Beyond Energy: Inflationary Effects of Metal Price Shocks in Production Networks

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This paper

What

- We quantify and rationalize the effect of base metals prices on headline and core inflation for a sample of 39 economies

Why

- Metals are key inputs in production (e.g., structures)
- Their importance and their price volatility are expected to grow along the energy transition

How

- Guided by a small open economy model of production networks estimate local projection regressions to assess effect of copper supply shocks on inflation
  - Use inflation and input-output network data for a sample of 39 countries
  - Copper price supply shocks from Baumeister, Ohnsorge, and Verduzco-Bustos (2024).

Results

- Metals are key direct and indirect inputs in the production of large investment sectors: construction, machinery, electrical equipment, and furniture, among others.

- Supply shocks to copper prices have significant and persistent effects on both core and headline inflation,
  - Similar to oil in headline but much larger than oil in core inflation

- As predicted by the model, countries with high production network exposure to metals display larger effects

Theoretical Framework

Small open economy with production networks (Silva, 2023)

Two types of goods:

- domestically produced goods: $Q_i = Z_i F_i\left(\{L_{if}\}_{f \in F}, \{M_{ij}\}_{j \in N}, \{M_{im}\}_{m \in M}\right)$
- imported goods M_m, $m \in M$

A set F that comprises various factors of production, each factor labeled as f

- Representative Household: consumes N and M, owns F
- Firms: produce N, use N, M, F as inputs
- Equilibrium

Market Clearing and Nominal Anchor

$$Q_i = C_i + X_i + \sum_{j \in N} M_{ji} \quad \text{for each } i \in N.$$

Assume the following cash-in-advance constraint:

$$PC \leq M^u = E.$$

The central bank, with money supply (M^u) as an exogenous factor, dictates nominal spending (E) to maintain a set benchmark.

By monitoring consumption (C) affected by real factors, the central bank can implement any price level (P) accordingly.

▸ More on the Model

Main Proposition

Consider a perturbation $\left(\widehat{\boldsymbol{Z}}, \widehat{\boldsymbol{W}}, \widehat{\boldsymbol{P}}_M\right)$ around some initial equilibrium. Up to a first order, changes in the aggregate price index $\widehat{P}$ satisfy:

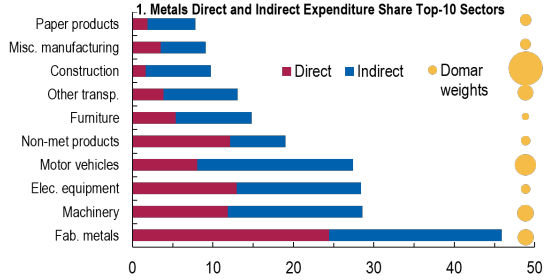
$$\widehat{P} = -\left(\overline{\boldsymbol{\lambda}}^T - \widetilde{\boldsymbol{\lambda}}^T\right)\widehat{\boldsymbol{Z}} + \left(\overline{\boldsymbol{\Lambda}}^T - \widetilde{\boldsymbol{\Lambda}}^T\right)\widehat{\boldsymbol{W}} + \left(\overline{\boldsymbol{b}}_M^T + \widetilde{\boldsymbol{b}}_M^T\right)\widehat{\boldsymbol{P}}_M$$

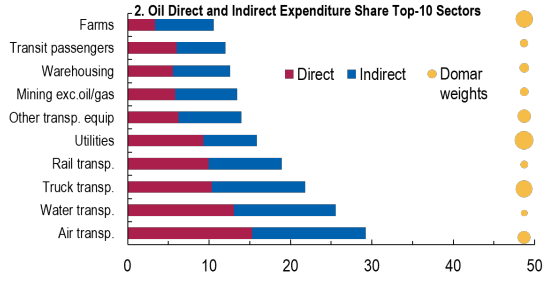
where

$$\widetilde{\boldsymbol{\lambda}}^T = \overline{\boldsymbol{x}}^T\boldsymbol{\Psi}_D; \quad \widetilde{\boldsymbol{\Lambda}}^T = \overline{\boldsymbol{x}}^T\boldsymbol{\Psi}_D\boldsymbol{A}; \quad \widetilde{\boldsymbol{b}}_M^T = \overline{\boldsymbol{b}}_D^T\boldsymbol{\Psi}_D\boldsymbol{\Gamma}$$

with $\overline{\boldsymbol{\lambda}}$ Domar weight, Ψ_D the Leontief inverse, $\overline{b}_D$ domestic consumption shares, Γ vector of imported goods, A factor (labor) spending matrix, $\overline{x}$ vector of exports.

Metals vs Oil Production Network Exposures in US Sectors





Focus on shocks to imported metals prices

Up to a first order, changes in the aggregate price index $\widehat{P}$ satisfy:

$$\widehat{P} = -\left(\overline{\lambda}^T - \widetilde{\lambda}^T\right)\widehat{\boldsymbol{Z}} + \left(\overline{\Lambda}^T - \widetilde{\Lambda}^T\right)\widehat{\boldsymbol{W}} + \left(\overline{\boldsymbol{b}}_M^T + \widetilde{\boldsymbol{b}}_M^T\right)\widehat{\boldsymbol{P}}_M$$

- $\overline{\boldsymbol{b}_M}^T$: consumers purchase metals directly (small)
- $\overline{\boldsymbol{b}_D}^T \boldsymbol{\Psi}_D \boldsymbol{\Gamma}$: consumers purchase metals indirectly by purchasing domestic goods that directly or indirectly use metals as inputs

Intuition: $\uparrow$ metals prices $\Rightarrow \uparrow$ producer h's costs via $\Gamma_{hM} \Rightarrow \uparrow p_h$
indirectly $\uparrow$ prices for other goods via $\Psi_D \Rightarrow \uparrow$ CPI via b_D^T

Data

- Use 2018 OECD 45 sectors' input-output data (including sectoral imports) to calculate country i's exposures
- Define metals = non-energy mining + basic metals (robustness add fabricated metals)
- Define oil = energy mining + coke and refined petroleum products
- Monthly aggregate price indexes (CPI headline and core, PPI) from the World Bank
- Monthly controls: global economic activity index, US 1 year treasury bill yield, bilateral exchange rates, and excess bond premium (EBP).

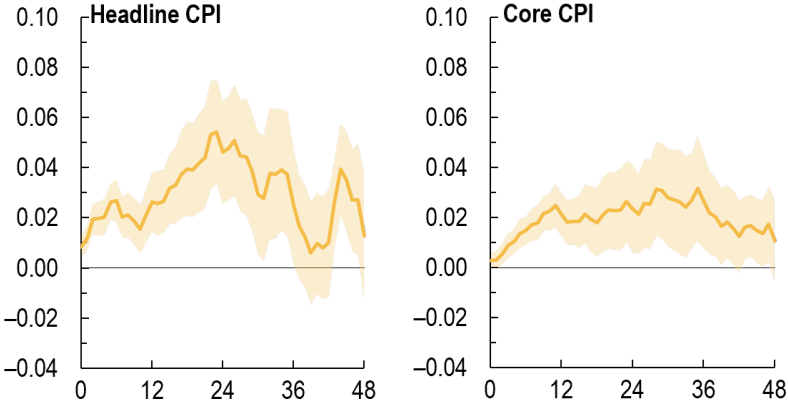
▸ OECD sectors

Panel LP

$$\log CPI_{it+h} - \log CPI_{it-1} = \alpha_i^h + \beta^h p_t^{copper} + \sum_{l=0}^{L} \phi_{xl}^h X_{it-l} + \epsilon_{it+h} \quad \text{for } h = 0, 1, 2, \ldots$$

- Sample: 1996m2 to 2019m12; balanced panel with 39 countries
- p_t^{copper} is the log of real copper price, instrumented by Baumeister et al. (2024) copper supply shock ‣ copper supply shocks
- X_{it-l} includes $L = 12$ lags of real copper price and the log change of CPI, as well as a global economic activity index, US 1 year treasury bill yield, bilateral exchange rates, excess bond premium (EBP). We also include contemporaneous and 12 lags of log of food prices and oil prices.

CPI Responses to a 1% Increase in Copper Prices



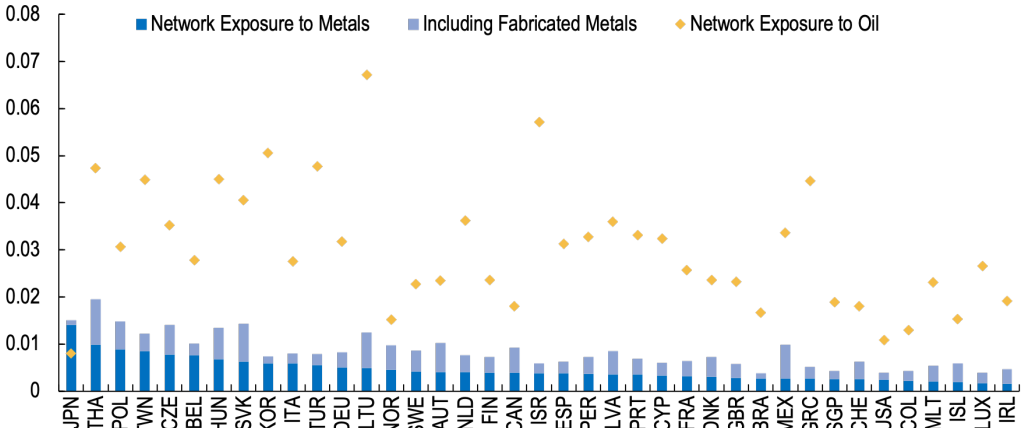
A 1 percent increase in copper prices raises both headline and core inflation by about 0.02 p.p. within 12 months. Responses peak around 2 to 3 years after the shock, reaching 0.05 p.p. for headline and 0.03 p.p. for core.

High Metals Exposure vs Low Metals Exposure

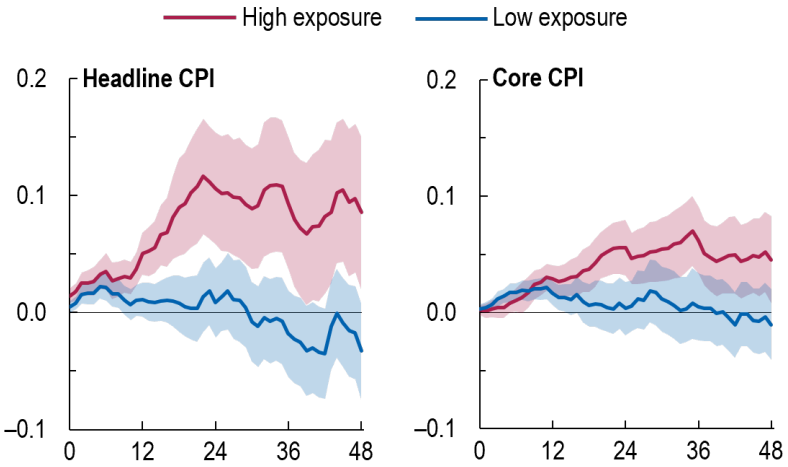
$$\log CPI_{it+h} - \log CPI_{it-1} = \alpha_i^h + \beta_1^h p_t^{copper} + \beta_2^h p_t^{copper}(z_i - \bar{z}) + \sum_{l=0}^{L} \phi_{xl}^h X_{t-l}^i + \epsilon_{it+h}$$

- z_i represents country i's measure of primary metal exposure; $\bar{z}$ is the average exposure across countries
- $\beta_1^h + \beta_2^h(z_i - \bar{z})$ captures the impact of negative copper supply shocks that increase real copper prices
- we evaluate the impacts with z_i at the 90th and 10th percentiles

Imports Exposure to Metals and Oil

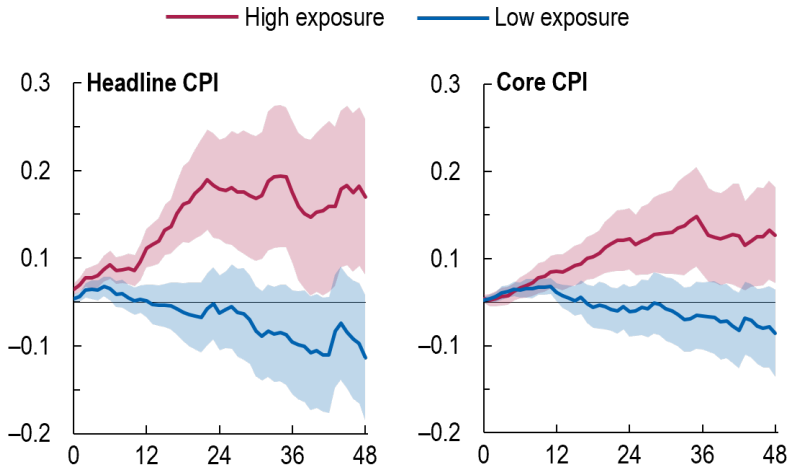


High Metals Exposure vs Low Metals Exposure



A 1 percent increase in copper prices raises both headline and core inflation, in high-exposure countries, by about 0.12 and 0.06 p.p. within 24 months, respectively.

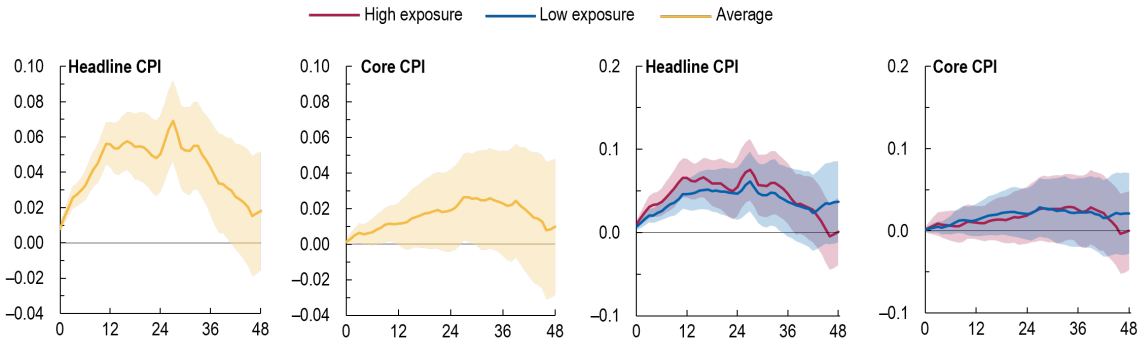
Include Fabricated Metals



The heterogeneity becomes more pronounced and effects become significantly larger

CPI Responses to a 1% Increase in Oil Prices

Use Baumeister and Hamilton (2019) oil supply shocks ▸ oil supply shocks :



Oil prices mainly affect headline inflation. The network does not appear to play a role

Additional Results and Robustness

- Include fabricated metals
- Non-network-adjusted exposure (b_M)
- High vs low net import share
- Base metals index

▸ See Impulse Responses

Conclusions and Next Steps

- Given metals' key role in the production network, metal supply shocks can have significant and persistent impacts on both core and headline inflation.

- Central banks need to prepare for a more metal-intensive global economy, where inflation could become more persistent.
    - However, if these shocks are identified on time, their delay effects play in their favor

Next Steps:

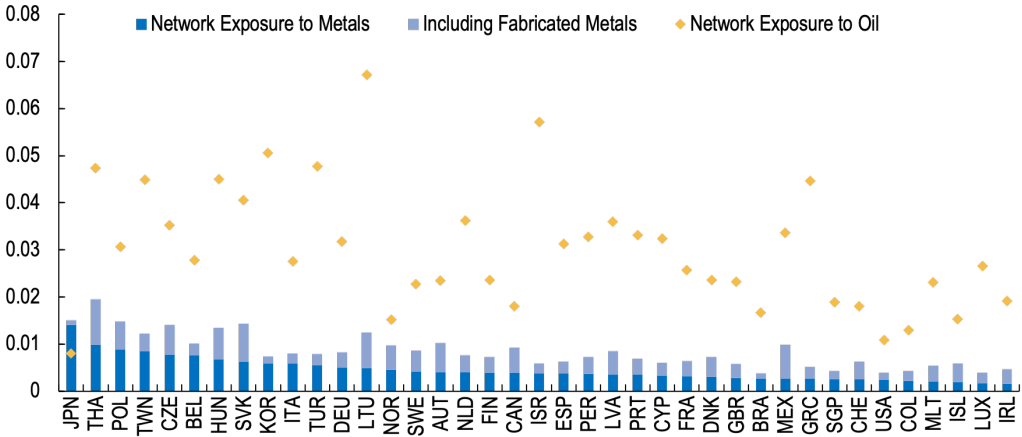
- add investment network – SOE dynamic model with production and investment network
- consider metals exports – demand channel

Thank You!

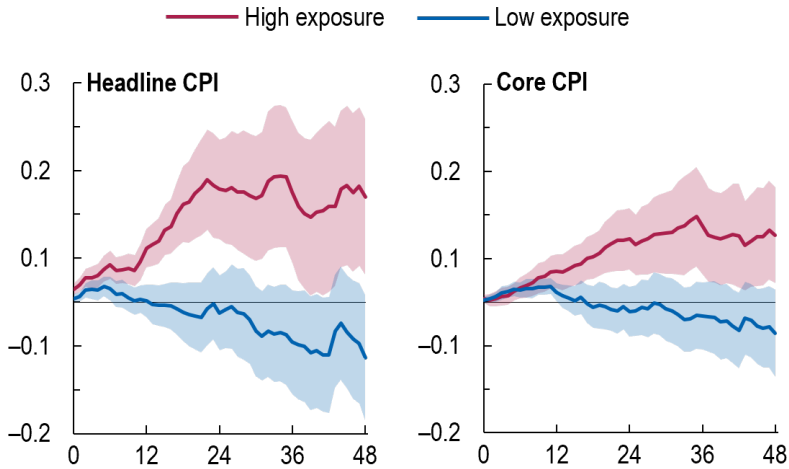
Section 2

Additional Results

Include Fabricated Metals



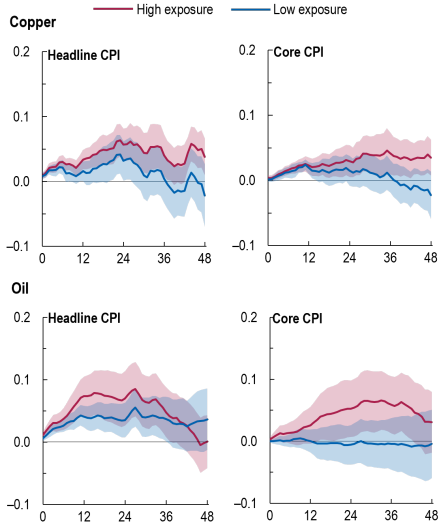
Include Fabricated Metals



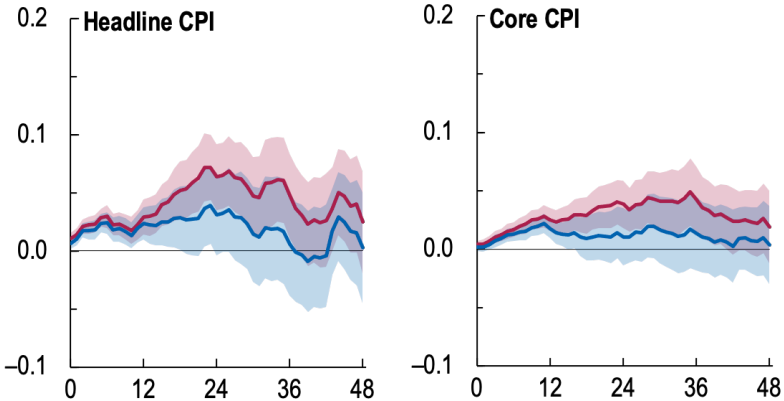
The heterogeneity becomes more pronounced.

Non-network-adjusted exposure

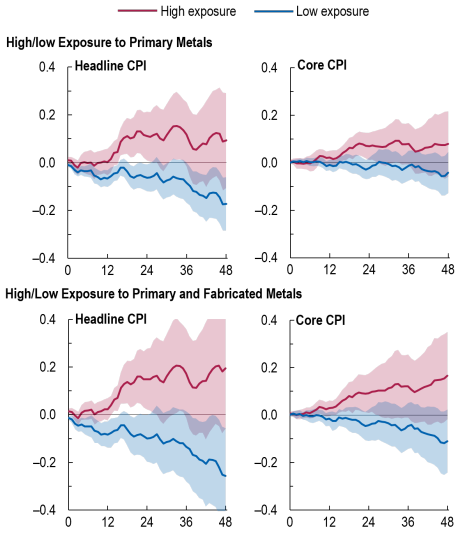
Exposures here are consumption share of imported base copper/oil (b_M)



High/Low Net Import Share



CPI responses to 1% increase in base metal index



Section 3

Silva (2023)

Representative Household

A representative household consumes both domestic goods ($C_N = \{C_i\}_{i \in N}$) and foreign goods ($C_M = \{C_m\}_{m \in M}$), deriving instantaneous utility $U(C_D, C_M)$. This household owns and supplies production factors L_f at fixed prices W_f. It minimize costs given the price vectors of both domestic goods ($P_N = \{P_i\}_{i \in N}$) and foreign goods ($P_M = \{P_m\}_{m \in M}$).

$$PC = \min_{C_D, C_M} \sum_{i \in N} P_i C_i + \sum_{m \in M} P_m C_m$$
$$\text{subject to } U(C_D, C_M) \geq \bar{U}$$

Budget constraint:

$$PC + T = \sum_{f \in F} W_f L_f + \sum_{i \in N} \Pi_i$$

where T is an exogenous net transfer to the rest of the world, Π_i is profits from sector i.

Firms

Within each sector i, there is a representative firm with a production function that exhibits constant returns to scale:

$$Q_i = Z_i F_i \left(\{L_{if}\}_{f \in F}, \{M_{ij}\}_{j \in N}, \{M_{im}\}_{m \in M} \right)$$

where Z_i is sector-specific productivity, L_{if} is the demand for factor f by firm i, M_{ij} represents intermediate input demand for good $j \in N$ by firm i, and M_{im} represents input demand for imported good $m \in M$.

Perfectly competitive markets:

$$P_i Q_i = \sum_{f \in F} W_f L_{if} + \sum_{j \in N} P_j M_{ij} + \sum_{m \in M} P_m M_{im} \quad \text{for all } i \in N$$

Firms choose input demand to minimize cost.

Equilibrium

Domestic market clearance:

$$Q_i = C_i + X_i + \sum_{j \in n} M_{ij}$$

- X_i is exogenous export

Cash-in-advance constraint:

$$PC \leq M = E$$

- M is exogenous money supply

Section 4

Appendix

Responses of commodity prices to supply shocks

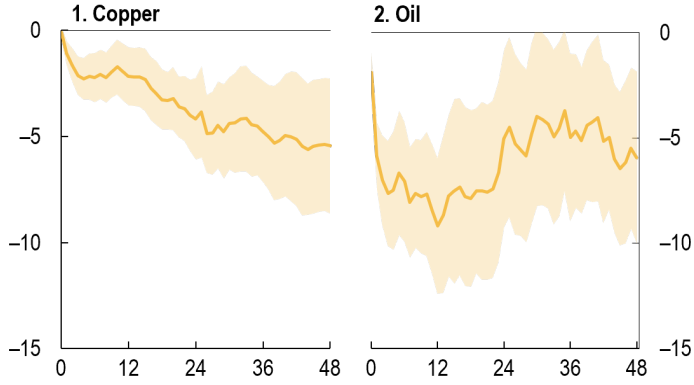


Figure: Impulse responses of real copper (oil) prices to positive copper (oil) supply shocks. Use Baumeister et al. (2024) for copper and Baumeister and Hamilton (2019) for oil.

▸ Back to Empirical Results

BEA Sectoral Classification (Part 1)

Farms	Water transportation
Forestry, fishing, and related activities	Truck transportation
Oil and gas extraction	Transit and ground passenger transportation
Mining except oil and gas	Pipeline transportation
Support activities for mining	Other transportation and support activities
Utilities	Warehousing and storage
Construction	Publishing industries (except internet)
Wood products	Motion picture and sound recording industries
Nonmetallic mineral products	Broadcasting and telecommunications
Primary metals	Data processing, internet publishing, and other information services
Fabricated metal products	Federal Reserve banks, credit intermediation, and related activities
Machinery	Securities, commodity contracts, and investments
Computer and electronic products	Insurance carriers and related activities
Electrical equipment, appliances, and components	Funds, trusts, and other financial vehicles
Motor vehicles, bodies, trailers, and parts	Housing
Other transportation equipment	Other real estate
Furniture and related products	Rental and leasing services, and lessors of intangible assets
Miscellaneous manufacturing	Legal services
Food and beverage and tobacco products	Computer systems design and related services

Back to Main

BEA Sectoral Classification (Part 2)

Textile mills and textile product mills	Miscellaneous professional, scientific, and technical services
Apparel and leather and allied products	Management of companies and enterprises
Paper products	Administrative and support services
Printing and related support activities	Waste management and remediation services
Petroleum and coal products	Educational services
Chemical products	Ambulatory health care services
Plastics and rubber products	Hospitals
Wholesale trade	Nursing and residential care facilities
Motor vehicle and parts dealers	Social assistance
Food and beverage stores	Performing arts, spectator sports, museums, and related activities
General merchandise stores	Amusements, gambling, and recreation industries
Other retail	Accommodation
Air transportation	Food services and drinking places
Rail transportation	Other services except government

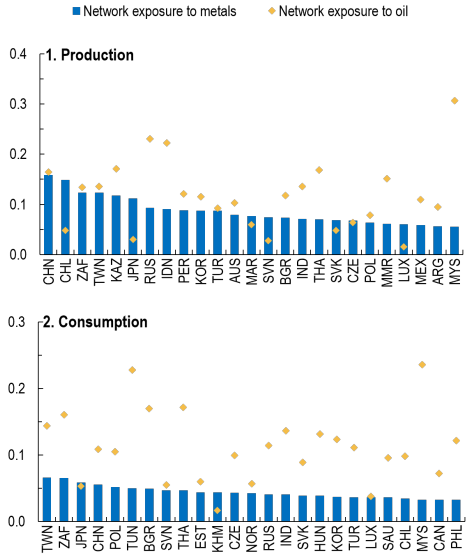
Back to Main

OECD Sectoral Classification

Agriculture, hunting, forestry	Electricity, gas, steam and air conditioning supply
Fishing and aquaculture	Construction
Mining and quarrying, energy producing products	Wholesale and retail trade; repair of motor vehicles
Mining and quarrying, non-energy producing products	Land transport and transport via pipelines
Mining support service activities	Water transport
Food products, beverages and tobacco	Air transport
Textiles, textile products, leather and footwear	Warehousing and support activities for transportation
Wood and products of wood and cork	Postal and courier activities
Paper products and printing	Accommodation and food service activities
Coke and refined petroleum products	Publishing, audiovisual and broadcasting activities
Chemical and chemical products	Telecommunications
Rubber and plastics products	IT and other information services
Other non-metallic mineral products	Financial and insurance activities
Basic metals	Real estate activities
Fabricated metal products	Professional, scientific and technical activities
Computer, electronic and optical equipment	Administrative and support services
Electrical equipment	Education
Machinery and equipment, nec	Human health and social work activities
Motor vehicles, trailers and semi-trailers	Arts, entertainment and recreation
Other transport equipment	Other service activities
Manufacturing nec; repair and installation of machinery and equipment	Water supply; sewerage, waste management and remediation activities
Pharmaceuticals, medicinal chemical and botanical products	Public administration and defence; compulsory social security

‣ Back to Main

Cross-country evidence (closed economy)



References I

Baumeister, C., F. Ohnsorge, and G. Verduzco-Bustos. 2024. "Evaluating the Role of Demand and Supply Shocks in Copper and Aluminum Price Fluctuations." *Unpublished Manuscript*.

Baumeister, Christiane, and James D Hamilton. 2019. "Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and demand shocks." *American Economic Review* 109 (5): 1873–1910.

Silva, Alvaro. 2023. "Inflation in disaggregated small open economies."Technical report, Mimeo, The University of Maryland.