The Macroeconomic Effects of Import-Price Shocks: Theory and an Application to the Pandemic Inflation

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Motivation

- U.S. inflation has surged since 2020s following the COVID-19 pandemic and has persisted through early 2023 High Inflation
- Heated debate and discussions over the potential causes of inflation
  1. High prices and shortage of imported goods due to supply chain disruption import price inflation
  2. Domestic expansionary policy ie. loose monetary policy, large fiscal stimulus
- Costs contribute to changes in the shadow prices of imports(i.e., the price at the time of contract signing) not show up in import price indexes(Identification Challenge)

Research Question

- What is the main cause of the surge in inflation since pandemic? import price increase vs expansionary domestic policy
- Additionally, how important have each of these domestic or foreign causes been in explaining the observed high inflation?

Main Conclusions and Contributions

Theoretical Model

- Import price increase will have qualitatively distinct impact on macro variables compared with domestic expansionary policy
  suggest an innovative identification strategy impulse response
- Import price shock acts as a supply shock which can shift the Phillips Curve, for both inflation measured with PCE index or GDP deflator. NKPC

Empirical Analysis

- The initial surge in inflation is primarily attributed to expansionary monetary policy
- the effects of import price increases and demand recovery on inflation become more pronounced from 2022 onward.

Key Model Elements

- **A Small Open Economy (SOE) New Keynesian model**
  - Dual Stickiness: Sticky Domestic Price, Sticky Import Goods Selling Price
  - Household, Producer, Government, Importer, Central Bank
- **Takes the world price of imports as exogenously given:**

$$\ln(\tau_t) = \rho_p \ln(\tau_{t-1}) + \epsilon_{p,t} + \epsilon_{p,t-s}$$

  where τ_t is the world import price relative to the domestic price
- **Balanced Trade Assumption:**

$$\text{Import Value} = \text{Export Value}$$

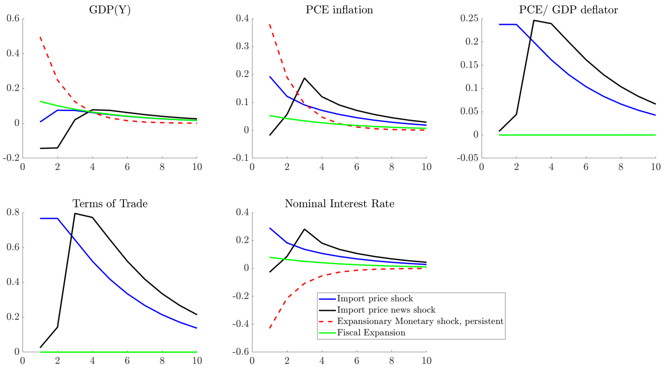
- **Taylor Rule targets PCE inflation:**

$$i_t = i_{ss} + \delta_\pi \pi_{c,t}$$

- **Shocks to world import prices ("surprise" and "news" shocks), fiscal policy, and monetary policy**

Model Details

Model Implied Impulse Response



- Import price **surprise** & **news shock**: $\pi \uparrow$, $i \uparrow$ and also $\frac{PCE}{GDPdeflator} \uparrow$
- Expansionary MP: $\pi \uparrow$, $i \downarrow$ while leave $\frac{PCE}{GDPdeflator}$ unchanged.
- Positive Demand Shock: $\pi \uparrow$, $i \uparrow$ while leave $\frac{PCE}{GDPdeflator}$ unchanged.

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Identification

Identify Import Price Shock by $\frac{PCE}{GDPdeflator}$

- **Sign restriction**: Import price shock (surprise & news) $\Rightarrow$ $\frac{PCE}{GDPdeflator}\uparrow$
- **Zero restriction**: Domestic Shock $\Rightarrow$ $\frac{PCE}{GDPdeflator}$ unchange

Identify monetary policy vs domestic demand by $\pi + i$

- MP shock: $\pi_t \uparrow$, $i \downarrow$
- Demand shock: $\pi_t \uparrow$, $i \uparrow$

$$\begin{pmatrix} u_t^{\frac{p_c}{p_y}} \\ u_t^{\pi_c} \\ u_t^{i} \\ u_t^{y} \end{pmatrix} = \begin{bmatrix} * & 0 & 0 & + \\ * & + & - & * \\ * & + & + & * \\ * & * & * & * \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{residual}} \\ \varepsilon_t^{\text{demand policy}} \\ \varepsilon_t^{\text{monetary policy}} \\ \varepsilon_t^{\text{import price}} \end{pmatrix}$$

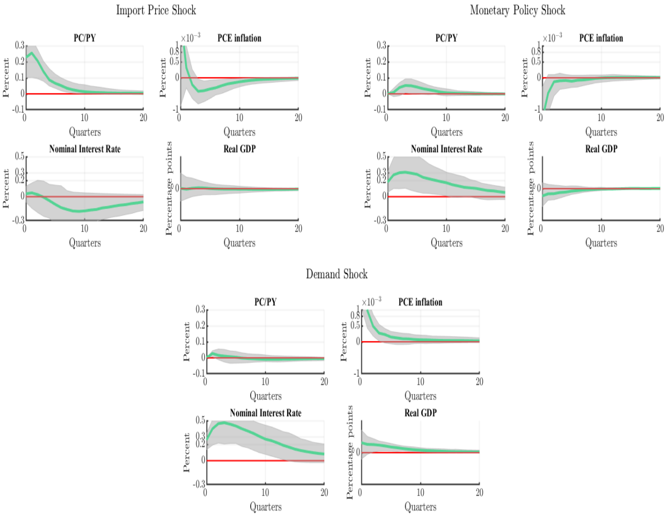
SVAR Data

- **Sample Period**: 1984Q2 to 2023Q3
- **Variables**: Relative Price Ratio $\ln\left(\frac{P_c}{P_y}\right)$, PCE inflation ($\pi_c$), Federal Funds Rate ($i$), Real GDP ($\ln(y)$)
- **Source**: BEA, FRED, BLS
- **Restrictions**

$$\begin{pmatrix} u_t^{\frac{p_c}{p_y}} \\ u_t^{\pi_c} \\ u_t^{i} \\ u_t^{y} \end{pmatrix} = \begin{bmatrix} * & 0 & 0 & + \\ * & + & - & * \\ * & + & + & * \\ * & * & * & * \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{residual}} \\ \varepsilon_t^{\text{demand policy}} \\ \varepsilon_t^{\text{monetary policy}} \\ \varepsilon_t^{\text{import price}} \end{pmatrix}$$

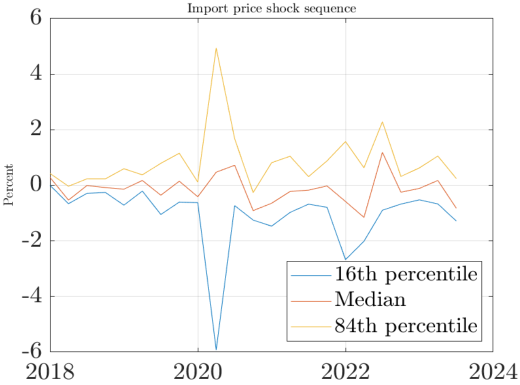
Main reference*: Arias, Rubio-Ramírez, and Waggoner (2018, ECMA)*

SVAR: Impulse Response



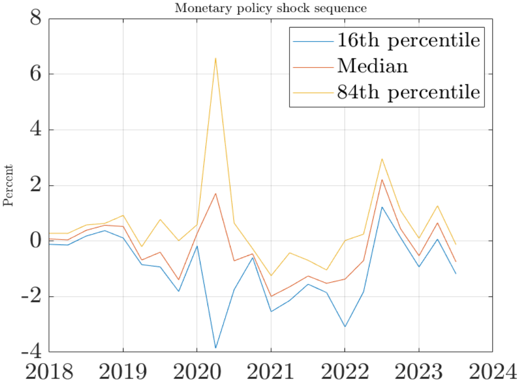
- SVAR IRF is consistent to theoretical IRF

SVAR: Identified Import Price Shock



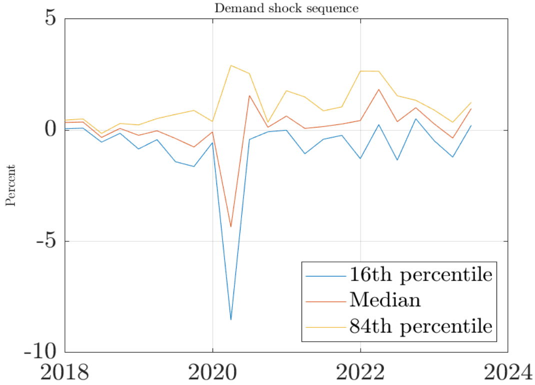
- Import prices surged at the onset of 2020 and again with the outbreak of the Ukraine War in early 2022

SVAR: Identified MP Shock



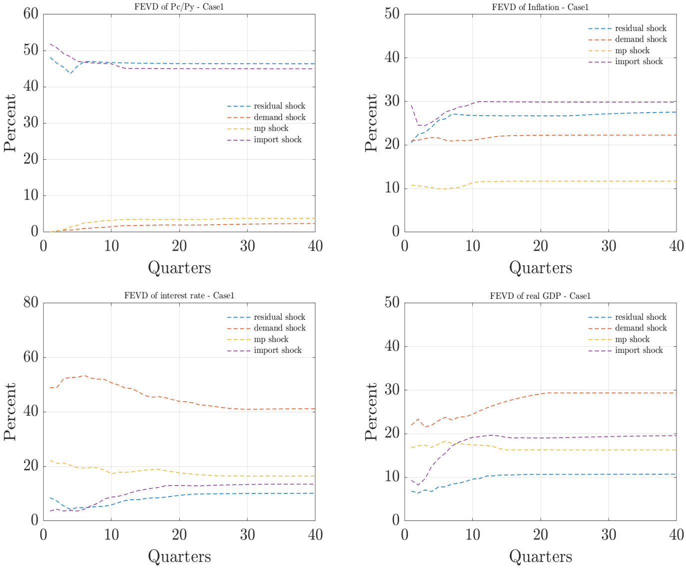
- Starting from 2021, monetary policy initially becomes expansionary to stimulate demand but subsequently tightens to combat inflation

SVAR: Identified Demand Shock

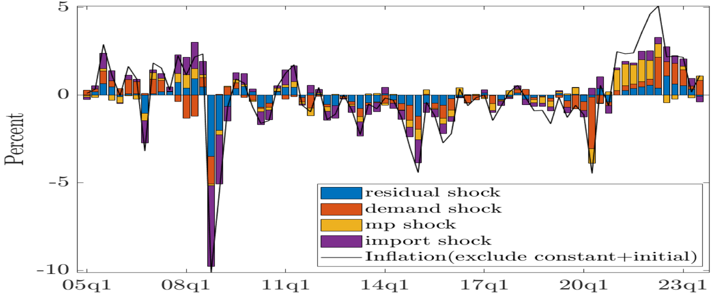


- Aggregate demand plunged when the pandemic broke out but recover rapidly

Forecast Error Variance Decomposition



SVAR: Historical Decomposition



- Demand-driven factors exert downward pressure on prices at the outset of the pandemic
- The initial pick up of inflation is mainly contributed to expansionary monetary policy
- The contribution of supply-driven inflation and demand shock was small initially but began rising since 2022 IMF comparison

Import price shock acts like supply shock

- **NKPC for GDP Y**

$$\pi_{Y,t}=\beta E_t\left[\pi_{Y,t+1}\right]+\frac{S_M(1-\theta)}{1-S_M}\left(\beta E_t\left[\pi_{r,t+1}\right]-\pi_{r,t}\right)+\kappa_Y\left(\hat{Y}_t-\hat{Y}_t^f\right)$$

$S_M(1-\theta)$: share of M_F in production

- **NKPC for C**

$$\pi_{C,t}=\beta E_t\left[\pi_{C,t+1}\right]-(1-\gamma)\left[\beta E_t\left[\pi_{r,t+1}\right]-\pi_{r,t}\right]+\kappa_C\left(\hat{C}_t-\hat{C}_t^f\right)$$

$1-\gamma$: share of C_F in consumption

$\Rightarrow \beta E_t\left[\pi_{r,t+1}\right]-\pi_{r,t}$ serves as a supply shock in both NKPCs Other Results Conclusion

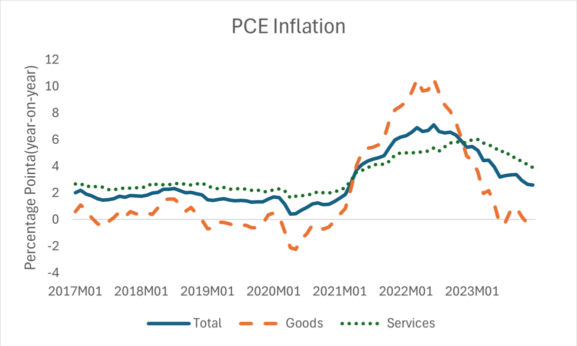
Main Conclusions So far

- **Propose an innovative Identification Strategy**:
  - Import price shock(surprise & news shock):$\pi \uparrow, \frac{PCE}{GDPdeflator} \uparrow$
  - Monetary Policy and Demand shock: $\pi \uparrow, \frac{PCE}{GDPdeflator}$ unchange
- Import price shock acts as a supply shock such that it can shift the Phillips curve, for both inflation measured with PCE index or GDP deflator.
- The Initial inflation is mainly driven by expansionary monetary policy
- The effects of import price increases and demand recovery on inflation become more pronounced from 2022 onward.

Thanks

Appendix

Appendix: High inflation during Pandemic



Note: Inflation is measured using the Personal Consumption Expenditure (PCE) price index, from the US Bureau of Economic Analysis.

Source: BEA

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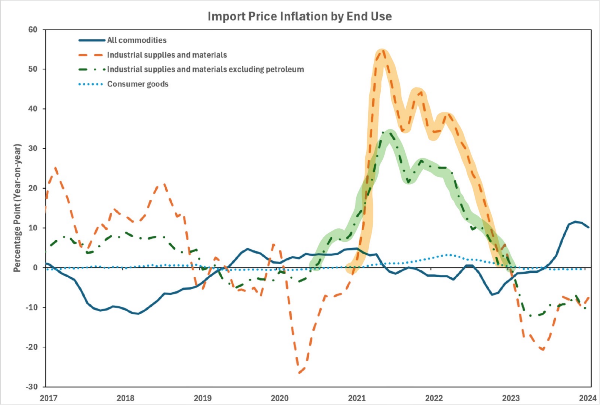
Appendix: Import Price Inflation by end use



Note: Import price indexes are collected from the US bureau of Labor Statistics (series identifiersL EIUIR for total imports, EIUIR1 for industrial materials, EIUIR1EXFUEL for industrial materials excluding fuels, and EIUIR4 for consumer goods.)

Prices for imported inputs rose dramatically in 2021, including energy inputs as well as non-energy inputs.

Source: BEA Back

Appendix: Model Outline

Household

- Household consumes final good and supplies labor to max utility
- Consumption good is a combination of domestic and import good
- Import price enter PCE index directly

Importing Firm

- Individual importer sells foreign goods to domestic agent and the relative import price is sticky

Production

- Firm choose labor and intermediate good to maximize profit.
- Intermediate good is a combination of domestic and import intermediate good.
- Import price index is eliminated from GDP deflator

Monetary and Fiscal Policy

- Central Bank following a Taylor Rule; Government conduct fiscal stimulus.

Appendix: Household

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{H_t^{1+\varphi}}{1+\varphi} \right]$$

$$\text{st.} P_{C,t} C_t + B_t = W_t H_t + (1 + i_{t-1}) B_{t-1} + \Pi_t$$

- $C_t = \left(\gamma (C_{D,t})^{\frac{\omega_c - 1}{\omega_c}} + (1-\gamma) (C_{F,t})^{\frac{\omega_c - 1}{\omega_c}} \right)^{\frac{\omega_c}{\omega_c - 1}}$
- $P_{C,t} = \left(\gamma^{\omega_c} P_{D,t}^{1-\omega_c} + (1-\gamma)^{\omega_c} P_F^{1-\omega_c} \right)^{\frac{1}{1-\omega_c}}$

Appendix: Importing Firm

$$\max_{P_{R,t}(j)} \mathbb{E}_t \left[\sum_{s=0}^{\infty} \omega^s \beta^s \left(\frac{C_{t+s}}{C_t} \right)^{-\sigma} \frac{P_{C,t}}{P_{C,t+s}} \left(P_{R,t}(j) P_{D,t+s} Y_{F,t+s}(j) \right. \right.$$

$$\left. \left. - \tau_{t+s} P_{D,t+s} Y_{F,t+s}(j) \right) \right]$$

$$\text{s.t. } Y_{F,t}(j) = \left(\frac{P_{R,t}(j)}{P_{R,t}} \right)^{-\xi} Y_{F,t}$$

- τ_{t+s} : relative import goods cost
- $P_{R,t}$: relative import goods selling price

Appendix: Gross output vs Value added

Production Function

$$Q = G(F(K, H, Z), W(M))$$

- Q:gross output, M:intermediate goods, H:labor, Kcapital, Z:tech
- Value added and GDP deflator:

$$\hat{F} \equiv \frac{\hat{Q} - \epsilon_m \hat{M}}{1 - \epsilon_m}, \;\; GDP\hat{deflator} \equiv \frac{\hat{P_Q} - \epsilon_m \hat{P_M}}{1 - \epsilon_m}$$

where output elasticity $\epsilon_m = \left[\frac{W_M M}{Q}\right] = \mu \left[\frac{P_M M}{P_Q Q}\right] = \mu S_M$

Appendix: Final goods aggregating firm

$$\min \int_0^1 P_{Q,i,t} Q_{i,t} \, \mathrm{d}i$$

$$\text{s.t.} \quad \left[\int_0^1 Q_{i,t}^{\frac{\xi-1}{\xi}} \, \mathrm{d}j \right]^{\frac{\xi}{\xi-1}} = Q_t$$

Cost minimization yields:

$$\begin{cases} Q_{i,t} = \left(\dfrac{P_{Q,i,t}}{P_{Q,t}} \right)^{-\xi} Q_t \\ P_{Q,t} = \left[\displaystyle\int_0^1 P_{Q,i,t}^{1-\xi} \mathrm{d}j \right]^{\frac{1}{1-\xi}} \end{cases}$$

Appendix: Differentiated goods producing firm

$$\max P_{Q,i,t} Q_{i,t} - W_t H_{i,t} - P_{D,t} M_{D,i,t} - P_{F,t} M_{F,i,t}$$

$$\text{s.t. } Q_{i,t} = \left(\alpha \left(Z_t H_{i,t} \right)^{\frac{\omega_Q - 1}{\omega_Q}} + (1-\alpha) \left(M_{i,t} \right)^{\frac{\omega_Q - 1}{\omega_Q}} \right)^{\frac{\omega_Q}{\omega_Q - 1}}$$

$$M_{i,t} = \left(\theta \left(M_{D,i,t} \right)^{\frac{\omega_M - 1}{\omega_M}} + (1-\theta) \left(M_{F,i,t} \right)^{\frac{\omega_N - 1}{\omega_M}} \right)^{\frac{\omega_M}{\omega_M - 1}}$$

$$Q_t = \left[\int_0^1 Q_{i,t}^{\frac{\xi - 1}{\xi}} di \right]^{\frac{\xi}{\xi - 1}}$$

- $P_{Q,t} = P_{D,t}$; $P_{M,t} = \left(\theta^{\omega_m} P_{D,t}^{1-\omega_m} + (1-\theta)^{\omega_m} P_{F,t}^{1-\omega_m} \right)^{\frac{1}{1-\omega_m}}$
- $M_D(M_F)$: Domestic(Foreign) intermediate goods

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Appendix: Other Model Elements

Price Setting

$$\text{NKPC}: \pi_{Q,t} = \beta E_t\left[\pi_{Q,t+1}\right] + \lambda m\hat{c}_{q,t}$$

where Producer price inflation $\pi_{Q,t} = \hat{P}_{Q,t} - \hat{P}_{Q,t-1}$

Government

$$T_t = G_t,\ \ln\left(G_t\right) = \rho_g \ln\left(G_{t-1}\right) + \epsilon_{g,t}$$

Monetary Authority

$$i_t = i_{ss} + \delta_\pi \pi_{c,t} \text{ where } i_{ss} = \frac{1}{\beta} - 1$$

where PCE inflation $\pi_{c,t} = \hat{P}_{C,t} - \hat{P}_{C,t-1}$

Terms of Trade

$$\ln\left(\tau_t\right) = \rho_p \ln\left(\tau_{t-1}\right) + \epsilon_{p,t} + \epsilon_{p,t-s}$$

where $\epsilon_{p,t}$ is surprise shock, $\epsilon_{p,t}$ is news shock

Productivity:

$$\hat{Z}_t = \rho_z \hat{Z}_{t-1} + \epsilon_z$$

Appendix Close the Economy

Market Clearing Condition

$$P_{D,t}Q_t = P_{D,t}C_{D,t} + P_{D,t}M_{D,t} + P_{D,t}G_{D,t} + X_t$$
$$= P_{C,t}C_t - P_{F,t}C_{F,t} + P_{M,t}M_t - P_{F,t}M_{F,t} + P_{C,t}G_t - P_{F,t}G_{F,t} + X_t$$

Under **balanced trade assumption**, export $X_t = P_{Ft}C_{Ft} + P_{Ft}M_{Ft}$

$$\Rightarrow P_{D,t}Q_t = P_{C,t}\left(C_t + G_t\right) + P_{M,t}M_t$$

GDP in National Account

$$\hat{Y} \equiv \frac{\hat{Q} - S_M\hat{M}}{1 - S_M}, GDP\hat{deflator}(P_Y) \equiv \frac{\hat{P_Q} - S_M\hat{P_M}}{1 - S_M}$$

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Appendix: Calibration

Parameter	Description	Value
σ	Risk Aversion	2
φ	Inverse Frisch Elasticity	3
β	Steady State discount factor	0.9
S_M	Share of intermediate good expenditure	0.5
S_g	Share of government consumption	0.2
μ	Steady State Markup	1.2
α	Share of Labor input in total cost	0.4
s_{mf}	Foreign Material Share	0.2
θ	Home bias in intermediate input usage	0.8
s_{cf}	Share of C_F in C_t	0.11
γ	Home bias in C_t consumption	0.89
ξ	Elasticity between varieties	6
ω_c	Substitution between C_D and C_F	1
ω_m	Substitution between M_D and M_F	1
ω_q	Substitution between H and M	1
ω	Domestic Price stickiness	0.6
ω_R	Relative Price stickiness	0.2
δ_π	Taylor Weight on inflation	1.5
ρ_z	AR(1) coefficient of productivity	0.66
ρ_p	AR(1) coefficient of τ	0.8

Appendix: SVAR Model

Structural representation

$$\mathbf{y}_t'\mathbf{A}_0 = \mathbf{x}_t'\mathbf{A}_+ + \varepsilon_t' \quad \text{for } 1 \leq t \leq T$$

where $\mathbf{y}_t' = \left[\frac{P_{c,t}}{P_{Y,t}}, \pi_t, i_t, Y_t\right]$, $\mathbf{x}_t' = \begin{bmatrix} \mathbf{y}_{t-1}' & \cdots & \mathbf{y}_{t-p}' \end{bmatrix}$, $\varepsilon_t' = \left[\varepsilon_t^{im}, \varepsilon_t^{mp}, \varepsilon_t^{demand}, \varepsilon_t^{ls}\right]$, $\mathbf{A}_+' = \begin{bmatrix} \mathbf{A}_1' & \cdots & \mathbf{A}_p' & \mathbf{c}' \end{bmatrix}$.

Reduced form representation:

$$\mathbf{y}_t' = \mathbf{x}_t'\mathbf{B} + \mathbf{u}_t' \quad \text{for } 1 \leq t \leq T$$

where $\mathbf{B} = \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}_t' = \varepsilon_t'\mathbf{A}_0^{-1}$, $\mathbb{E}\left[\mathbf{u}_t\mathbf{u}_t'\right] = \Sigma = \left(\mathbf{A}_0\mathbf{A}_0'\right)^{-1}$.

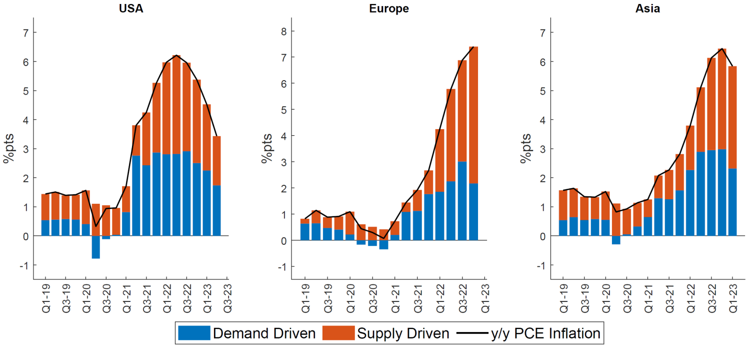
Mapping: $f_h^{-1}(\mathbf{B}, \mathbf{\Sigma}, \mathbf{Q}) = (\underbrace{h(\mathbf{\Sigma})^{-1}\mathbf{Q}}_{\mathbf{A}_0}, \underbrace{\mathbf{B}h(\mathbf{\Sigma})^{-1}\mathbf{Q}}_{\mathbf{A}_+})$

Restrictions: $\mathbf{S}_j\mathbf{IRF}\left(f_h^{-1}(\mathbf{B}, \mathbf{\Sigma}, \mathbf{Q})\right)\mathbf{e}_j > 0$, $\mathbf{Z}_j\mathbf{IRF}\left(f_h^{-1}(\mathbf{B}, \mathbf{\Sigma}, \mathbf{Q})\right)\mathbf{e}_j = 0$. *Main reference: Arias, Rubio-Ramírez, and Waggoner (2018, ECMA)*

Appendix: IMF Inflation Decomposition

Figure 3: Inflation Decomposition: Historical Evidence

(a) Decomposition of y/y PCE inflation during Pandemic Era



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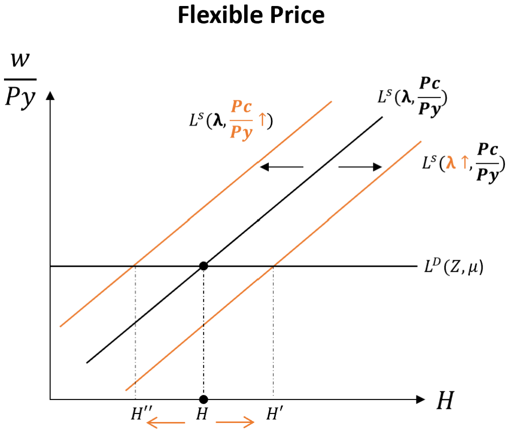
Appendix: Effect on labor supply is ambiguous



Import Price Increase: Back LD LS

- Negative wealth effect **shift out** labor supply
- $\frac{PCE}{GDPdeflator}\uparrow$ **shift in** labor supply

Appendix: Labor Demand

$$P_Q = \mu \left(\frac{W}{Z}\right)^{\alpha} (P_M)^{1-\alpha}$$

$$\hat{P}_Q = \hat{\mu} + \alpha(\hat{W} - \hat{Z}) + (1-\alpha)\left(\hat{P}_M\right)$$

$$\frac{\hat{P}_Q - (1-\alpha)\left(\hat{P}_M\right)}{\alpha} = \frac{\hat{\mu}}{\alpha} + (\hat{W} - \hat{Z})$$

$$\frac{\hat{P}_Q - \mu s_M \hat{P}_M}{1 - \mu s_M} \equiv \hat{P}_{YY} = \frac{\hat{\mu}}{1 - \mu s_M} + (\hat{W} - \hat{Z})$$

$$\hat{W} - \hat{P}_{YY} = \hat{Z} - \frac{\hat{\mu}}{1 - \mu S_M}$$

Appendix: Labor Supply

Separate Utility: $U(C_t, H_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{H_t^{1+\varphi}}{1+\varphi}$

$$C^{-\sigma} = \lambda P_c, H^{\varphi} = \lambda W$$

$$\frac{W}{P_C} = C^{\sigma} H^{\varphi}$$

$$\frac{W}{P_{YY}} = C^{\sigma} H^{\varphi} \frac{P_C}{P_{YY}}$$

GHH: $U(C_t, H_t) = \log\left(C_t - \frac{H_t^{1+\varphi}}{1+\varphi}\right)$

$$\lambda P_C = \frac{1}{C - \frac{H^{1+\varphi}}{1+\varphi}}, \frac{1}{C - \frac{H^{1+\varphi}}{1+\varphi}} H^{\varphi} = \lambda W$$

$$\frac{W}{P_C} = H^{\varphi}$$

$$\frac{W}{P_{YY}} = H^{\varphi} \frac{P_C}{P_{YY}}$$

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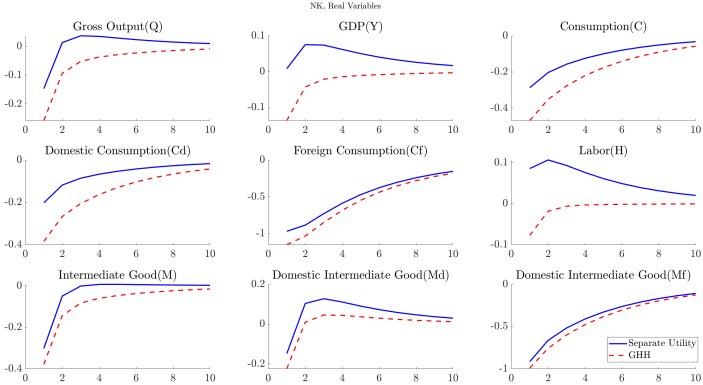
Appendix: Separable Utility vs GHH



Separable Utility: $H\uparrow$ since wealth effect dominate
GHH Utility: $H\downarrow$ without wealth effect Back