following a change in prices. Thus, following a change in prices in the exogenous sector ΔP_X, the price change in the remaining sectors, ΔP_E, is given by

$$\Delta P_E = (I - A'_{EE})^{-1} A'_{XE} \Delta P_X \,.$$

Leontief Price Model

At this point we introduce the expenditure shares $Es_{x,q,i}$, which is the expenditure share of quintile$_q$ in country$_i$ in the exogeneous sector$_x$. $Es_{b,q,i}$ gives the expenditure share of quintile$_q$ in country$_i$ in the endogeneous sector$_b$

The direct, indirect and total effect is then given by

$$\Delta\pi_{Q,I}^{direct} = Es_{x,q,i}\Delta P_X$$

$$\Delta\pi_{Q,I}^{indirect} = \sum_{b\neq x} Es_{b,q,i}\,\Delta P_E^b\,.$$

$$\Delta\pi_{Q,I}^{total} = Es_{x,q,i}\Delta P_X + \sum_{b\neq x} Es_{b,q,i}\,\Delta P_E^b\,.$$

Stress-Test Scenario

Mean of yearly logarithmic price changes

$$\Delta P_X = \frac{1}{T} \Delta\% P_X^t$$

inserting price shocks into price formation process gives

$$P_E = (I - A'_{EE})^{-1} A'_{XE} \Delta P_X$$

with σ_E =volatility in endogenous sectors induced by σ_x