Beyond the Aggregates: Unpacking Inflation in Small Open Economies

Alvaro Silva

University of Maryland

April 4, 2023

709, University of Maryland

Motivation

- Three motivating facts:

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot
  2. Most Central banks tightened their policy rate across the globe in response plot

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot
  2. Most Central banks tightened their policy rate across the globe in response plot
  3. Economies features a network structure: importance of sectoral view of the economy plot

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot
  2. Most Central banks tightened their policy rate across the globe in response plot
  3. Economies features a network structure: importance of sectoral view of the economy plot
- Supply versus demand shocks (aggregate and sectoral) in current inflationary environment

  Krugman and Summers debate, Shapiro (2022), Cerrato and Gitti (2023), Ferrante, Graves, and Iacoviello (2023), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022, 2023), Rubbo (2023), Luo and Villar (2023),...

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot
  2. Most Central banks tightened their policy rate across the globe in response plot
  3. Economies features a network structure: importance of sectoral view of the economy plot
- Supply versus demand shocks (aggregate and sectoral) in current inflationary environment

  Krugman and Summers debate, Shapiro (2022), Cerrato and Gitti (2023), Ferrante, Graves, and Iacoviello (2023), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022, 2023), Rubbo (2023), Luo and Villar (2023),...
  - Focused on advanced economies through a closed economy lens...

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot
  2. Most Central banks tightened their policy rate across the globe in response plot
  3. Economies features a network structure: importance of sectoral view of the economy plot
- Supply versus demand shocks (aggregate and sectoral) in current inflationary environment

  Krugman and Summers debate, Shapiro (2022), Cerrato and Gitti (2023), Ferrante, Graves, and Iacoviello (2023), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022, 2023), Rubbo (2023), Luo and Villar (2023),...
  - Focused on advanced economies through a closed economy lens...
  - or role for monetary policy coordination (Bianchi and Coulibaly, 2023; Fornaro and Romei, 2022).

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot
  2. Most Central banks tightened their policy rate across the globe in response plot
  3. Economies features a network structure: importance of sectoral view of the economy plot
- Supply versus demand shocks (aggregate and sectoral) in current inflationary environment

  Krugman and Summers debate, Shapiro (2022), Cerrato and Gitti (2023), Ferrante, Graves, and Iacoviello (2023), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022, 2023), Rubbo (2023), Luo and Villar (2023),...
  - Focused on advanced economies through a closed economy lens...
  - or role for monetary policy coordination (Bianchi and Coulibaly, 2023; Fornaro and Romei, 2022).
- What about inflation in emerging markets and/or small open economies?

Motivation

- Three motivating facts:
  1. Inflation has been on the rise everywhere in the past 2-3 years plot
  2. Most Central banks tightened their policy rate across the globe in response plot
  3. Economies features a network structure: importance of sectoral view of the economy plot
- Supply versus demand shocks (aggregate and sectoral) in current inflationary environment

  Krugman and Summers debate, Shapiro (2022), Cerrato and Gitti (2023), Ferrante, Graves, and Iacoviello (2023), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022, 2023), Rubbo (2023), Luo and Villar (2023),...
  - Focused on advanced economies through a closed economy lens...
  - or role for monetary policy coordination (Bianchi and Coulibaly, 2023; Fornaro and Romei, 2022).
- What about inflation in emerging markets and/or small open economies?

  $\Longrightarrow$ **This paper!**

Research Questions and Preview of Answers

1. How do supply and demand shocks (aggregate–sectoral– external) affect inflation in small open economies with *realistic* production networks?

2. Is this different from closed economies?

3. How important is this difference in the data?

4. What can Central Banks do?

Research Questions and Preview of Answers

1. How do supply and demand shocks (aggregate–sectoral– external) affect inflation in small open economies with *realistic* production networks?
   - Provide a general framework and a non-parametric inflation "decomposition": *ex-post* sufficient statistics.
2. Is this different from closed economies?
3. How important is this difference in the data?
4. What can Central Banks do?

Research Questions and Preview of Answers

1. How do supply and demand shocks (aggregate–sectoral– external) affect inflation in small open economies with *realistic* production networks?
   - Provide a general framework and a non-parametric inflation "decomposition": *ex-post* sufficient statistics.
2. Is this different from closed economies?
   - Yes: closed economy sufficient statistics are no longer valid.
3. How important is this difference in the data?

4. What can Central Banks do?

Research Questions and Preview of Answers

1. How do supply and demand shocks (aggregate–sectoral– external) affect inflation in small open economies with *realistic* production networks?
   * Provide a general framework and a non-parametric inflation "decomposition": *ex-post* sufficient statistics.
2. Is this different from closed economies?
   * Yes: closed economy sufficient statistics are no longer valid.
3. How important is this difference in the data?
   * Quantitatively important.
4. What can Central Banks do?

Research Questions and Preview of Answers

1. How do supply and demand shocks (aggregate–sectoral– external) affect inflation in small open economies with *realistic* production networks?
   * Provide a general framework and a non-parametric inflation "decomposition": *ex-post* sufficient statistics.
2. Is this different from closed economies?
   * Yes: closed economy sufficient statistics are no longer valid.
3. How important is this difference in the data?
   * Quantitatively important.
4. What can Central Banks do?
   * Work in progress... but will show some preliminary thoughts

Intuition

1. To a first-order

$$
\begin{aligned}
\text{Inflation} = &\ \text{weighted aggregate demand changes} \\
&- \text{weighted average of sectoral productivity changes} \\
&- \text{weighted average of factor supply changes} \\
&+ \text{weighted average of factor demand reallocation} \\
&+ \text{weighted average of import price changes}
\end{aligned}
$$

Intuition

1. To a first-order

$$
\begin{aligned}
\text{Inflation} = {} & \text{weighted aggregate demand changes} \\
& - \text{weighted average of sectoral productivity changes} \\
& - \text{weighted average of factor supply changes} \\
& + \text{weighted average of factor demand reallocation} \\
& + \text{weighted average of import price changes}
\end{aligned}
$$

2. **Opening up** the economy and **production network** changes relevant weights.

Intuition

1. To a first-order

$$
\begin{aligned}
\text{Inflation} = {} & \text{weighted aggregate demand changes} \\
& - \text{weighted average of sectoral productivity changes} \\
& - \text{weighted average of factor supply changes} \\
& + \text{weighted average of factor demand reallocation} \\
& + \text{weighted average of import price changes}
\end{aligned}
$$

2. **Opening up** the economy and **production network** changes relevant weights.
3. Production network **matters** beyond sales to GDP ratios (Domar weights) and factor payments to GDP (factor shares).

Related Literature

1. Inflation in *closed economies* with production networks, sectoral and/or aggregate shocks

   Pasten, Schoenle, and Webber (2020), Guerrieri, Lorenzoni, Straub, and Werning (2021, 2022), Baqaee and Farhi (2022), La'O and Tahbaz-Salehi (2022), Rubbo (2022), Afrouzi and Bhattarai (2022), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022, 2023), Ferrante, Graves, and Iacovello (2023), Luo and Villar (2023),...

   $\Longrightarrow$ I provide a inflation decomposition in a small open economy setup.

Related Literature

1. Inflation in *closed economies* with production networks, sectoral and/or aggregate shocks

   Pasten, Schoenle, and Webber (2020), Guerrieri, Lorenzoni, Straub, and Werning (2021, 2022), Baqaee and Farhi (2022), La'O and Tahbaz-Salehi (2022), Rubbo (2022), Afrouzi and Bhattarai (2022), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022, 2023), Ferrante, Graves, and Iacovello (2023), Luo and Villar (2023),...

   $\Longrightarrow$ I provide a inflation decomposition in a small open economy setup.

2. Inflation in *open economies* with sectoral and/or aggregate shocks

   Gali and Monacelli (2005), Comin and Johnson (2020), Fornaro and Romei (2022), Ho, Sarte, and Schwartzmann (2022), di Giovanni, Kalemli-Özcan, Silva, and Yıldırım (2022)

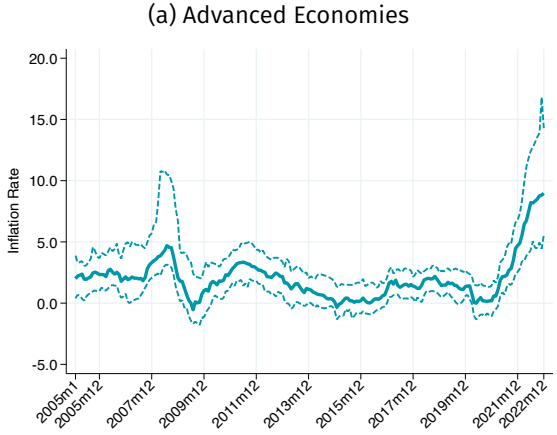
   $\Longrightarrow$ Embed realistic production network.

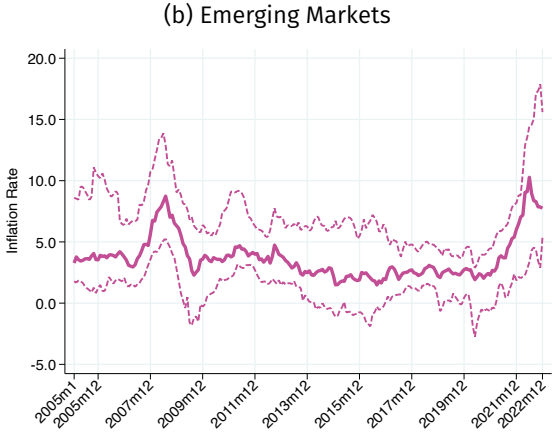
Outline

1. Stylized Facts
2. Non-Parametric Model
3. Inflation “Decomposition"
4. Data
5. Next Steps

Stylized Facts

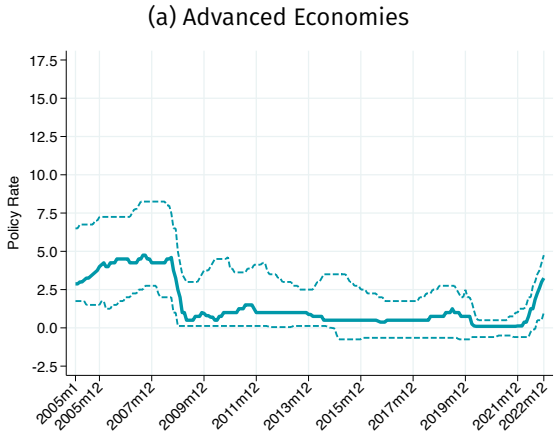
Fact 1: Inflation strikes back

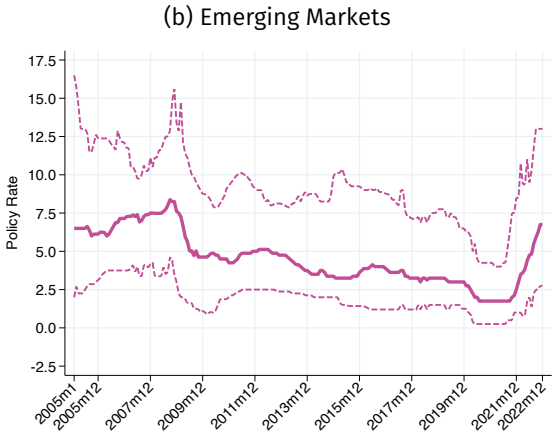




Note: Consumer Price Index year-on-year change. Dashed Lines: 90-10 percentile bands. Source: Bank for International Settlements. 35 AE, 22 Emerging Markets.

Fact 2: Median Central Bank hiked

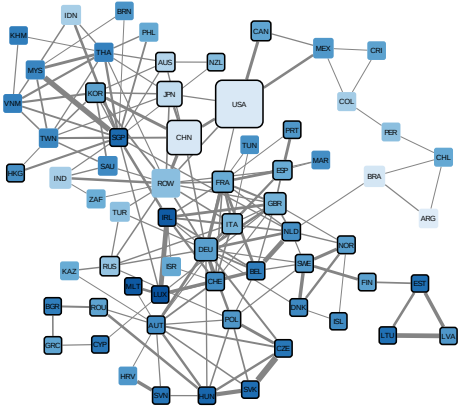




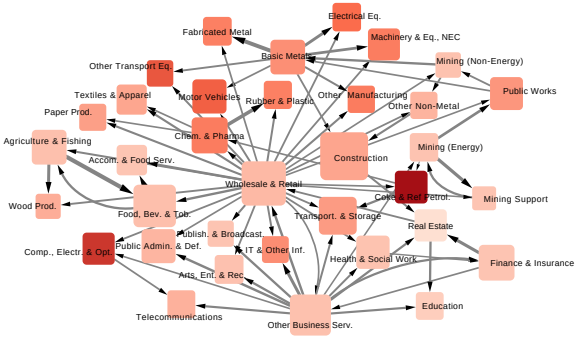
Note: Monetary policy rates. Dashed Lines: 90-10 percentile bands. Source: Bank for International Settlements.

Fact 3: Economies are networks!

(a) International Production Network



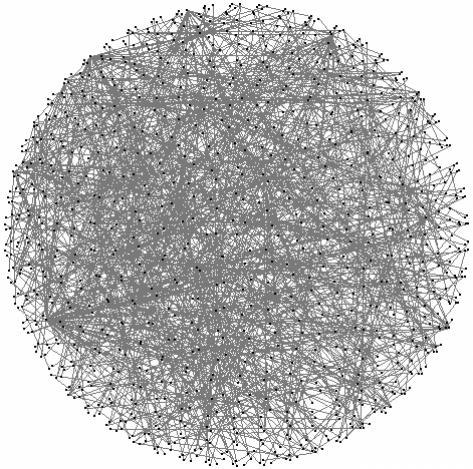
(b) Sectoral Production Network



Source: Cakmakli, Demiralp, Kalemli-Özcan, Yeşiltaş, and Yıldırım (2022) based on OECD Input-Output Tables 2018.

Fact 3: Economies are networks!

(c) Chile's Firm-to-Firm Level Production Network

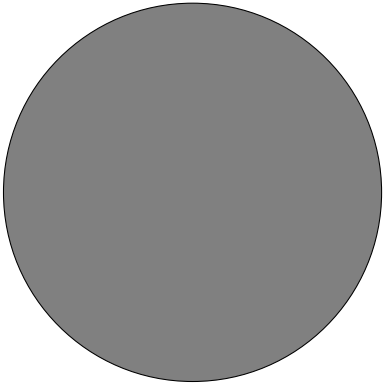


Note: Chilean firm-to-firm level network 2019Q4: 2000 firms random sample, intermediate input sales represents at least 10% of client's total intermediate input purchases.

Source: Miranda-Pinto, Silva, and Young (2023).

Fact 3: Economies are networks!

(c) Chile's Firm-to-Firm Level Production Network



Note: Chilean firm-to-firm level network 2019Q4.

Model

Non-Parametric Model of a Small Open Economy with Production Networks

- Static setup
- Many domestic goods ($i \in N$), multiple factors ($f \in F$) and imported goods ($m \in M$)
- Perfectly competitive goods and factor markets

Household

- Representative household with homothetic preferences

$$U(\{C_i^D\}_{i\in N}, \{C_m^M\}_{m\in M})$$

- Budget constraint

$$\underbrace{\sum_{i\in N} P_i^D C_i^D + \sum_{m\in M} P_m^M C_m^M}_{\equiv E} + T \leq \underbrace{\sum_{f\in F} W_f L_f + \sum_{i\in N} \Pi_i}_{\equiv nGDP}$$

T: net transfer to the rest of the world.

- Cash-in-advance constraint

$$\sum_{i\in N} P_i^D C_i^D + \sum_{m\in M} P_m^M C_m^M \leq \mathcal{M}$$

$\mathcal{M}$: money supply.

Firms

- Representative firm in each domestic sector $i \in N$ with constant returns to scale production function

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

  Note: i is buyer (user), j is supplier (seller).

- Given $(\boldsymbol{W}, \boldsymbol{P}_M, \boldsymbol{P}_D)$ and production function, firms solve

$$\min_{\{L_{if}\}_{f \in F}, \{M^D_{ij}\}_{j \in N}, \{M^M_{ij}\}_{m \in M}} \sum_{f \in F} W_f L_{if} + \sum_{j \in N} P^D_j M^D_{ij} + \sum_{m \in M} P^M_m M^M_{im}$$

$$\text{subject to} \quad Z_i F_i(\{L_{if}\}_{f \in F}, \{M^D_{ij}\}_{j \in N}, \{M^M_{im}\}_{m \in M}) \geq \bar{Q}_i$$

Market Clearing

- Factor markets clear

$$\bar{L}_f = \sum_{i \in N} L_{if} \quad f \in F$$

- Goods markets clear

$$Q_i = C_i^D + X_i + \sum_{j \in N} M_{ji}^D \quad i \in N$$

- Aggregate resource constraint

$$\sum_{i \in N} P_i^D X_i - \sum_{m \in M} P_m^M (C_m + \sum_{i \in N} M_{im}) = T$$

Equilibrium Detailed

- Households maximize utility subject to budget and cash-in-advance constraint.
- Firms minimize costs.
- Goods and factor market clears.

Price changes

- Consider changes $(\mathrm{d}\log \boldsymbol{W}, \mathrm{d}\log \boldsymbol{Z}, \mathrm{d}\log \boldsymbol{P}_M)$

Price changes

- Consider changes ($\mathrm{d}\log \boldsymbol{W}, \mathrm{d}\log \boldsymbol{Z}, \mathrm{d}\log \boldsymbol{P}_M$)
- Changes in domestic prices (to a first-order)

$$\mathrm{d}\log P_i^D = -\mathrm{d}\log Z_i + \sum_{f\in F} \underbrace{\frac{W_f L_{if}}{P_i^D Q_i}}_{\equiv a_{if}} \mathrm{d}\log W_f + \sum_{j\in N} \underbrace{\frac{P_j^D M_{ij}}{P_i^D Q_i}}_{\equiv \Omega_{ij}} \mathrm{d}\log P_j^D + \sum_{m\in M} \underbrace{\frac{P_m^M M_{im}}{P_i^D Q_i}}_{\equiv \Gamma_{im}} \mathrm{d}\log P_m^M \tag{1}$$

Price changes

- Consider changes ($\mathrm{d}\log \boldsymbol{W}, \mathrm{d}\log \boldsymbol{Z}, \mathrm{d}\log \boldsymbol{P}_M$)
- Changes in domestic prices (to a first-order)

$$\mathrm{d}\log P_i^D = -\mathrm{d}\log Z_i + \sum_{f\in F} \underbrace{\frac{W_f L_{if}}{P_i^D Q_i}}_{\equiv a_{if}} \mathrm{d}\log W_f + \sum_{j\in N} \underbrace{\frac{P_j^D M_{ij}}{P_i^D Q_i}}_{\equiv \Omega_{ij}} \mathrm{d}\log P_j^D + \sum_{m\in M} \underbrace{\frac{P_m^M M_{im}}{P_i^D Q_i}}_{\equiv \Gamma_{im}} \mathrm{d}\log P_m^M \tag{1}$$

- "Leontieff-Inverse" $\boldsymbol{\Psi} = (\boldsymbol{I} - \boldsymbol{\Omega})^{-1} = \sum_{s=0}^{\infty} \boldsymbol{\Omega}^s$: direct and indirect production network linkages across producers intuition det

Price changes

- Consider changes $(\mathrm{d}\log \boldsymbol{W}, \mathrm{d}\log \boldsymbol{Z}, \mathrm{d}\log \boldsymbol{P}_M)$
- Changes in domestic prices (to a first-order)

$$\mathrm{d}\log P_i^D = -\mathrm{d}\log Z_i + \sum_{f\in F} \underbrace{\frac{W_f L_{if}}{P_i^D Q_i}}_{\equiv a_{if}} \mathrm{d}\log W_f + \sum_{j\in N} \underbrace{\frac{P_j^D M_{ij}}{P_i^D Q_i}}_{\equiv \Omega_{ij}} \mathrm{d}\log P_j^D + \sum_{m\in M} \underbrace{\frac{P_m^M M_{im}}{P_i^D Q_i}}_{\equiv \Gamma_{im}} \mathrm{d}\log P_m^M \tag{1}$$

- "Leontieff-Inverse" $\boldsymbol{\Psi} = (\boldsymbol{I} - \boldsymbol{\Omega})^{-1} = \sum_{s=0}^{\infty} \boldsymbol{\Omega}^s$: direct and indirect production network linkages across producers intuition
- Domestic price changes

$$\mathrm{d}\log \boldsymbol{P}_D = -\boldsymbol{\Psi}\mathrm{d}\log \boldsymbol{Z} + \boldsymbol{\Psi}\boldsymbol{A}\mathrm{d}\log \boldsymbol{W} + \boldsymbol{\Psi}\boldsymbol{\Gamma}\mathrm{d}\log \boldsymbol{P}_M \tag{2}$$

Consumer Price Index Changes

- Changes in CPI

$$\mathrm{d}\log CPI = \sum_{i \in N} \frac{P_i^D C_i^D}{E} \mathrm{d}\log P_i^D + \sum_{m \in M} \frac{P_m^M C_m^M}{E} \mathrm{d}\log P_m^M \tag{3}$$

Consumer Price Index Changes

- Changes in CPI

$$\mathrm{d}\log CPI = \sum_{i \in N} \frac{P_i^D C_i^D}{E} \mathrm{d}\log P_i^D + \sum_{m \in M} \frac{P_m^M C_m^M}{E} \mathrm{d}\log P_m^M \tag{3}$$

- Then

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left(-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right)$$

Consumer Price Index Changes

- Changes in CPI

$$\mathrm{d}\log CPI = \sum_{i\in N} \frac{P_i^D C_i^D}{E} \mathrm{d}\log P_i^D + \sum_{m\in M} \frac{P_m^M C_m^M}{E} \mathrm{d}\log P_m^M \tag{3}$$

- Then

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left(-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right)$$

  - Where

$$\lambda_i = \frac{P_i^D Q_i}{nGDP}; \quad b_i = \frac{P_i^D C_i}{nGDP}; \quad b_m^M = \frac{P_m^M C_m}{nGDP}; \quad x_i = \frac{P_i^D X_i}{nGDP}; \quad E + T = nGDP; \quad \Lambda_f = \frac{W_f \bar{L}_f}{nGDP}$$

Consumer Price Index Changes

- Changes in CPI

$$\mathrm{d}\log CPI = \sum_{i\in N} \frac{P_i^D C_i^D}{E} \mathrm{d}\log P_i^D + \sum_{m\in M} \frac{P_m^M C_m^M}{E} \mathrm{d}\log P_m^M \tag{3}$$

- Then

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left(-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right)$$

  - Where

$$\lambda_i = \frac{P_i^D Q_i}{nGDP}; \quad b_i = \frac{P_i^D C_i}{nGDP}; \quad b_m^M = \frac{P_m^M C_m}{nGDP}; \quad x_i = \frac{P_i^D X_i}{nGDP}; \quad E + T = nGDP; \quad \Lambda_f = \frac{W_f \bar{L}_f}{nGDP}$$

- Compared with closed economy counterpart (Baqaee and Farhi,2022)

$$\mathrm{d}\log CPI = -\boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} + \boldsymbol{\Lambda}^T \mathrm{d}\log \boldsymbol{W}$$

Consumer Price Index Changes

- Changes in CPI

$$\mathrm{d}\log CPI = \sum_{i\in N} \frac{P_i^D C_i^D}{E} \mathrm{d}\log P_i^D + \sum_{m\in M} \frac{P_m^M C_m^M}{E} \mathrm{d}\log P_m^M \tag{3}$$

- Then

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left(-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right)$$

  - Where

$$\lambda_i = \frac{P_i^D Q_i}{nGDP};\quad b_i = \frac{P_i^D C_i}{nGDP};\quad b_m^M = \frac{P_m^M C_m}{nGDP};\quad x_i = \frac{P_i^D X_i}{nGDP};\quad E + T = nGDP;\quad \Lambda_f = \frac{W_f \bar{L}_f}{nGDP}$$

- Compared with closed economy counterpart (Baqaee and Farhi,2022)

$$\mathrm{d}\log CPI = -\boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} + \boldsymbol{\Lambda}^T \mathrm{d}\log \boldsymbol{W}$$

- **Open economy coupled with production networks changed the weights!**

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right]$$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right]$$

- Break relationship between what is produced ($nGDP$) and what is consumed (E): $E \neq nGDP$

$$E = nGDP - T \Longrightarrow \uparrow T, \downarrow E \quad \text{given } nGDP$$

- Net exporter: lower E. Net importer: higher E.

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right]$$

- Role of **production network** goes beyond usual sufficient statistics in closed economies with production networks.
  - Knowledge of domar weights ($\boldsymbol{\lambda}$), factor shares ($\boldsymbol{\Lambda}$), and direct import consumption shares ($\boldsymbol{b}^M$) is **not enough**.

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z}\right]$$

- What is key for CPI is what consumer ends up consuming either directly or indirectly:
  $\Longrightarrow$ all about market clearing conditions! intuition

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z}\right]$$

- What is key for CPI is what consumer ends up consuming either directly or indirectly:
  $\Longrightarrow$ all about market clearing conditions! intuition

$$Q_i = C_i \Longrightarrow \qquad \boldsymbol{\lambda}^T = \boldsymbol{b}^T \qquad \text{(Closed economy without production networks)}$$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z}\right]$$

- What is key for CPI is what consumer ends up consuming either directly or indirectly:
  $\Longrightarrow$ all about market clearing conditions! intuition

$$Q_i = C_i \Longrightarrow \qquad \boldsymbol{\lambda}^T = \boldsymbol{b}^T \qquad \text{(Closed economy without production networks)}$$

$$Q_i - \sum_{j\in N} M_{ji} = C_i \Longrightarrow \qquad \boldsymbol{\lambda}^T = \boldsymbol{b}^T\boldsymbol{\Psi} \qquad \text{(Closed economy with production networks)}$$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z}\right]$$

- What is key for CPI is what consumer ends up consuming either directly or indirectly:
  $\Longrightarrow$ all about market clearing conditions! intuition

$$Q_i = C_i \Longrightarrow \quad \boldsymbol{\lambda}^T = \boldsymbol{b}^T \quad \text{(Closed economy without production networks)}$$

$$Q_i - \sum_{j\in N} M_{ji} = C_i \Longrightarrow \quad \boldsymbol{\lambda}^T = \boldsymbol{b}^T\boldsymbol{\Psi} \quad \text{(Closed economy with production networks)}$$

$$Q_i - X_i = C_i \Longrightarrow \quad \boldsymbol{\lambda}^T - \boldsymbol{x}^T = \boldsymbol{b}^T \quad \text{(Small open economy w/o prod. networks)}$$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[-\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\right)\mathrm{d}\log \boldsymbol{Z}\right]$$

- What is key for CPI is what consumer ends up consuming either directly or indirectly:
  $\Longrightarrow$ all about market clearing conditions! intuition det

$$Q_i = C_i \Longrightarrow \quad \boldsymbol{\lambda}^T = \boldsymbol{b}^T \quad \text{(Closed economy without production networks)}$$

$$Q_i - \sum_{j\in N} M_{ji} = C_i \Longrightarrow \quad \boldsymbol{\lambda}^T = \boldsymbol{b}^T\boldsymbol{\Psi} \quad \text{(Closed economy with production networks)}$$

$$Q_i - X_i = C_i \Longrightarrow \quad \boldsymbol{\lambda}^T - \boldsymbol{x}^T = \boldsymbol{b}^T \quad \text{(Small open economy w/o prod. networks)}$$

$$Q_i - X_i - \sum_{j\in N} M_{ji} = C_i \Longrightarrow \quad \boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi} = \boldsymbol{b}^T\boldsymbol{\Psi} \quad \text{(Small open economy with prod. networks)}$$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W}\right]$$

- In general,

$$\Lambda_f = \frac{\sum_{i\in N} W_f L_{if}}{nGDP} = \sum_{i\in N} \frac{W_f L_{if}}{P_i^D Q_i}\frac{P_i^D Q_i}{nGDP} = \sum_{i\in N} a_{if}\lambda_i \Longrightarrow \boldsymbol{\Lambda}^T = \boldsymbol{\lambda}^T\boldsymbol{A}$$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left(\mathbf{\Lambda}^T - \boldsymbol{x}^T\Psi\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W}\right]$$

- In general,

$$\Lambda_f = \frac{\sum_{i\in N} W_f L_{if}}{nGDP} = \sum_{i\in N}\frac{W_f L_{if}}{P_i^D Q_i}\frac{P_i^D Q_i}{nGDP} = \sum_{i\in N} a_{if}\lambda_i \Longrightarrow \mathbf{\Lambda}^T = \boldsymbol{\lambda}^T\boldsymbol{A}$$

Closed economy without production networks : $\mathbf{\Lambda}^T = \boldsymbol{b}^T\boldsymbol{A}$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W}\right]$$

- In general,

$$\Lambda_f = \frac{\sum_{i\in N} W_f L_{if}}{nGDP} = \sum_{i\in N}\frac{W_f L_{if}}{P_i^D Q_i}\frac{P_i^D Q_i}{nGDP} = \sum_{i\in N} a_{if}\lambda_i \Longrightarrow \boldsymbol{\Lambda}^T = \boldsymbol{\lambda}^T\boldsymbol{A}$$

Closed economy without production networks : $\boldsymbol{\Lambda}^T = \boldsymbol{b}^T\boldsymbol{A}$

Closed economy with production networks : $\boldsymbol{\Lambda}^T = \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{A}$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W}\right]$$

- In general,

$$\Lambda_f = \frac{\sum_{i\in N} W_f L_{if}}{nGDP} = \sum_{i\in N}\frac{W_f L_{if}}{P_i^D Q_i}\frac{P_i^D Q_i}{nGDP} = \sum_{i\in N} a_{if}\lambda_i \Longrightarrow \boldsymbol{\Lambda}^T = \boldsymbol{\lambda}^T\boldsymbol{A}$$

Closed economy without production networks : $\boldsymbol{\Lambda}^T = \boldsymbol{b}^T\boldsymbol{A}$

Closed economy with production networks : $\boldsymbol{\Lambda}^T = \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{A}$

Small open economy without production networks : $\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{A} = \boldsymbol{b}^T\boldsymbol{A}$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left(\Lambda^T - \boldsymbol{x}^T\Psi\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W}\right]$$

- In general,

$$\Lambda_f = \frac{\sum_{i\in N} W_f L_{if}}{nGDP} = \sum_{i\in N}\frac{W_f L_{if}}{P_i^D Q_i}\frac{P_i^D Q_i}{nGDP} = \sum_{i\in N} a_{if}\lambda_i \Longrightarrow \Lambda^T = \boldsymbol{\lambda}^T\boldsymbol{A}$$

Closed economy without production networks :	$\Lambda^T = \boldsymbol{b}^T\boldsymbol{A}$
Closed economy with production networks :	$\Lambda^T = \boldsymbol{b}^T\Psi\boldsymbol{A}$
Small open economy without production networks :	$\Lambda^T - \boldsymbol{x}^T\boldsymbol{A} = \boldsymbol{b}^T\boldsymbol{A}$
Small open economy with production networks :	$\Lambda^T - \boldsymbol{x}^T\Psi\boldsymbol{A} = \boldsymbol{b}^T\Psi\boldsymbol{A}$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A}\right)\mathrm{d}\log \boldsymbol{W}\right]$$

- In general,

$$\Lambda_f = \frac{\sum_{i\in N} W_f L_{if}}{nGDP} = \sum_{i\in N}\frac{W_f L_{if}}{P_i^D Q_i}\frac{P_i^D Q_i}{nGDP} = \sum_{i\in N} a_{if}\lambda_i \Longrightarrow \boldsymbol{\Lambda}^T = \boldsymbol{\lambda}^T\boldsymbol{A}$$

Closed economy without production networks :	$\boldsymbol{\Lambda}^T = \boldsymbol{b}^T\boldsymbol{A}$
Closed economy with production networks :	$\boldsymbol{\Lambda}^T = \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{A}$
Small open economy without production networks :	$\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{A} = \boldsymbol{b}^T\boldsymbol{A}$
Small open economy with production networks :	$\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}\boldsymbol{A} = \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{A}$

- Factor content of exports augmented: economy is effectively sending its factors away via exports ($\boldsymbol{x}$) and production networks ($\boldsymbol{\Psi}$).

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right]$$

- Direct import consumption share, $\boldsymbol{b}^M$, not a sufficient statistics for effect of import prices on CPI!

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right]$$

- Direct import consumption share, $\boldsymbol{b}^M$, not a sufficient statistics for effect of import prices on CPI!
  - Part of domestic prices depend directly and indirectly on import prices: import content of domestic goods!

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right]$$

- Direct import consumption share, $\boldsymbol{b}^M$, not a sufficient statistics for effect of import prices on CPI!
  - Part of domestic prices depend directly and indirectly on import prices: import content of domestic goods!
  - Ignoring productivity ($\mathrm{d}\log \boldsymbol{Z} = \mathbf{o}_N$) and factor price changes ($\mathrm{d}\log \boldsymbol{W} = \mathbf{o}_F$), domestic price changes:

$$\mathrm{d}\log \boldsymbol{P}_D = \boldsymbol{\Psi}\boldsymbol{\Gamma}\mathrm{d}\log \boldsymbol{P}_M \Longrightarrow$$

What's new? Insights from the decomposition

$$\mathrm{d}\log CPI = \frac{nGDP}{E}\left[\left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\mathrm{d}\log \boldsymbol{P}_M\right]$$

- Direct import consumption share, $\boldsymbol{b}^M$, not a sufficient statistics for effect of import prices on CPI!
  - Part of domestic prices depend directly and indirectly on import prices: import content of domestic goods!
  - Ignoring productivity ($\mathrm{d}\log \boldsymbol{Z} = \boldsymbol{0}_N$) and factor price changes ($\mathrm{d}\log \boldsymbol{W} = \boldsymbol{0}_F$), domestic price changes:

$$\mathrm{d}\log \boldsymbol{P}_D = \boldsymbol{\Psi}\boldsymbol{\Gamma}\mathrm{d}\log \boldsymbol{P}_M \Longrightarrow \boldsymbol{b}^T\mathrm{d}\log \boldsymbol{P}_D = \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\mathrm{d}\log \boldsymbol{P}_M$$

Linking CPI changes to sectoral and aggregate component

- Factor prices $\mathrm{d}\log \boldsymbol{W}$ are *endogenous objects*

Linking CPI changes to sectoral and aggregate component

- Factor prices $\mathrm{d}\log \boldsymbol{W}$ are *endogenous objects*
- Key to link CPI changes to demand side of the economy: factor shares!

$$\mathrm{d}\log W_f = \mathrm{d}\log \Lambda_f + \mathrm{d}\log nGDP - \mathrm{d}\log \bar{L}_f$$

Linking CPI changes to sectoral and aggregate component

- Key to link CPI changes to demand side of the economy: factor shares!

$$\mathrm{d}\log W_f = \mathrm{d}\log \Lambda_f + \mathrm{d}\log nGDP - \mathrm{d}\log \bar{L}_f$$

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI =$$

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right)$$

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right)$$

- Dampens aggregate demand and have additional term from trade balance.

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right) - \left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \right) \frac{nGDP}{E} \mathrm{d}\log \boldsymbol{Z}$$

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right) - \left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \right) \frac{nGDP}{E} \mathrm{d}\log \boldsymbol{Z}$$

- Dampens sectoral technology shocks through exports/production network. Ambiguous $nGDP/E$.

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right) - \left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \right) \frac{nGDP}{E} \mathrm{d}\log \boldsymbol{Z} - \frac{nGDP}{E} \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \right) \mathrm{d}\log \bar{\boldsymbol{L}}$$

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right) - \left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \right) \frac{nGDP}{E} \mathrm{d}\log \boldsymbol{Z} - \frac{nGDP}{E} \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \right) \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Dampens factor supply shocks through factor content of exports. Ambiguous $nGDP/E$.

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right) - \left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \right) \frac{nGDP}{E} \mathrm{d}\log \boldsymbol{Z} - \frac{nGDP}{E} \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \right) \mathrm{d}\log \bar{\boldsymbol{L}}$$
$$\left(-\boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathrm{d}\log \boldsymbol{\Lambda} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T \boldsymbol{\Psi} \boldsymbol{\Gamma} \right) \mathrm{d}\log \boldsymbol{P}_M \right) \frac{nGDP}{E}$$

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right) - \left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \right) \frac{nGDP}{E} \mathrm{d}\log \boldsymbol{Z} - \frac{nGDP}{E} \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \right) \mathrm{d}\log \bar{\boldsymbol{L}}$$
$$\left(-\boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathrm{d}\log \boldsymbol{\Lambda} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T \boldsymbol{\Psi} \boldsymbol{\Gamma} \right) \mathrm{d}\log \boldsymbol{P}_M \right) \frac{nGDP}{E}$$

- **New** factor reallocation term that dampens inflation from factor prices and **new** total import exposure.

Linking CPI changes to sectoral and aggregate component

- Closed economy with production networks (Baqaee and Farhi, 2022)

$$\mathrm{d}\log CPI = \mathrm{d}\log \mathcal{M} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{Z} - \boldsymbol{\Lambda}^T \mathrm{d}\log \bar{\boldsymbol{L}}$$

- Small open economy with production networks

$$\mathrm{d}\log CPI = (1 - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathbf{1}_F) \left(\mathrm{d}\log \mathcal{M} + \frac{T}{E} \mathrm{d}\log T \right) - \left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \right) \frac{nGDP}{E} \mathrm{d}\log \boldsymbol{Z} - \frac{nGDP}{E} \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \right) \mathrm{d}\log \bar{\boldsymbol{L}}$$
$$\left(-\boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A} \mathrm{d}\log \boldsymbol{\Lambda} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T \boldsymbol{\Psi} \boldsymbol{\Gamma} \right) \mathrm{d}\log \boldsymbol{P}_M \right) \frac{nGDP}{E}$$

- Bottom line: **network + openness do matter for inflation!**

Data

Data

- Data from the World Input-Output Table Release 2016
  - 56 sectors and 43 countries.
  - Detailed information on intermediate input usage, exports, imports, sales.
  - Domestic Input-Output Tables.

Data

- Data from the World Input-Output Table Release 2016
  - 56 sectors and 43 countries.
  - Detailed information on intermediate input usage, exports, imports, sales.
  - Domestic Input-Output Tables.
- Measures of

Data

- Data from the World Input-Output Table Release 2016
  - 56 sectors and 43 countries.
  - Detailed information on intermediate input usage, exports, imports, sales.
  - Domestic Input-Output Tables.
- Measures of
  - Export shares: $\boldsymbol{x}$
  - Network-Adjusted export shares: $\boldsymbol{x}^T \Psi$
  - Factor content of exports: $\boldsymbol{x}^T \Psi \boldsymbol{A}$

Data

- Data from the World Input-Output Table Release 2016
  - 56 sectors and 43 countries.
  - Detailed information on intermediate input usage, exports, imports, sales.
  - Domestic Input-Output Tables.
- Measures of
  - Export shares: $\boldsymbol{x}$
  - Network-Adjusted export shares: $\boldsymbol{x}^T \boldsymbol{\Psi}$
  - Factor content of exports: $\boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A}$
  - Domar weights: $\boldsymbol{\lambda}$

Data

- Data from the World Input-Output Table Release 2016
  - 56 sectors and 43 countries.
  - Detailed information on intermediate input usage, exports, imports, sales.
  - Domestic Input-Output Tables.
- Measures of
  - Export shares: $\boldsymbol{x}$
  - Network-Adjusted export shares: $\boldsymbol{x}^T \boldsymbol{\Psi}$
  - Factor content of exports: $\boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A}$
  - Domar weights: $\boldsymbol{\lambda}$
  - Direct import consumption shares: b_M

Data

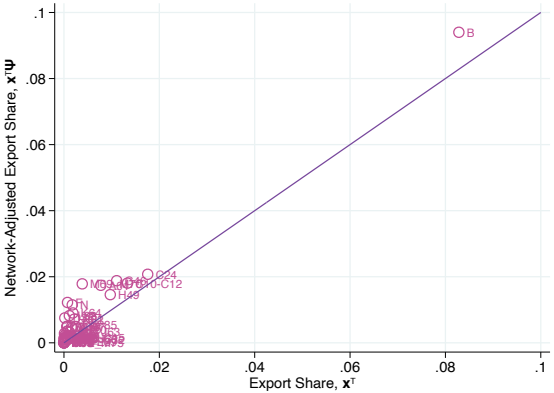
- Data from the World Input-Output Table Release 2016
  - 56 sectors and 43 countries.
  - Detailed information on intermediate input usage, exports, imports, sales.
  - Domestic Input-Output Tables.
- Measures of
  - Export shares: $\boldsymbol{x}$
  - Network-Adjusted export shares: $\boldsymbol{x}^T \boldsymbol{\Psi}$
  - Factor content of exports: $\boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A}$
  - Domar weights: $\boldsymbol{\lambda}$
  - Direct import consumption shares: b_M
  - Import content of domestic goods: $\boldsymbol{b}^T \boldsymbol{\Psi} \boldsymbol{\Gamma}$

Data

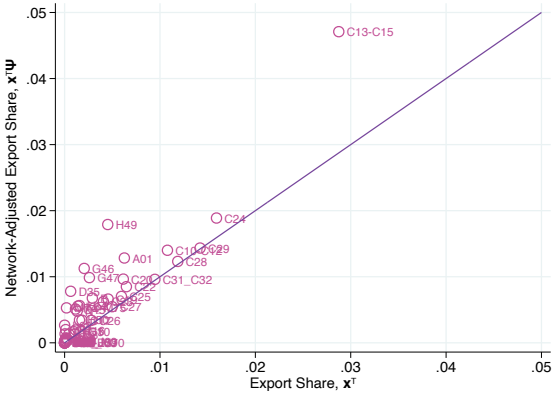
- Data from the World Input-Output Table Release 2016
  - 56 sectors and 43 countries.
  - Detailed information on intermediate input usage, exports, imports, sales.
  - Domestic Input-Output Tables.
- Measures of
  - Export shares: $\boldsymbol{x}$
  - Network-Adjusted export shares: $\boldsymbol{x}^T \boldsymbol{\Psi}$
  - Factor content of exports: $\boldsymbol{x}^T \boldsymbol{\Psi} \boldsymbol{A}$
  - Domar weights: $\boldsymbol{\lambda}$
  - Direct import consumption shares: b_M
  - Import content of domestic goods: $\boldsymbol{b}^T \boldsymbol{\Psi} \boldsymbol{\Gamma}$
- All cross-sectional plots based on year 2014 (last year available).

Export shares (x^T) and network-adjusted export shares ($x^T\Psi$)

(a) Australia



(b) Turkey



- Export adjustment is quantitatively important.

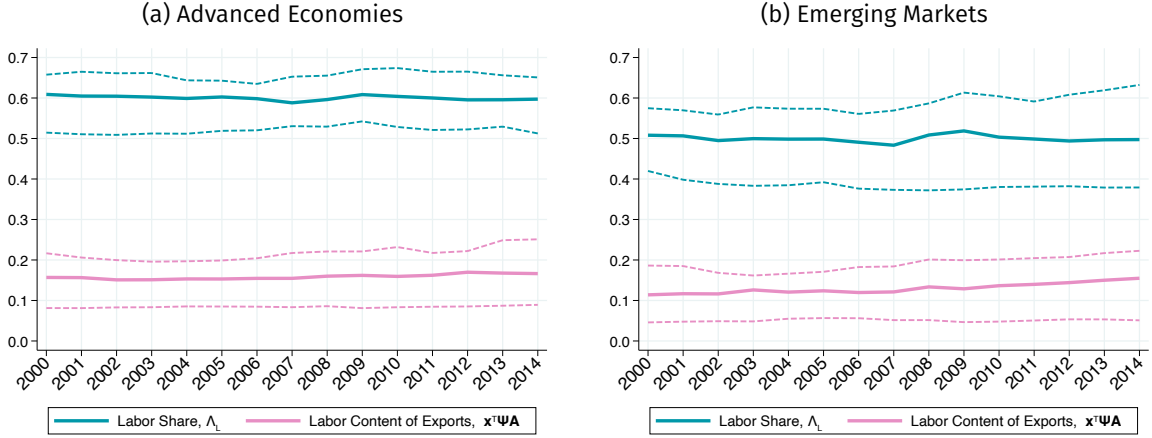
Sectoral Technology Shocks Pass-through: $(\lambda^T - x^T\Psi)\mathrm{d}\log Z$ Class 1 Class 2

(a) Australia

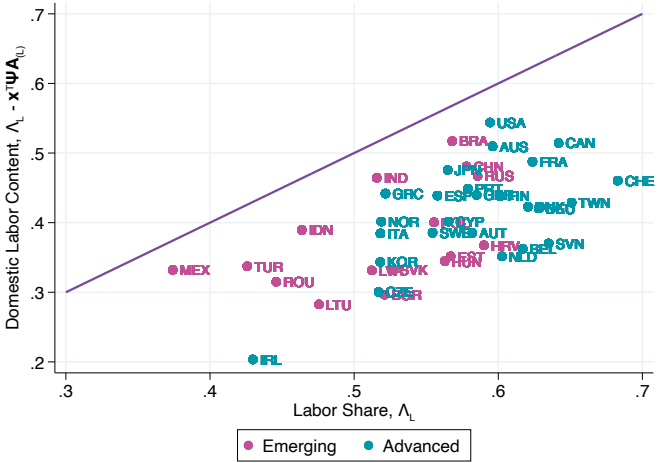
(b) Turkey

- Take textiles (C13-C15) in Turkey:
  - Domar weight = 8.4%, Export share = 2.8% $\Longrightarrow$ Adj. domar weight w/o network = 8.4 - 2.8 = 5.6%
  - Adjusted domar weight with production network: 3.7%!!!

Factor Price Changes Pass-through: $(\Lambda^T - \boldsymbol{x}^T\Psi\boldsymbol{A})\mathrm{d}\log \boldsymbol{W}$



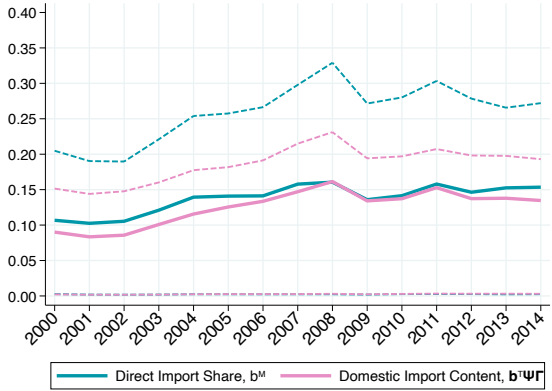
Factor Price Changes Pass-Through: Cross-Country Evidence ($(\Lambda^T - \boldsymbol{x}^T \Psi \boldsymbol{A}) \mathrm{d} \log \boldsymbol{W}$)



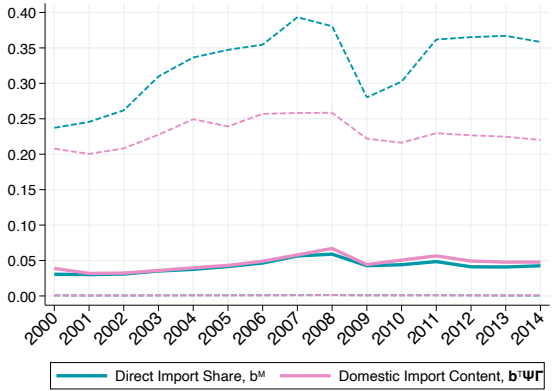
- Adjustment is homogeneous across advanced and emerging markets.

Import Shares: Time Series ($(b_M + \boldsymbol{b}^T \Psi \Gamma) \mathrm{d} \log P_M$)

(a) Advanced Economies

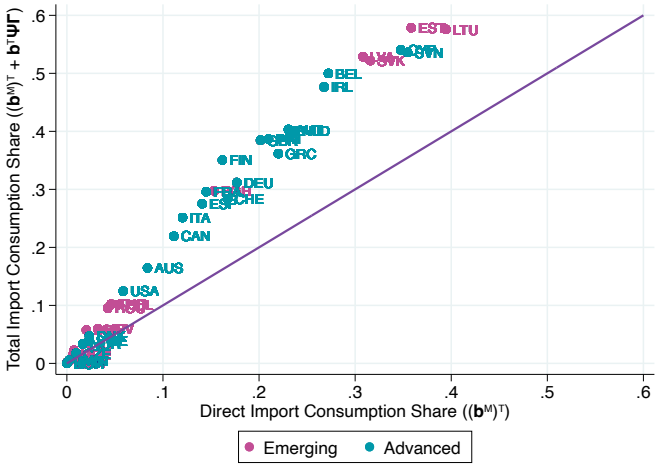


(b) Emerging Markets



- Domestic import content as important as direct import share.

Import Shares: Cross-Country Evidence ($(b_M + \boldsymbol{b}^T \Psi \Gamma) \mathrm{d} \log P_M$)



- Countries with higher direct import consumption share also tend to have a higher total import consumption share.

Taking Stock: Empirics

- Decomposition shows that sufficient statistics for inflation are different in small open economies
- Adjustment seems to quantitatively matter empirically

Taking Stock: Empirics

- Decomposition shows that sufficient statistics for inflation are different in small open economies
- Adjustment seems to quantitatively matter empirically
  - Adjusted domar weights can changes substantially beyond direct exporting: highlight role of production network

Taking Stock: Empirics

- Decomposition shows that sufficient statistics for inflation are different in small open economies
- Adjustment seems to quantitatively matter empirically
  - Adjusted domar weights can changes substantially beyond direct exporting: highlight role of production network
  - Adjusted labor shares decline by around 15 percentage points.

Taking Stock: Empirics

- Decomposition shows that sufficient statistics for inflation are different in small open economies
- Adjustment seems to quantitatively matter empirically
  - Adjusted domar weights can changes substantially beyond direct exporting: highlight role of production network
  - Adjusted labor shares decline by around 15 percentage points.
  - Indirect importing is as important as direct importing for CPI across countries.

Conclusion and Next Steps

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
    - Escaping Hulten's theorem straightjacket.

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   * Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps
   * Clean and improve empirical part

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps
   - Clean and improve empirical part
   - Embed logic into a sectoral price stickiness model a la Rubbo (2023) and La'O and Tahbaz-Salehi (2022)

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps
   - Clean and improve empirical part
   - Embed logic into a sectoral price stickiness model a la Rubbo (2023) and La'O and Tahbaz-Salehi (2022)
     - Works above show central bank should target a reweighted version of Producer Price Inflation (PPI): sticky price version of Leontieff-inverse.

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps
   - Clean and improve empirical part
   - Embed logic into a sectoral price stickiness model a la Rubbo (2023) and La'O and Tahbaz-Salehi (2022)
     - Works above show central bank should target a reweighted version of Producer Price Inflation (PPI): sticky price version of Leontieff-inverse.
     - Open economy has a similar flavor

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps
   - Clean and improve empirical part
   - Embed logic into a sectoral price stickiness model a la Rubbo (2023) and La'O and Tahbaz-Salehi (2022)
     - Works above show central bank should target a reweighted version of Producer Price Inflation (PPI): sticky price version of Leontieff-inverse.
     - Open economy has a similar flavor
     - Gali and Monacelli (2005): Target PPI inflation (no intermediate inputs in production, no sectoral perspective).

Conclusion and Next Steps

1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps
   - Clean and improve empirical part
   - Embed logic into a sectoral price stickiness model a la Rubbo (2023) and La'O and Tahbaz-Salehi (2022)
     - Works above show central bank should target a reweighted version of Producer Price Inflation (PPI): sticky price version of Leontieff-inverse.
     - Open economy has a similar flavor
     - Gali and Monacelli (2005): Target PPI inflation (no intermediate inputs in production, no sectoral perspective).
     - This paper (speculative): not PPI but trade-network-adjusted PPI (by indirect exporting and importing).

Conclusion and Next Steps

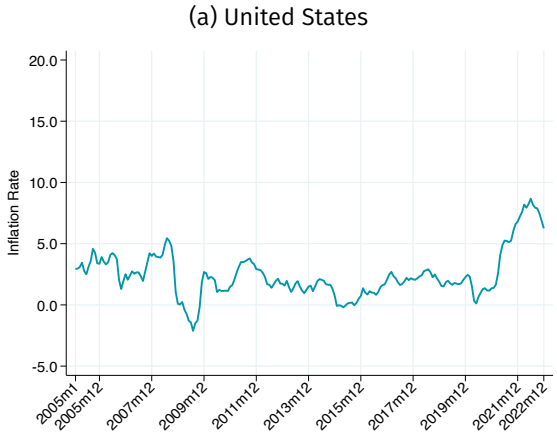
1. I show sufficient statistics for inflation pass-through of supply and demand shocks in small open economies with realistic production networks
2. Statistics differ from those in closed economies and **require knowledge of the production network structure**
   - Escaping Hulten's theorem straightjacket.
3. Provide suggestive empirical evidence that this is quantitatively important in the data.
4. Tentative next steps
   - Clean and improve empirical part
   - Embed logic into a sectoral price stickiness model a la Rubbo (2023) and La'O and Tahbaz-Salehi (2022)
     - Works above show central bank should target a reweighted version of Producer Price Inflation (PPI): sticky price version of Leontieff-inverse.
     - Open economy has a similar flavor
     - Gali and Monacelli (2005): Target PPI inflation (no intermediate inputs in production, no sectoral perspective).
     - This paper (speculative): not PPI but trade-network-adjusted PPI (by indirect exporting and importing).
     - Work in progress...

Thank you!

asilvub@umd.edu
asilvub.github.io

Fact 1: Inflation strikes back

Back

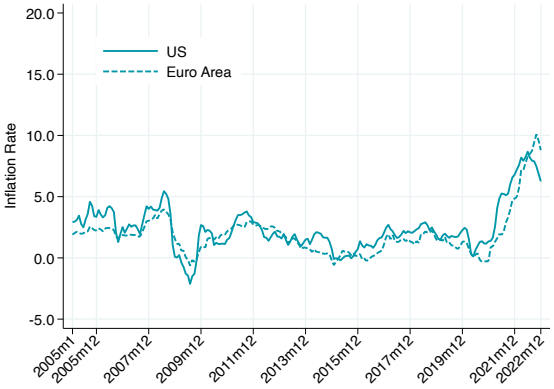


Note: Consumer Price Index year-on-year change. Source: Bank for International Settlements.

Fact 1: Inflation strikes back

Back

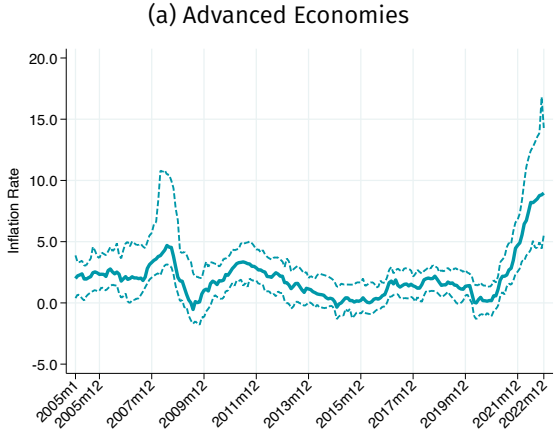
(a) United States and Euro Area



Note: Consumer Price Index year-on-year change. Source: Bank for International Settlements.

Fact 1: Inflation strikes back

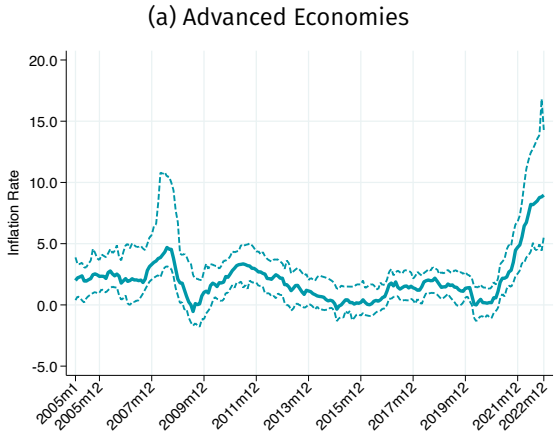
Back

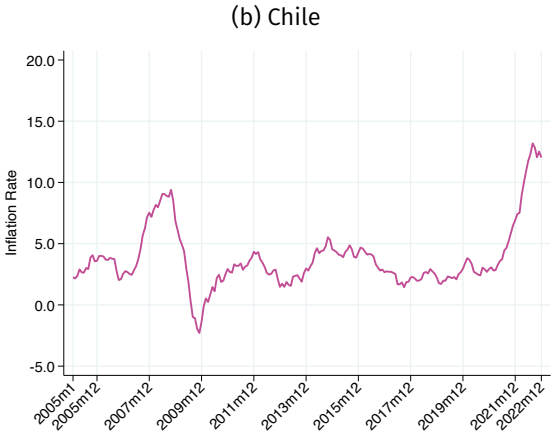


Note: Consumer Price Index year-on-year change. Source: Bank for International Settlements.

Fact 1: Inflation strikes back

Back



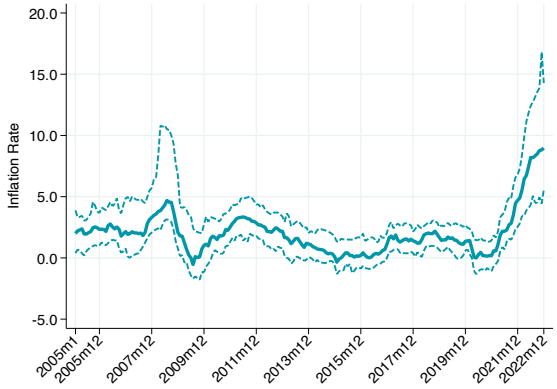


Note: Consumer Price Index year-on-year change. Source: Bank for International Settlements.

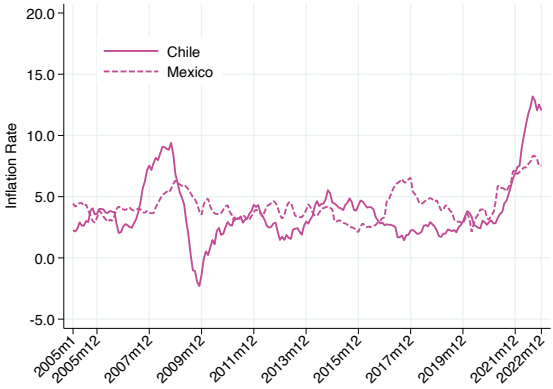
Fact 1: Inflation strikes back

Back

(a) Advanced Economies



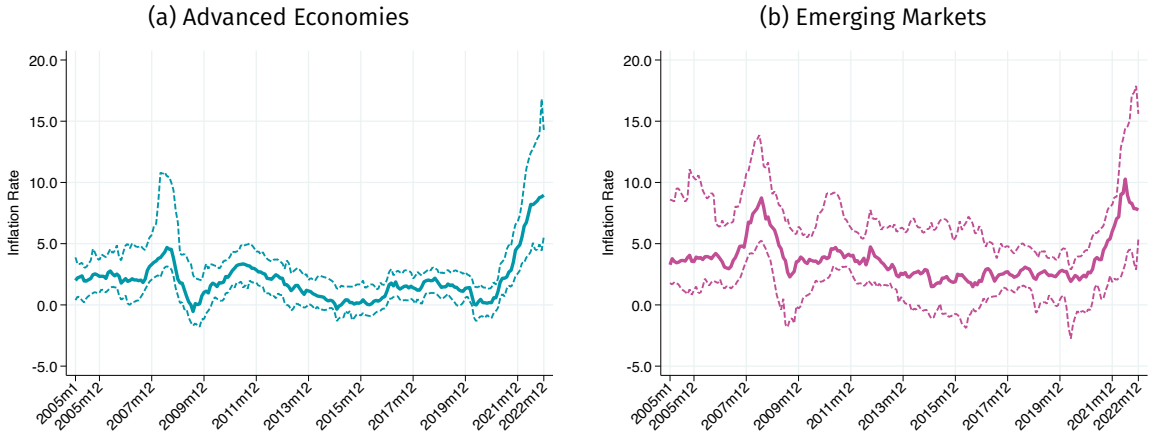
(b) Chile and Mexico



Note: Consumer Price Index year-on-year change. Source: Bank for International Settlements.

Fact 1: Inflation strikes back

Back

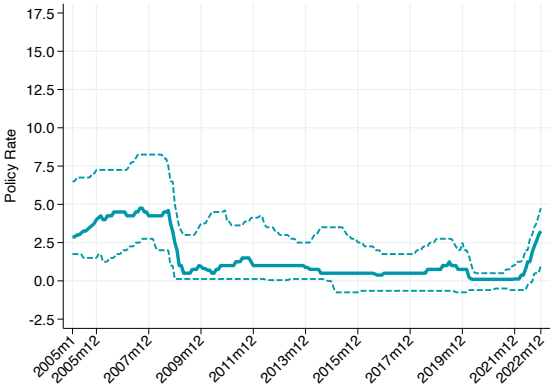


Note: Consumer Price Index year-on-year change. Source: Bank for International Settlements.

Fact 2: Median Central Bank hiked

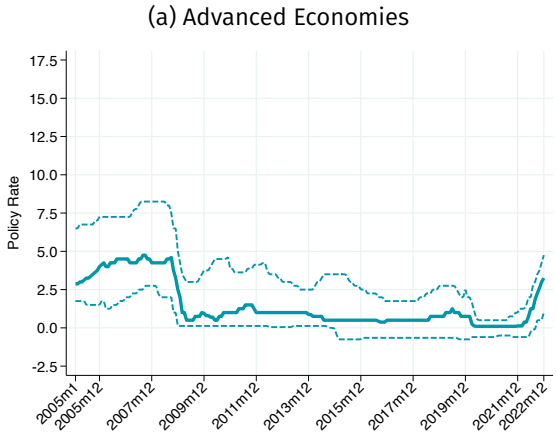
Back

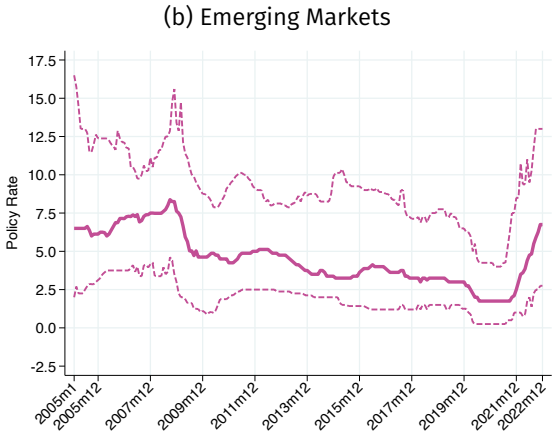
(a) Advanced Economies



Note: Monetary policy rates. Source: Bank for International Settlements.

Fact 2: Median Central Bank hiked Back

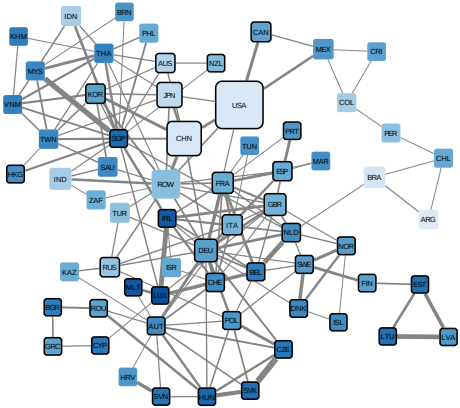




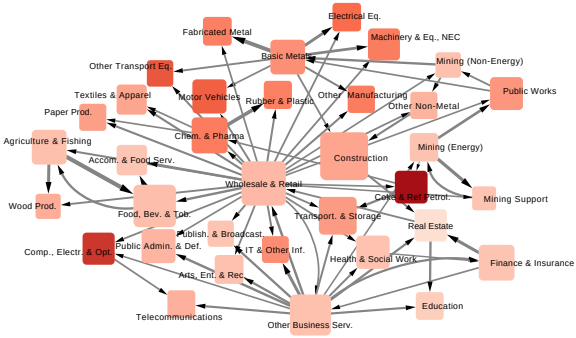
Note: Monetary policy rates. Source: Bank for International Settlements.

Fact 3: Economies are networks! Back

(a) International Production Network



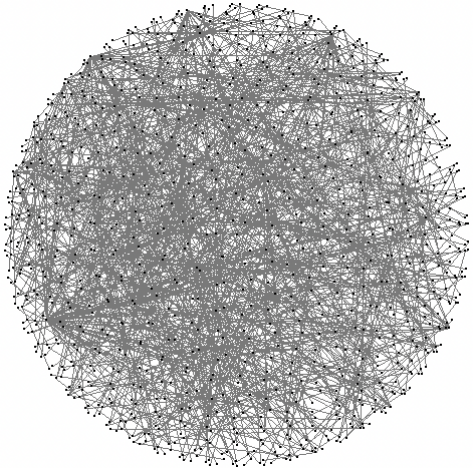
(b) Sectoral Production Network



Source: Cakmakli, Demiralp, Kalemli-Özcan, Yeşiltaş, and Yıldırım (2022) based on OECD Input-Output Tables 2018.

Fact 3: Economies are networks! Back

(c) Chile's Firm-to-Firm Level Production Network

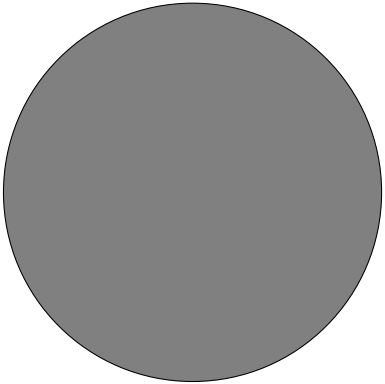


Note: Chilean firm-to-firm level network 2019Q4: 2000 firms random sample, intermediate input sales represents at least 10% of client's total intermediate input purchases.

Source: Miranda-Pinto, Silva, and Young (2023).

Fact 3: Economies are networks! Back

(c) Chile's Firm-to-Firm Level Production Network



Note: Chilean firm-to-firm level network 2019Q4.

Equilibrium Back

1. Given sequences $(\boldsymbol{W}, \boldsymbol{P}_D, \boldsymbol{\Pi}, \boldsymbol{P}_M)$ and exogenous parameters $(T, \mathcal{M})$, the household chooses $(\boldsymbol{C}_D, \boldsymbol{C}_M)$ to maximize its utility subject to its budget constraint and the cash-in-advanced constraint.
2. Given $(\boldsymbol{W}, \boldsymbol{P}_D, \boldsymbol{P}_M)$ and production technologies, firms choose $(\boldsymbol{L}_i, \boldsymbol{M}_i)$ to minimize their cost of production.
3. Given $\boldsymbol{X}$, goods and factor markets clears.

Key Equations

$$Q_i = C_i^D + X_i + \sum_{j=1}^{N} M_{ji}^D \quad \text{for each } i = 1, 2, ..., N \tag{4}$$

$$\bar{L}_f = \sum_{i=1}^{N} L_{if} \quad \text{for each } f = 1, 2, ..., F \tag{5}$$

$$\boldsymbol{\lambda} = \Psi^T(\boldsymbol{b} + \boldsymbol{x}) \tag{6}$$

$$\boldsymbol{\lambda}^M = \boldsymbol{b}_M + \Gamma^T \boldsymbol{\lambda} \tag{7}$$

$$\boldsymbol{\Lambda} = \boldsymbol{A}^T \boldsymbol{\lambda} \tag{8}$$

$$\mathrm{d}\log CPI = \tilde{\boldsymbol{b}}^T \mathrm{d}\log \boldsymbol{P}_D + (\tilde{\boldsymbol{b}}^M)^T \mathrm{d}\log \boldsymbol{P}_M \tag{9}$$

$$(\boldsymbol{b}^T + (\boldsymbol{x})^T)\mathbf{1}_N - (\boldsymbol{\lambda}^M)^T \mathbf{1}_M = 1 \tag{10}$$

$$\tilde{\boldsymbol{b}}^T \mathbf{1}_N + (\tilde{\boldsymbol{b}}^M)^T \mathbf{1}_M = 1 \tag{11}$$

$$\mathrm{d}\log \boldsymbol{P}_D = -\Psi \mathrm{d}\log \boldsymbol{Z} + \Psi \boldsymbol{A} \mathrm{d}\log \boldsymbol{W} + \Psi \Gamma \mathrm{d}\log \boldsymbol{P}_M \tag{12}$$

Another way to write CPI changes

$$\mathrm{d}\log CPI = -\boldsymbol{b}^T\boldsymbol{\Psi}_D\frac{GDP}{E}\mathrm{d}\log \boldsymbol{Z} + \boldsymbol{b}^T\boldsymbol{\Psi}_D\boldsymbol{A}\frac{GDP}{E}\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\frac{GDP}{E}\mathrm{d}\log \boldsymbol{P}_M$$

$$\mathrm{d}\log CPI = -\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}_D\right)\frac{GDP}{E}\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}_D\boldsymbol{A}\right)\frac{GDP}{E}\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{\lambda}^M)^T - \boldsymbol{x}^T\boldsymbol{\Psi}_D\boldsymbol{\Gamma}\right)\frac{GDP}{E}\mathrm{d}\log \boldsymbol{P}_M$$

$$\mathrm{d}\log CPI = -\left(\boldsymbol{\lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}_D\right)\frac{GDP}{E}\mathrm{d}\log \boldsymbol{Z} + \left(\boldsymbol{\Lambda}^T - \boldsymbol{x}^T\boldsymbol{\Psi}_D\boldsymbol{A}\right)\frac{GDP}{E}\mathrm{d}\log \boldsymbol{W} + \left((\boldsymbol{b}^M)^T + \boldsymbol{b}^T\boldsymbol{\Psi}\boldsymbol{\Gamma}\right)\frac{GDP}{E}\mathrm{d}\log \boldsymbol{P}_M$$

WIOT Classification I

Back

Code	Sector Name
A01	Crop and animal production, hunting and related service activities
A02	Forestry and logging
A03	Fishing and aquaculture
B	Mining and quarrying
C10-C12	Manufacture of food products, beverages and tobacco products
C13-C15	Manufacture of textiles, wearing apparel and leather products
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31_C32	Manufacture of furniture; other manufacturing
C33	Repair and installation of machinery and equipment
D35	Electricity, gas, steam and air conditioning supply
E36	Water collection, treatment and supply
E37-E39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
F	Construction
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
G46	Wholesale trade, except of motor vehicles and motorcycles

WIOT Classification II

Back

Code	Sector Name
G47	Retail trade, except of motor vehicles and motorcycles
H49	Land transport and transport via pipelines
H50	Water transport
H51	Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities
I	Accommodation and food service activities
J58	Publishing activities
J59_J60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
J61	Telecommunications
J62_J63	Computer programming, consultancy and related activities; information service activities
K64	Financial service activities, except insurance and pension funding
K65	Insurance, reinsurance and pension funding, except compulsory social security
K66	Activities auxiliary to financial services and insurance activities
L68	Real estate activities
M69_M70	Legal and accounting activities; activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74_M75	Other professional, scientific and technical activities; veterinary activities
N	Administrative and support service activities
O84	Public administration and defence; compulsory social security
P85	Education
Q	Human health and social work activities
R_S	Other service activities
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Activities of extraterritorial organizations and bodies

Leontieff-Inverse Intuition

Back

$\downarrow Z_A \Longrightarrow \uparrow P_A \Longrightarrow \uparrow P_{B_1} = \Omega_{B_1,A} d \log P_A$ (First round) $\Longrightarrow P_{B_2} = \Omega_{B_2,B_1} d \log P_{B_1}$ (Second round)

$\Psi = \sum_{s=0}^{\infty} \Omega^s$ takes into account all these higher order effects!

Indirect Exporting Back

Direct Exports by A, $X_A = 0$

Total Exports by A $= X_B \Psi_{BA}$

Direct Exports by B, $X_B \neq 0$

Total Exports by B $= X_B \Psi_{BB}$