Supply Bottlenecks, US Inflation, and Monetary Policy

Moaz Elsayed[1] [2] Christoph Grosse-Steffen[1]
Magali Marx[1]

[1]Banque de France

[2]Paris-Dauphine University (PSL)

- EEA-ESEM Congress -
August 30th, 2023

*Disclaimer: *The views and opinions expressed in the presentation are not necessarily those of the Banque de France or the Eurosystem.*

Reuters: drought causing transportation bottleneck at the Panama Canal, August 2023 (1/2)

REUTERS® World Business Markets Sustainability Legal Breakingviews Technology Investigation

Climate & Energy | Climate Change | Climate Solutions

Focus: Historic drought, hot seas slow Panama Canal shipping

By **Lisa Baertlein** and **Marianna Parraga**

August 21, 2023 1:09 PM GMT+2 · Updated 9 days ago

[1/2] Monrovia NSU CHALLENGER bulk carrier transits the expanded canal through Cocoli Locks at the Panama Canal, on the outskirts of Panama City, Panama April 19, 2023. REUTERS/Aris Martinez/File photo *Acquire Licensing Rights*

Source: Reuters accessed on August 30th, 2023; https://www.reuters.com/business/environment/historic-drought-hot-seas-slow-panama-canal-shipping-2023-08-21/

Reuters: drought causing transportation bottleneck at the Panama Canal, August 2023 (2/2)

- "... **a historic drought forced [ships] to drop weight by offloading hundreds of containers**."
- "The Panama Canal Authority has **reduced maximum ship weights** and daily ship crossings in a bid to conserve water."
- "Ship owners have the options of **carrying less cargo, shifting to alternate routes** that can add thousands of miles to the trip **or grappling with queues** that earlier this month backed up 160 vessels and delayed some ships by as much as 21 days."

$\Longrightarrow$ "The restrictions already are sending **China-U.S. spot shipping prices up as much as 36 %**"

This paper: inspects the role of two global sectoral shocks on U.S inflation and systematic monetary policy

Motivation

- **Sector-specific shocks** generate macroeconomic dynamics along production chains (Acemoglu et al. 2012)
- Domestic production networks depend on **foreign inputs** (Dhyne et al. 2021)
- Transmission to **inflation** requires further investigation.
- Pivotal for central banks in formulating **monetary policy response**.

What we do

- Identification of two sectoral shocks that lead to supply bottlenecks in a **structural VAR** via sign restrictions using monthly global data (1974m1-)

  1. *Production bottleneck* shock
  2. *Transportation bottleneck* shock

- We develop a **production network model** with sectoral shocks leading to supply bottlenecks to derive assumptions for empirical identification.

Identification

What are we after?

Supply 1: Production bottleneck shock: *Exogenous limitation to availability of intermediate inputs.*

- **Shortage of raw materials**
  - Cobalt crisis 1977/79
- **Granularity & idiosyncratic shocks**
  - Shocks to large firms in production networks (Gabaix E'ca 2011, Carvalho & Grassi AER 2019)
  - Example: Fire at Japanese semiconductor producer Renesas (2021m3)
- **Business interruptions due to natural disasters**
  - Tohoku Earthquake (Japan), 2011m3 (Boehm et al. REStat 2019, Carvalho et al. QJE 2021)
  - Sichuan Earthquake (China), 2008 (Huang et al. 2021)

Identification

What are we after?

Supply 2: Transportation bottleneck shock: *Exogenous limitations of transportation capacity.*

- Force majeure: Piracy around the Horn of Africa (2011), Suez Canal blockings (groundings 2016m2, 2021m3, accident 2018m7), Panama canal closure (flooding 2010m12), eruption of Eyjafjallajökull (Feb-2010)
- Operational bottlenecks: Shanghai lockdown (2022m4-2022m5),

Propagation mechanisms on quantities, delivery time and prices

1. **Limited substitutability at firm level:** Intermediate products and new suppliers (Koptytov, Mishra, Nimark & Taschereau-Dumouchel 2022: endog. prod. networks w/ search and matching)
2. **Macro implications via input-output linkages:** (Acemoglu, Akcigit & Kerr 2016, Carvalho et al. 2016, Acemoglu, Tahbaz-Salehi 2020) **and across countries** (Dhyne et al. 2021)
3. **Cost push shock** on intermediate goods (Woodford 2003)

Main results

1. **US domestic effects of supply shocks** (real activity and prices)
   - *Transportation bottlenecks:* reduction in real activity. Strong and persistent increase in headline and core PCE (wage-price spiral)
   - *Production bottlenecks:* **Deflationary(!)**, due to rigid supply of transportation services.
2. **Monetary policy response**:
   - tightening for transportation specific bottlenecks
   - look through for production bottlenecks
3. **Decomposition of U.S inflation** (Post-covid, 2021q1-2022q2)
   - Supply bottlenecks contributed to increase post-covid US inflation by **1.8 pp** (out of 9.6 pp of inflation hike)

Related literature

- **Multisector general equilibrium production network models:** Long and Plosser (1983), Acemoglu et al. (2012), Baqaee (2018), Carvalho and Tahbaz-Salehi (2019), Koptytov et al. (2022)
- **Firm-level shocks within production networks (empirical)**: Barrot and Sauvagnat (2016), Boehm et al. (2019), Carvalho et al. (2021). **International trade:** Dhyne et al. (2021)
- **Measurement of supply bottlenecks:** Benigno et al. (2022), Burriel et al. (2023)
- **Covid shock:** Baqaee and Farhi (2022), di Giovanni et al. (2022), Fornaro and Romei (2022), Ferrante et al. (2023), Shapiro (2022)

Contribution

1. disentangle role of two sectoral bottlenecks:
   - **production bottleneck:** novel *deflationary mechanism*, due to production complementarity with transportation services which feature rigid supply, consistent with a production network model. Distinct from *Keynesian supply shock* (Guerrieri, Lorenzoni, Straub, Werning 2022)
   - **transportation bottleneck:** conventional supply-side effects on activity and prices; strong pass-through on core inflation.
2. **dynamic shock propagation**

Production network model

Production network with supply bottlenecks

- **Transportation services Y_s:**
  Rigid supply

$$Y_s = A_s K^{1-\alpha_s}$$

- **Essential good Y_e:**
  Elastic labor supply

$$Y_e = A_e L^{\alpha_e}.$$

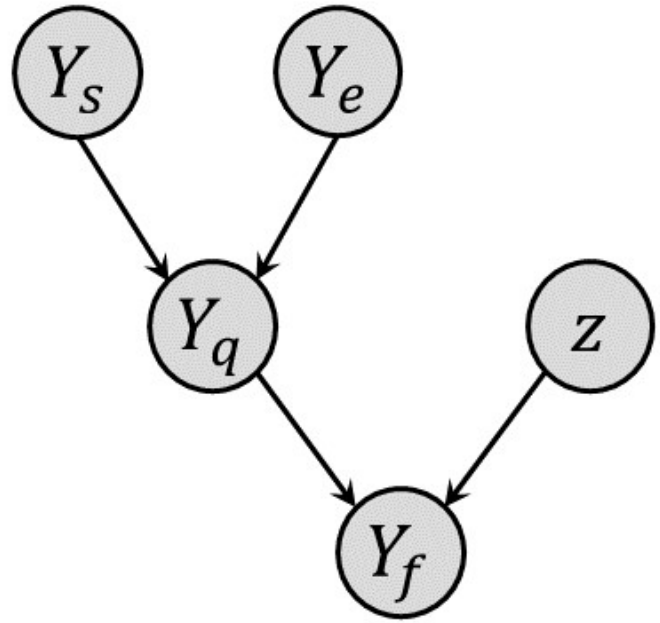
- **Intermediate good Y_q:**
  Complemntarity of essential goods and transportation services ($\nu < 1$)

$$Y_q = A_q \left[\varphi Y_s^{\frac{\nu-1}{\nu}} + (1-\varphi) Y_e^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}$$

- **Final good Y_f:**
  Substitutability of itermediate good and (inventories) time z ($\phi > 1$)

$$Y_f = A_f \left[\omega Y_q^{\frac{\phi-1}{\phi}} + (1-\omega) z^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}$$

Production chain



Industries e and s are gross complements to industry q. Transportation services industry s operates with rigid supply, shutting down the reallocation channel. Industry q and (inventories) time z are gross subsitutes for industry f producing the final consumer good.

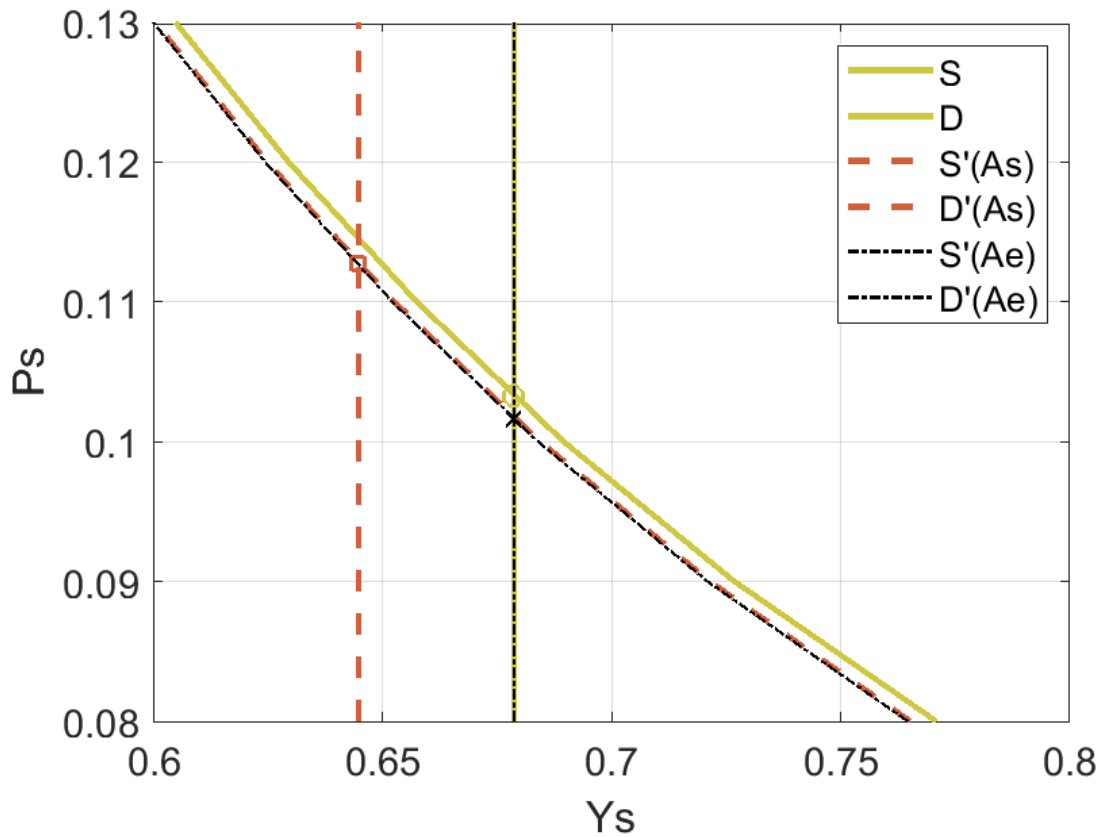
Market clearing transportation good

Transportation services shock

- Supply curve shifts to left
- Transportation price increases

Essential good shock

- Supply rigidity blocks reallocation channel
- Transportation services price decreases



Model responses to sector-specific shocks

- households: consumption-labor supply decision (static)
- numerical solution to non-linear system
- comparative-static analysis

	Y_f	z	P_s
transportation	-1.66% $(-)$	0.06% $(+)$	9.18% $(+)$
production	-1.18% $(-)$	0.03% $(+)$	-1.60% $(-)$

Notes: Responses are reported as a comparison in percentage changes between equilibrium allocations without shocks, i.e. $A_s = A_e = 1$, and allocations under a shock occurrence. The transportation shock is modeled as a decline in productivity A_s by 5 percent. In analogy, the production bottleneck shock is captured by a decline in productivity A_e by 5 percent. Assumptions used for sign restrictions in the empirical model are reported in parentheses.

Empirical methodology

Model

Static structural VAR on monthly frequency: 1974m1-2022m6

$$\mathbf{y}_t = \mathbf{c} + \mathbf{B}\mathbf{y}_{t-1} + \ldots + \mathbf{B}\mathbf{y}_{t-p} + u_t$$

Variables

1. **World industrial production** (OECD+6; Baumeister and Hamilton 2019)
2. **Manufacturing supplier deliveries (ISM)**
   - Part of ISM survey. (Survey question: *"The delivery performance of suppliers to manufacturing organizations" was (i) faster, (ii) stable or (iii) slower.*)
   - Aggregated in a monthly diffusion index; $SDI < 50 \sim$ *faster*, $SDI > 50 \sim$*slower*.
3. **Real transportation cost index** data
   - 3.1 Container shipping indices (HARPEX, China/Shanghai Containerized Freight Index, Con Tex, FBX Global Container Index, & Drewry World Container Index)
   - 3.2 Bulk freight: Baltic Dry Index
   - 3.3 Kilian nominal Drewry shipping index (Kilian 2009, Hamilton 2018)
   - 3.4 Inbound air freight (BLS)
4. **Real crude oil price**

Identification

Sign restrictions

	IP	Supply del.	Trans. cost	Oil price
Transp. bottleneck	$-$	$+$	$+$	$-$
Prod. bottleneck	$-$	$+$	$-$	$-$

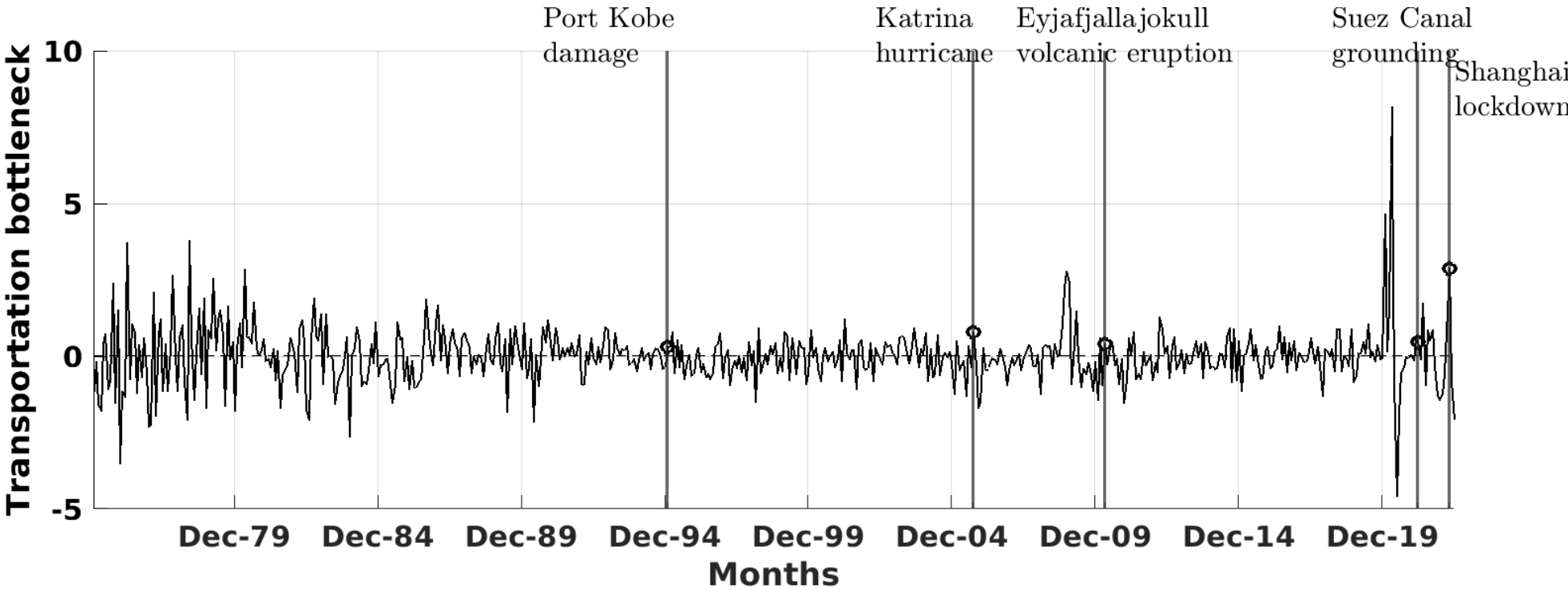
- **Sector-specific shocks:** key assumption on transportation cost
- **Propagation:** supplier deliveries

Narrative sign restrictions (Antolín-Díaz and Rubio-Ramírez 2018)

- Impose **restrictions on the sign** of the shocks during narrative exogenous episodes for bottleneck shocks
- Events: transportation (5) production (7)

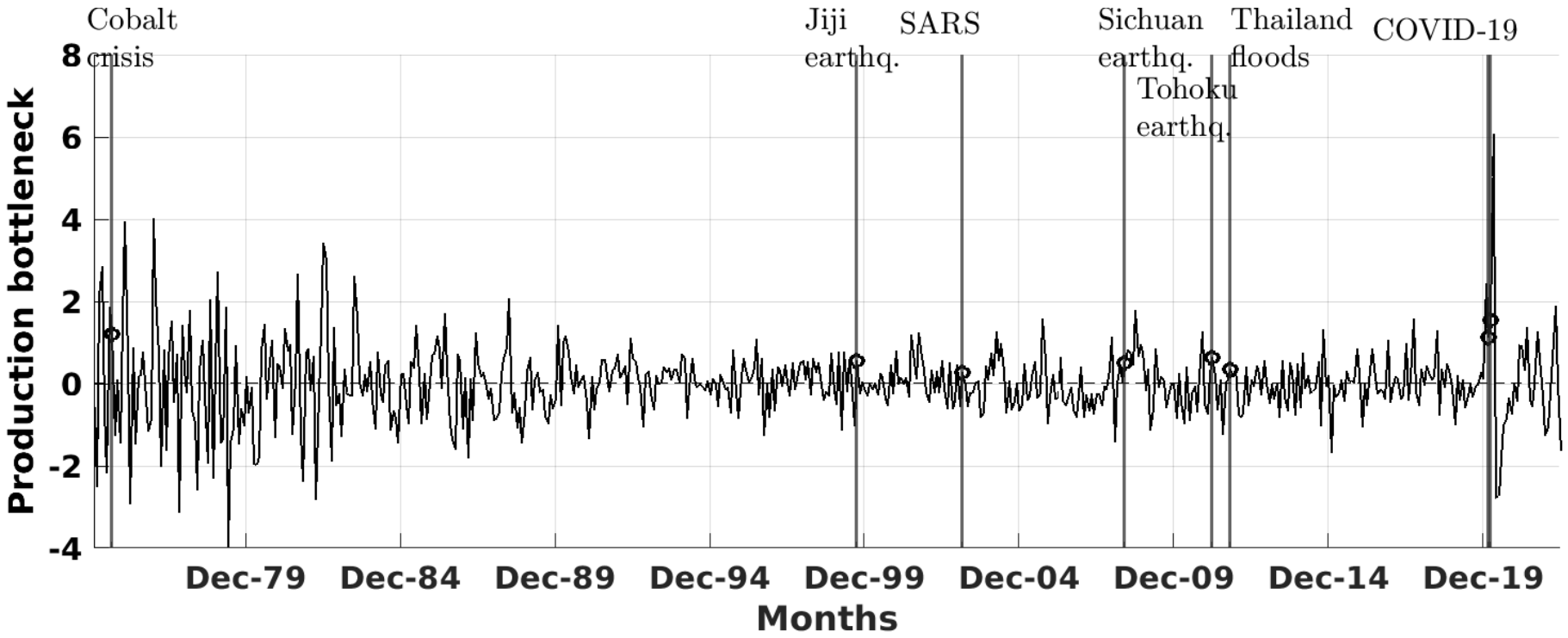
-Results-

Transportation bottlenecks



Notes: The graph shows the median of the shocks of the draws satisfying all narrative restrictions. Transportation bottleneck narrative restrictions in 1995-m1, 2005m9, 2010m4, 2021m3, and 2022m4.

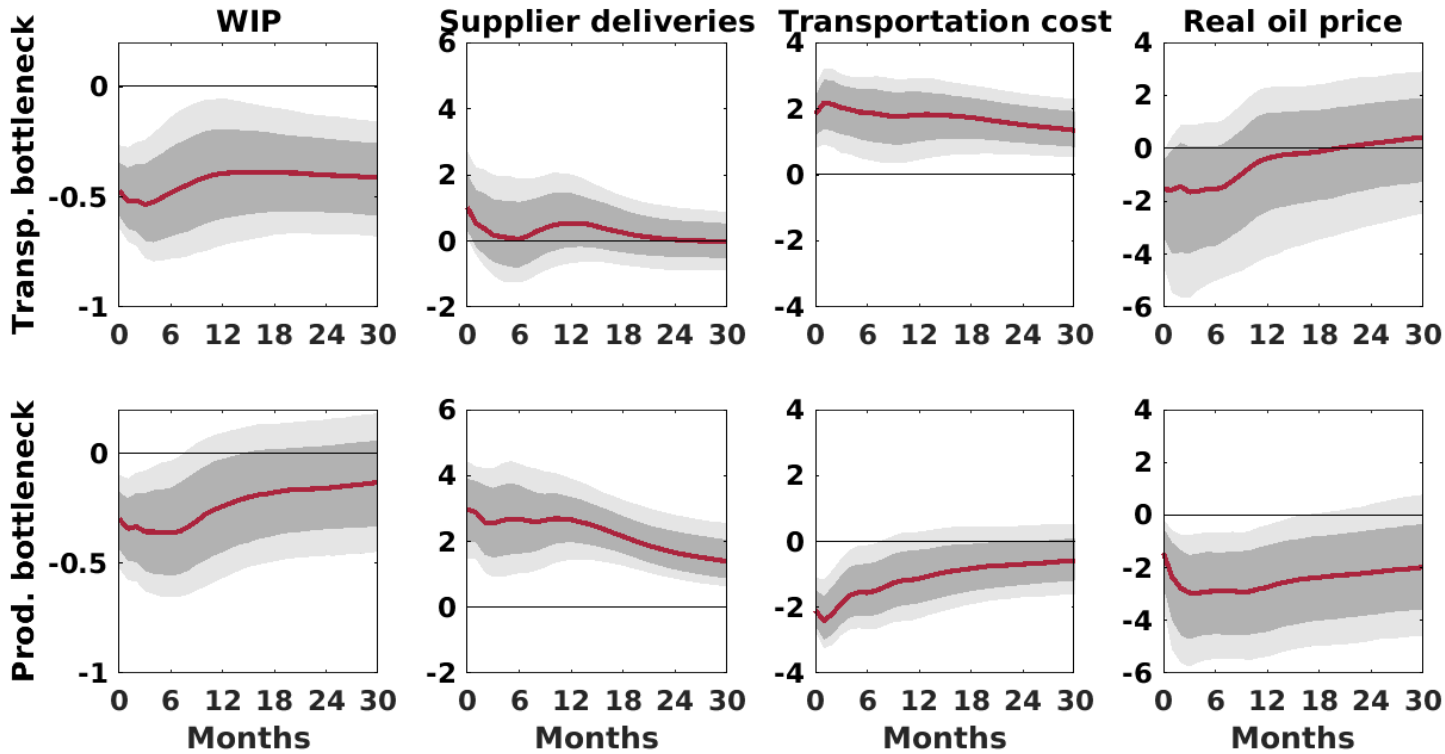
Production bottlenecks



Notes: Panel (b) Production bottleneck narrative restrictions in 1975m8, 1999m9, 2003m2, 2008m5, 2011m3, 2011m10, 2020m2, and 2020m3.

Model IRFs

- **Transportation bottlenecks** dampen global IP persistently, while have minor short run effect on real oil price.
- **Production bottlenecks** have minor short-term effect on global IP with persistent negative effect on real oil price



Notes: The gray area represents the 68% and 90% credible sets for the draws satisfying narrative restrictions, with the red line is the median. Responses are represented to one standard error shock. The vertical axis is interpreted in percentage points.

Transmission of bottlenecks to the US economy

We assume that there is no feedback from US variables to bottleneck shocks and, thus, could be treated as predetermined to US economy

1. For variables with **quarterly frequency** (real GDP, private investment, and corporate profits):
   - We construct measures of the quarterly shocks by averaging the monthly structural innovations for each quarter (Kilian AER 2009).
   - We use **local projection** to estimate the impact of the shocks on US variables
2. For variables of **monthly frequency** (PCE and Federal funds rate) we follow Peersman (2022) and consider the augmented model:

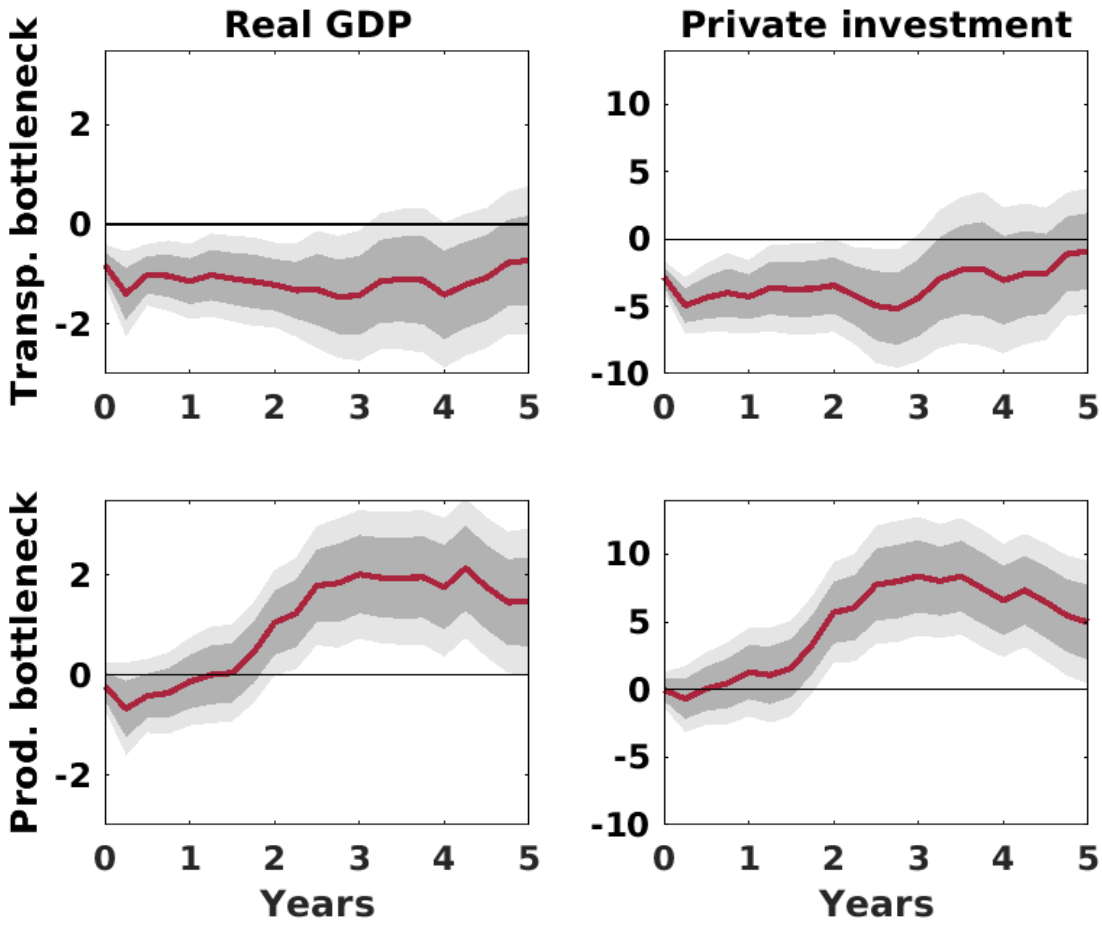
$$\begin{bmatrix} Y_t \\ x_t \end{bmatrix} = \begin{bmatrix} \alpha \\ c \end{bmatrix} + \begin{bmatrix} A(L) & 0 \\ C(L) & D(L) \end{bmatrix} \begin{bmatrix} Y_t \\ x_t \end{bmatrix} + \begin{bmatrix} B & 0 \\ b & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^Y \\ \varepsilon_t^X \end{bmatrix}$$

Where Y_t are the variables of the benchmark VAR model and x_t is for any additional US variable

   - We assume that the additional variable does not affect the benchmark variables.
   - The underlying shocks and interaction among the benchmark variables are invariant to the inclusion of the additional variable.

Impact on real GDP and private investment

- **Transportation bottleneck** has small, negative and persistent effect on real GDP.
- **Production bottleneck** has large, positive and lagged effect on real GDP. Profitable for firms on the long run (*reallocation effect?*)

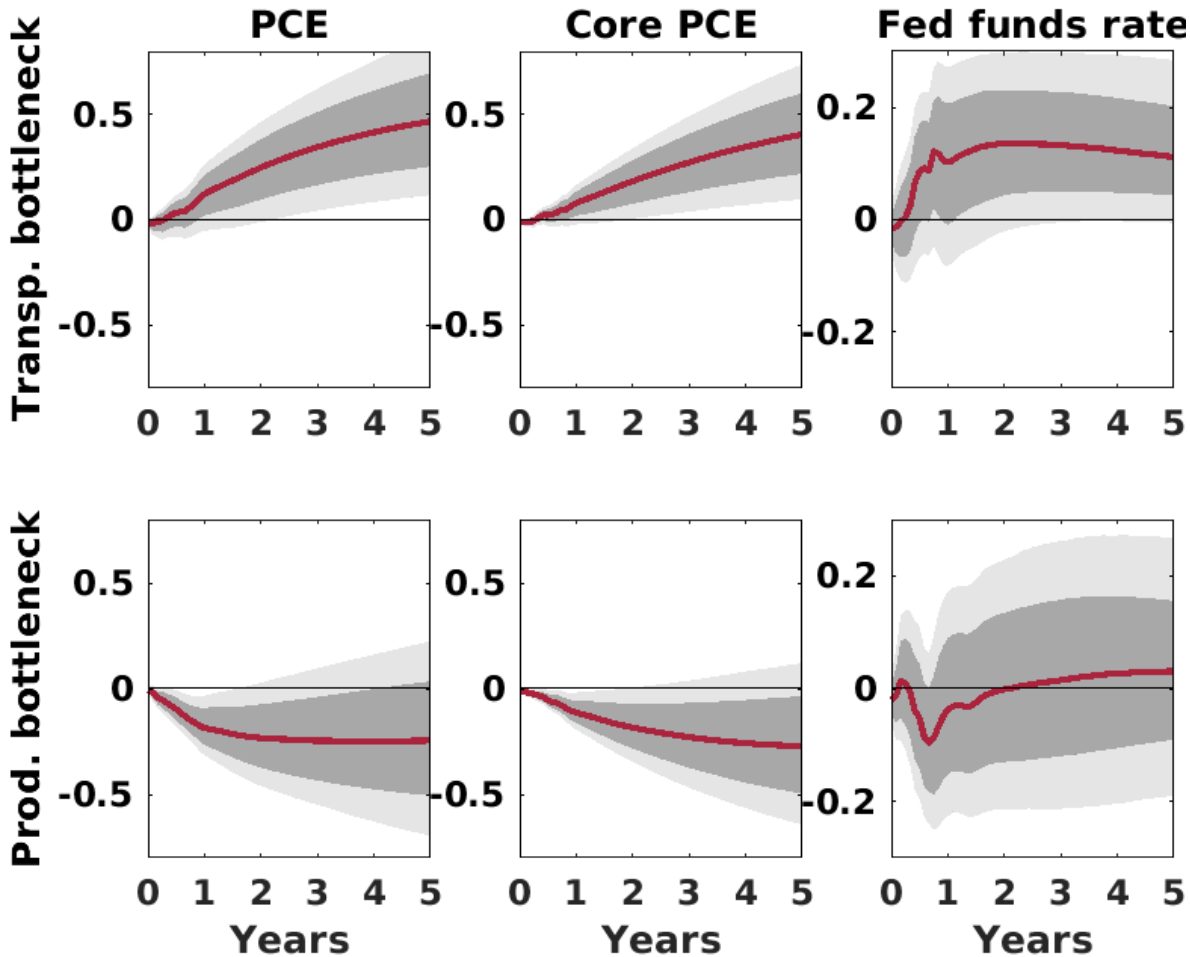


Notes: Responses of real GDP, private investment, and corporate profits are estimated using local projection method on quarterly frequency. Gray areas correspond to the 68% and 90% confidence intervals for the draws satisfying narrative restrictions. The solid red line represents the median. Responses to one standard error shock.

Propagation to prices and monetary policy response

- Heterogenous price effects: inflationary versus deflationary shocks
- Monetary policy response: looking through versus slight tightening

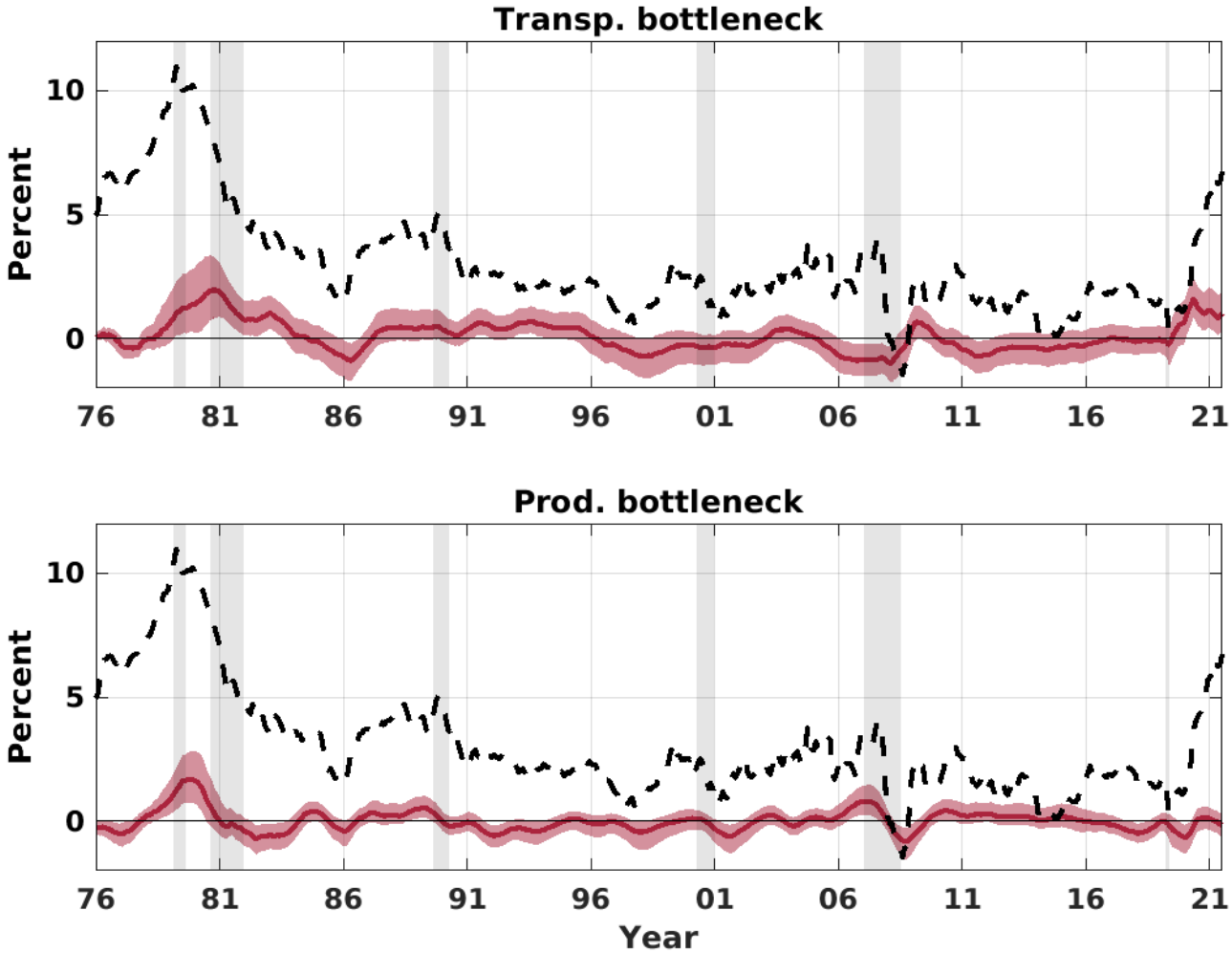
Unit labor cost and wage growth



Notes: Responses are estimated using bayesian exogenous block method. Gray areas correspond to the 68% and 90% credible sets for the draws satisfying narrative restrictions. The solid red line represents the median. Responses to one standard error shock

Decomposition of YoY PCE inflation

Jan 2021 - Jun 2022 monthly PCE inflation contributions: 1.7 pp transportation bottleneck and 0.1 pp production bottleneck



Notes: Vertical gray bar corresponds to the COVID identified NBER U.S recession. The dashed black line is the actual monthly PCE inflation. The red solid line is the median contribution of each shock with 68% credible set.

Conclusion

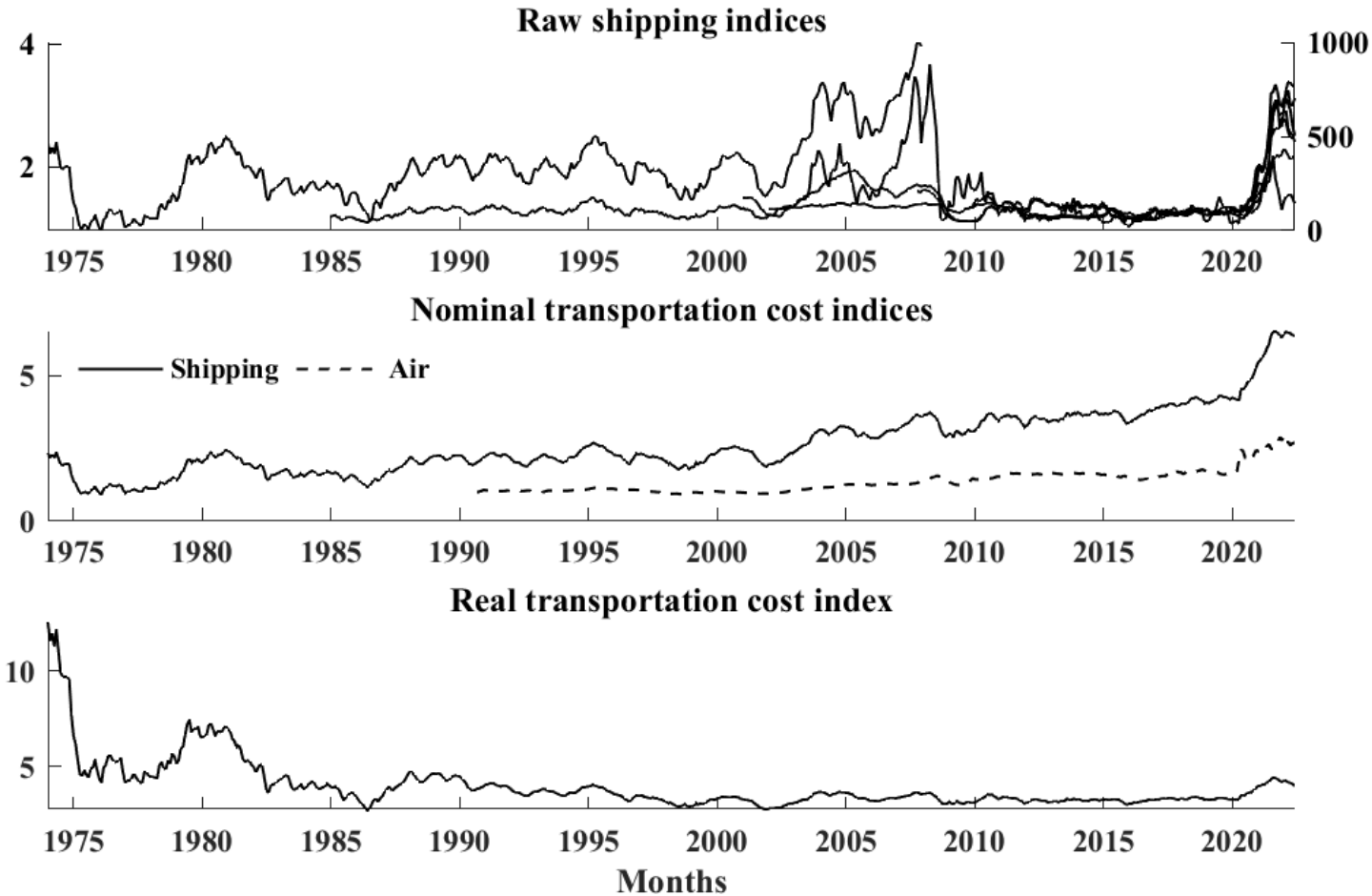
Structural VAR for analysis for dynamic implications of sector-specific shocks

Main findings: (global) prod. and transportation bottleneck shocks matter for US activity and prices

1. **Reallocation effect** following production bottleneck through a pickup in investment and real GDP
2. **Price inflation** heterogenous transmission:
   - *production bottleneck*: **deflationary mechanism** in production network due to rigid transportation supply
   - *transportation bottleneck*: more conventional supply-side shock, but **strong pass-through on core inflation**.
3. **Monetary policy** response is heterogeneous

APPENDIX

Data - Transportation cost index



Notes: The first panel shows the Kilian nominal index (LHS) and other raw shipping indices. Nominal shipping index in second panel is calculated based on the equal-weighted average of the first difference of Killian nominal index and percentage change of other shipping indices (normalized to base year 2018=100). Real transportation cost index is based on the weighted average of nominal shipping and air freight indices deflated using U.S consumer price index.

back

Narrative episode: Transportation bottlenecks

Events

1. **[Great Hanshin earthquake, Japan 1995m1]** Major damage to the port of Kobe on January 17 1995.
2. **[Katrina Hurricane, USA 2005m9]** damaging of three of Louisiana's ports including the largest port in the U.S (South Lousiana).
3. **[Eyjafjallajökull volcanic eruption, Iceland 2010m4]**Volcanic eruption leading to air transportation disruption for the period April 14 - May 22 2010 around Western Europe.
4. **[Suez Canal obstruction, Egypt 2021m3]** Grounding of the Ever Given container ship during the period March 23 - March 29 2021.
5. **[Shanghai lockdown, China 2022m4]** Shanghai port capacity reduction due to the lockdown restrictions for April-May 2022.

Agnostic about (Endogeneity)

- West Coast ports labor union tensions and strikes during, October 2002, December 2012, and February 2015. Labor shortage at Los Angeles and Long Beach ports in September 2004 (possibly endogenous events to economic conditions and inflationary pressures)

Back to identification

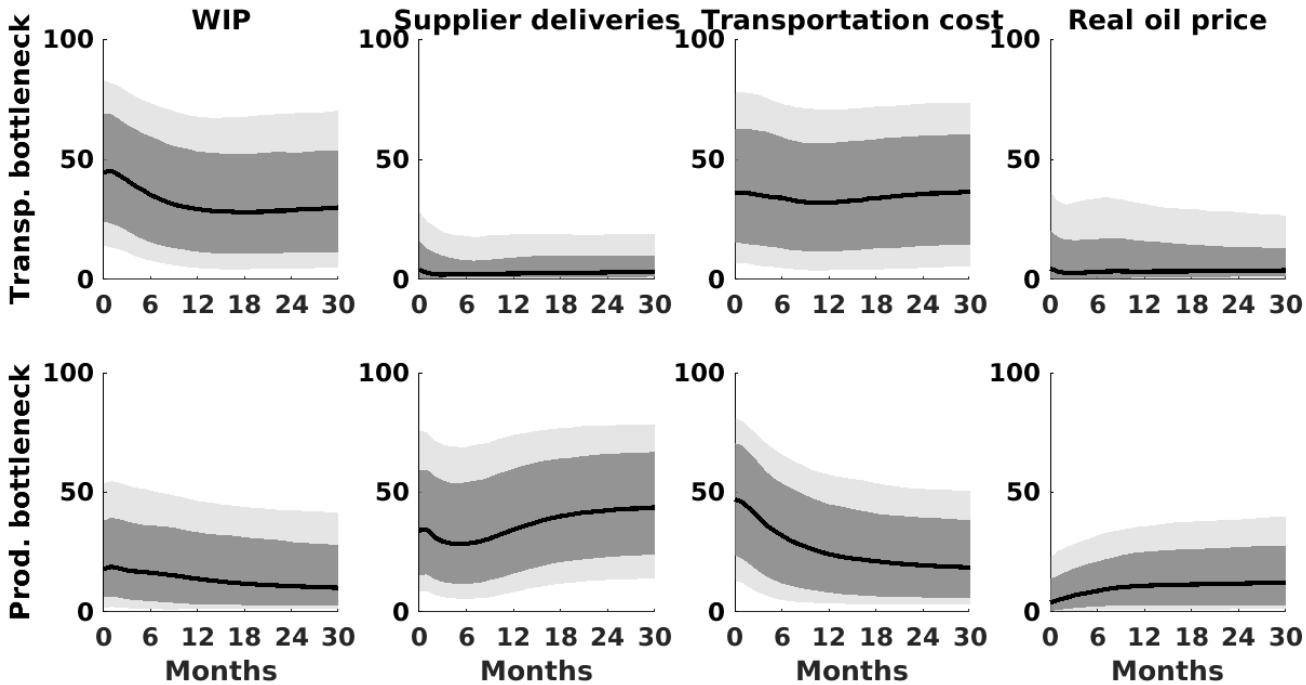
Narrative episode: Production bottlenecks

Events

1. **[Cobalt crisis, Angola 1975m8]** Complete closure of Benguela railway line in August 1975 leading to cut in cobalt production due to the impossibility of transporting the cobalt to outside of the production lines.
2. **[Chi-Chi earthquake, Taiwan 1999m9]** Disruption to Taiwan's semiconductor manufacturing sector (Chi-Chi Reconnaissance report)
3. **[SARS epidemic outbreak, China 2003m2.]** Epidemic breakout in China disrupting business activities (Tan and Enderwick (2006)
4. **[Sichuan earthquake, China 2008m5.]**
5. **[Tohoku earthquake and tsunami, Japan 2011m3]** Disrupting the production of automobiles and electronics due to supply chain disruptions caused by the earthquake and tsunami (Bohem (2019); Canis (2011))
6. **[Thailand flooding, Thailand 2011m10]** Impacting various production lines in Thailand.
7. **[COVID-19, 2020m2-2020m3]** Identifying COVID-19 pandemic as a disruption to production lines due to the restrictions and lockdown.

Back to identification

FEVD



Notes: Gray areas correspond to the 68% and 90% credible sets for the draws satisfying all narrative restrictions. The solid black line represents the median.

Propagation through Unit Labor Cost and wage growth

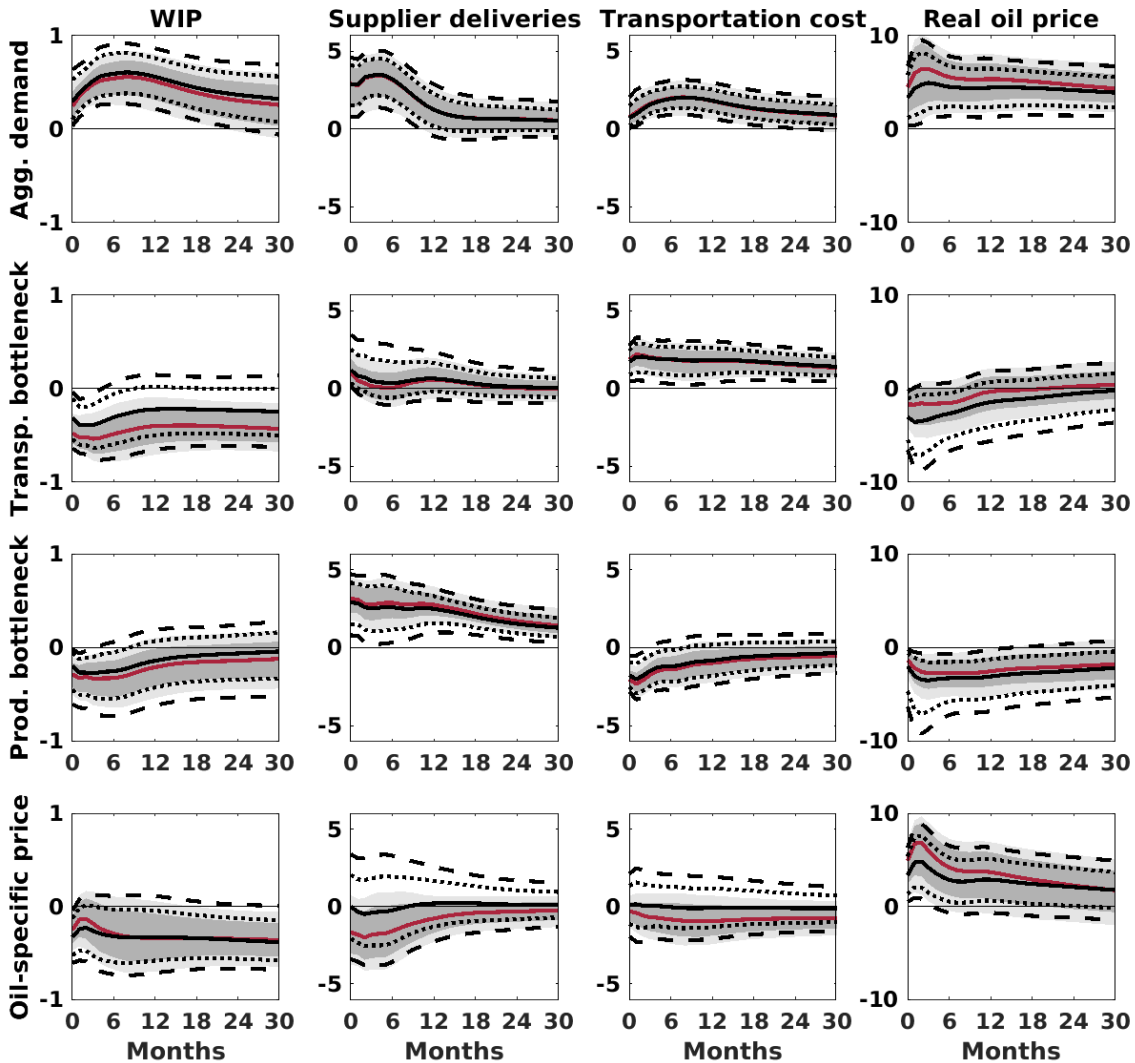
back to prices and MP

- **Transportation bottleneck** second round effects through wage growth and unit labor cost
- **Production bottleneck** deflationary, through marginal cost channel (lower labor cost and wage growth).

Notes: Responses of unit labor cost are estimated using local projection method on quarterly frequency. Wage growth is estimated using bayesian exogenous block method. Gray areas correspond to the 68% and 90% credible sets (respectively confidence intervals) for the draws satisfying narrative restrictions using the bayesian exogenous block method (respectively local projection point estimates).

Model with four shocks

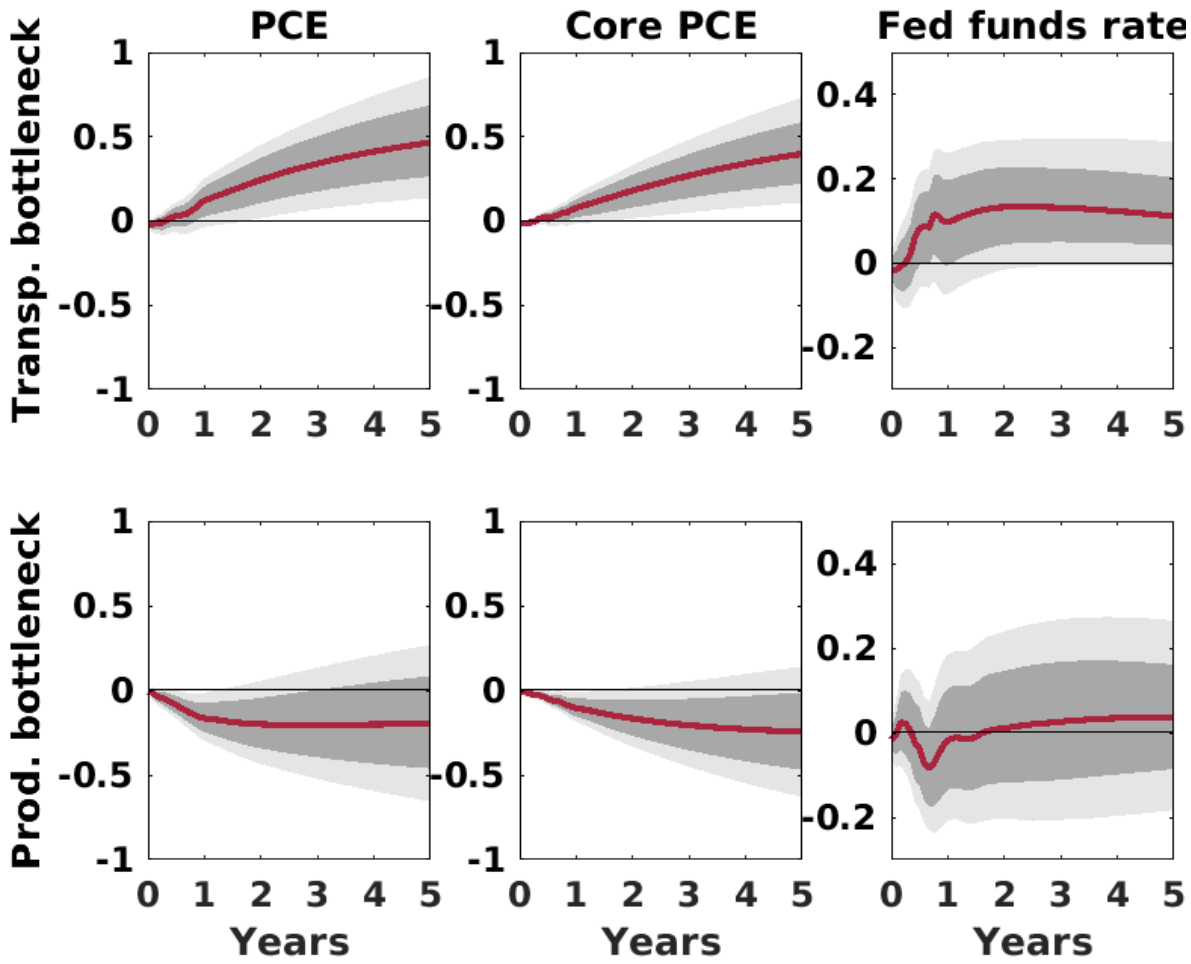
Model IRFs



Notes: The gray area represents the 68% and 90% credible sets for the draws satisfying narrative restrictions, with the red line is the median. Responses are represented to one standard error shock. The vertical axis is interpreted in

Model with four shocks

PCE and FFR responses



Notes: Responses are estimated using bayesian exogenous block method. Gray areas correspond to the 68% and 90% credible sets for the draws satisfying narrative restrictions. The solid red line represents the median. Responses to one standard error shock