Relative-Price Changes as Aggregate Supply Shocks Revisited: Theory and Evidence

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Introduction

Motivation: Recent Dynamics in the U.S. Economy

- Episodes of commodity price booms and supply chain disruptions
- Passthrough to headline and eventually, core inflation
- Accommodative monetary policy initially
- Inflation movements without aggregate slack (soft landing)

Research Questions

1. Can shocks to relative price of an upstream sector cause *persistent* movements in aggregate (core) inflation, *even without any aggregate slack*?

2. If so, can such a model account for recent U.S. headline and core inflation dynamics?

Research Questions

1. Can shocks to relative price of an upstream sector cause *persistent* movements in aggregate (core) inflation, *even without any aggregate slack*?

2. If so, can such a model account for recent U.S. headline and core inflation dynamics?

3. Are predictions of a model with input-output linkages and heterogeneity in price stickiness supported in detailed sectoral data?
    - What are estimated sectoral price responses to relative price of energy shocks?

What We Do and Find

- Theoretical and Quantitative:
  1. With input-output linkages, relative price changes can generate persistent aggregate inflation dynamics, *even without aggregate slack*
  2. Importance of (1) input-output linkages, (2) heterogeneity in price stickiness, and (3) monetary policy in shaping *inflation dynamics* in the *aftermath of COVID-19*

What We Do and Find

- Theoretical and Quantitative:
    1. With input-output linkages, relative price changes can generate persistent aggregate inflation dynamics, *even without aggregate slack*
    2. Importance of (1) input-output linkages, (2) heterogeneity in price stickiness, and (3) monetary policy in shaping *inflation dynamics* in the *aftermath of COVID-19*
- Empirical:
    1. Exogenous relative price of energy shocks act as *aggregate* supply shocks
    2. *Sectoral* consumer price responses to them in line with model predictions

Literature

- Relative-price changes as aggregate supply shocks: Ball and Mankiw (1995)
  - Input-output linkages under time-dependent pricing

- Multi-sector sticky price models with heterogeneity: Aoki (2001); Woodford (2003); Benigno (2004); Ruge-Murcia and Wolman (2022); Carvalho, Lee, and Park (2021); Pasten, Schoenle, and Weber (2020); La'O and Tahbaz-Salehi (2022); Afrouzi and Bhattarai (2022); Minton and Wheaton (2022); Rubbo (2023); Lorenzoni and Werning (2023)
  - How transition dynamics of relative prices along with realistic monetary policy can generate inflation dynamics similar to post-COVID period
  - Pass-through of *relative producer prices of energy* to sectoral consumer prices, using model based dynamic pass-through statistic

Model

Model–Overview

- Two sectors, $i \in \{u, d\}$: **u**pstream, **d**ownstream
- A measure of monopolistically competitive intermediate firms in each sector
    - Input-output linkages and price stickiness
- A final good producer in each sector packages and sells a sectoral good
    - Sectoral goods consumed by household and used for production

Model

- Household

$$\max \int_0^{\infty} e^{-\rho t} \left[\ln(C_t) - L_t\right] \mathrm{d}t$$

$$\textstyle\sum_{i \in \{u,d\}} P_{i,t} C_{i,t} + \dot{B}_t \leq W_t L_t + i_t B_t + T_t$$

$$C_t \equiv \left(\frac{C_{u,t}}{\beta}\right)^{\beta} \left(\frac{C_{d,t}}{1-\beta}\right)^{1-\beta}$$

$$P_t \equiv P_{u,t}^{\beta} P_{d,t}^{1-\beta}$$

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- Euler equation:

$$i_t = \rho + \frac{\dot{C}_t}{C_t} + \frac{\dot{P}_t}{P_t}$$

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- Euler equation:

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- Optimal labor supply:

$$W_t = P_t C_t \equiv M_t$$

- **Final Good** Producer

$$\max P_{i,t}Y_{i,t} - \int_0^1 P_{ij,t}Y_{ij,t}^d \mathrm{d}j \quad s.t.$$

$$Y_{i,t} = \left[\int_0^1 (Y_{ij,t}^d)^{1-\sigma_i^{-1}} \mathrm{d}j\right]^{\frac{1}{1-\sigma_i^{-1}}}$$

Model–Intermediate Good Producers

- **Production**: Firm $ij, i \in \{u, d\}, j \in [0, 1]$ produces with a CRS production function

$$Y^S_{uj,t} = Z_{u,t} L_{uj,t} \qquad\qquad Y^S_{dj,t} = Z_{d,t} L^{1-\alpha_{du}}_{dj,t} X^{\alpha_{du}}_{dj,u,t}$$

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- **Pricing**: In sector $i \in \{u, d\}$, i.i.d. price changes arrive at Poisson rate $\theta_i > 0$

- A firm ij that gets to change its price at time t maximizes

$$\max_{P_{ij,t}} \int_0^\infty \theta_i e^{-(\theta_i h + \int_0^h i_{t+s} \mathrm{d}s)} [\underbrace{(1 - \tau_{i,t}) P_{ij,t} \mathcal{D}({}^{P_{ij,t}}/{}_{P_{i,t+h}}; Y_{i,t+h})}_{\text{total revenue at time } t} - \underbrace{\mathcal{C}_i(Y^S_{ij,t+h}; \mathbf{P}_{t+h}, Z_{i,t+h})}_{\text{total cost at time } t}] \mathrm{d}h$$

$$\text{subject to} \quad Y^S_{ij,t+h} \geq \mathcal{D}({}^{P_{ij,t}}/{}_{P_{i,t+h}}; Y_{i,t+h}), \quad \forall h \geq 0$$

Theoretical Results

Results–Sectoral Price Dynamics

- Log-linearize around the efficient steady state
- Let $\mathsf{A} = [a_{ij}] \in \mathbb{R}^{2\times 2}$ be input-output matrix
- This presentation (General results in the paper):

$$\mathsf{A} = \begin{bmatrix} 0 & 0 \\ a_{du} & 0 \end{bmatrix}$$

- Domar weights of sectors in the efficient steady state:

$$\lambda_u \equiv \frac{P_u Y_u}{PC} = \beta + (1-\beta)a_{du}; \qquad \lambda_d \equiv \frac{P_d Y_d}{PC} = (1-\beta)$$

- **Assumption:** $\rho/\theta_i \to 0, i \in \{u, d\}$

Results–Sectoral Price Dynamics

Proposition

Sectoral Phillips curves given by:

$$\dot{\pi}_{u,t} = \theta_u^2(\lambda_d r_t - \alpha_u x_t)$$
$$\dot{\pi}_{d,t} = \theta_d^2(-\lambda_u r_t - \alpha_d x_t)$$

- $r_t \equiv (p_{u,t} - p_{d,t}) - (p_{u,t} - p_{d,t})^f$ is the *relative price gap* of upstream sector to downstream sector
- $x_t \equiv y_t - y_t^f$ is the GDP gap
- $\boldsymbol{\lambda} \equiv (\lambda_u, \lambda_d)'$ are the Domar weights of upstream and downstream sectors
- $\boldsymbol{\alpha} \equiv (\alpha_u, \alpha_d)'$ are the labor shares of upstream and downstream sectors
- $(p_{u,t} - p_{d,t})^f$ and y_t^f are independent of monetary policy

Results–Aggregate Price Dynamics

Definition (Aggregate Inflation)

$$\pi_t \equiv \beta\pi_{u,t} + (1-\beta)\pi_{d,t}$$

Corollary

$$\dot{\pi}_t = \underbrace{(\beta\lambda_d\theta_u^2 - (1-\beta)\lambda_u\theta_d^2)r_t}_{\text{Inflation due to relative price gaps}} - \underbrace{(\beta\alpha_u\theta_u^2 + (1-\beta)\alpha_d\theta_d^2)x_t}_{\text{Inflation due to aggregate slack}}$$

- Aggregate inflation dynamics not only determined by aggregate GDP gap, x_t

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- Aggregate inflation dynamics not only determined by aggregate GDP gap, x_t
- It also depends on relative price changes, captured by the *relative price gap*, r_t
- *Relative price gaps* relevant **except** for knife-edge case where

$$\beta\lambda_d\theta_u^2 = (1-\beta)\lambda_u\theta_d^2$$

Monetary policy

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$$x_t = 0, \ \forall t \geq 0$$

- **Transition dynamics**: one-time unanticipated permanent shock to relative prices (*productivity or wedge of the upstream sector*) so that $r_0 \neq 0$

Results–Inflation IRFs to Relative Price Shocks under $i_t = \dot{m}_t = 0$

Proposition

Under $i_t = \dot{m}_t = 0$, sectoral inflation IRFs to a one-time unanticipated permanent shock to relative prices:

$$\frac{\partial \pi_{u,t}}{\partial \pi_{u,0}} = e^{-\theta_u t} \qquad \text{(Upstream Sector Inflation IRF)}$$

$$\frac{\partial \pi_{d,t}}{\partial \pi_{u,0}} = a_{du} \frac{\theta_d}{\theta_d + \theta_u} \left(\frac{\theta_d e^{-\theta_u t} - \theta_u e^{-\theta_d t}}{\theta_d - \theta_u} \right) \qquad \text{(Downstream Sector Inflation IRF)}$$

- Inflation in the upstream sector propagates downstream ($a_{du} > 0$)
- Spillover inflation is positive positive along the whole transition path

IRF example | Long-run pass-through | Short-run pass-through

Results–Inflation IRFs to Relative Price Shocks under $x_t = 0, \forall t \geq 0$

Proposition

IRFs to a one-time unanticipated permanent shock to relative prices, when monetary policy implements $x_t = 0, \forall t \geq 0$:

$$r_t = r_0 e^{-\bar{\xi} t}, \quad \bar{\xi} = \sqrt{\lambda_d \theta_u^2 + \lambda_u \theta_d^2} \qquad \text{(Relative prices)}$$

where $\zeta \equiv \frac{\lambda_u \theta_d^2}{\lambda_u \theta_d^2 + \lambda_d \theta_u^2}$

- Even without any additional shocks, there is endogenous persistence

Example IRF

Results–Inflation IRFs to Relative Price Shocks under $x_t = 0, \forall t \geq 0$

PROPOSITION

IRFs to a one-time unanticipated permanent shock to relative prices, when monetary policy implements $x_t = 0, \forall t \geq 0$:

$$r_t = r_0 e^{-\bar{\xi} t}, \quad \bar{\xi} = \sqrt{\lambda_d \theta_u^2 + \lambda_u \theta_d^2} \qquad \text{(Relative prices)}$$

$$p_{u,t} = (1 - \zeta) r_t \qquad \text{(Upstream Sector Price IRF)}$$

$$p_{d,t} = -\zeta r_t \qquad \text{(Downstream Sector Price IRF)}$$

$$\pi_t = \bar{\xi}(\zeta - \beta) r_t \qquad \text{(Aggregate Inflation IRF)}$$

where $\zeta \equiv \frac{\lambda_u \theta_d^2}{\lambda_u \theta_d^2 + \lambda_d \theta_u^2}$

- Even without any additional shocks, there is endogenous persistence

Example IRF

Results–CPI inflation without aggregate slack

Proposition

Suppose $\theta_u > \theta_d$ and monetary policy implements $x_t = 0, \forall t \geq 0$. An increase in the relative price of the upstream sector caused by a permanent shock is *CPI inflationary* if and only if

$$a_{du} > \frac{\beta}{(1-\beta)} \times \left(\frac{\theta_u^2}{\theta_d^2} - 1\right)$$

- Without IO linkages, inflationary shock to the flexible upstream sector *can't* be CPI inflationary

GDP gap stabilization price index

Quantitative Results

Calibration

- 1997 IO Use table from the BEA at summary level (66 sectors)
- Frequency of price adjustment from Pasten et al. (2020)
- Divide sectors into a flexible upstream and a sticky downstream
- $a_{uu}, a_{dd} > 0$
- Examples in flex. upstream: Oil and gas extraction, Petroleum and coal products, Utilities, Primary metals

Parameter	Description	Value
β	Upstream sector consumption share	0.1
θ_u	Upstream sector frequency of price adjustment	0.29
θ_d	Downstream sector frequency of price adjustment	0.09
a_{uu}	Cost share of upstream sector on upstream sector	0.31
a_{du}	Cost share of downstream sector on upstream sector	0.13
a_{dd}	Cost share of downstream sector on downstream sector	0.47

Upstream

An Experiment for the Post-COVID-19 Inflation

- At $t = 0$, one-time unanticipated permanent shock to upstream sector, $r_0 \neq 0$
  - Shock such that y-o-y aggregate inflation reaches **7% after 12 months**

An Experiment for the Post-COVID-19 Inflation

- At $t = 0$, one-time unanticipated permanent shock to upstream sector, $r_0 \neq 0$
  - Shock such that y-o-y aggregate inflation reaches **7% after 12 months**
- Monetary policy reaction function:
  1. **No monetary policy response**: For $t < T$, $\dot{m}_t = 0 \implies i_t = 0$
  2. **Soft-landing**: For $t \geq T, x_t = 0$

Experiment for the Post-COVID-19 Inflation × Data

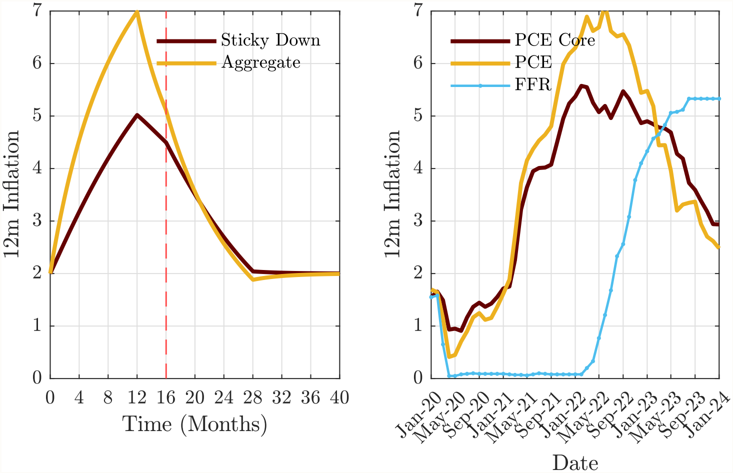
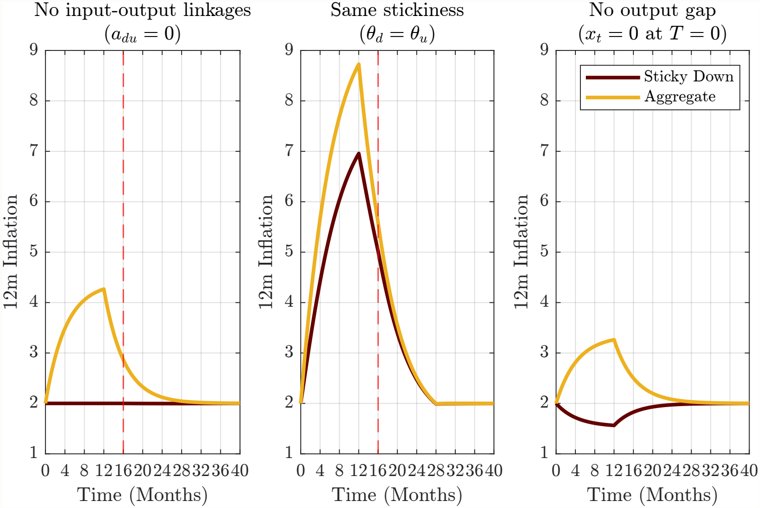


Figure 1: Left: Experiment. **Right**: Data. Shock at $t = 0$. Monetary policy reaction function: For $t < 16$, no monetary response. For $t \geq 16$, switch to a soft-landing policy. Relative Prices 12m

Three Counterfactuals



Left: No IO linkages. **Middle:** Hom. price stickiness. **Right:** GDP gap stabilization $\forall t \geq 0$.

Empirical Framework and Results

Data

- 1997 IO Use table from the BEA at summary level (66 sectors)
- Frequency of price adjustment from Pasten, Schoenle, and Weber (2020)
- 1997 BEA PCE-IO bridge
- BEA PCE price indices for (sectoral) consumer prices
- BEA PCE quantity indices for (sectoral) consumer quantities
- BLS producer price index for relative producer price of energy
- Känzig (2021) oil supply news shock as IV
- BLS unemployment rate

Heterogeneous Sectoral Effects of a Relative Price of Energy Shock

- **Our model predicts**: $p_{d,h} - p_{d,0} \propto \left[\frac{a_{j,\text{energy}}}{1-a_{jj}} \times \frac{\xi_j}{\xi_j+\xi_{\text{energy}}}\right] h \times |p_{u,0}|, \quad \xi_j \equiv \theta_j \sqrt{1-a_{jj}}$
- Panel local projection IV specification:

$$\begin{aligned}
\log P_{jt+h} - \log P_{jt-1} = \beta_0^{(h)} + \beta_1^{(h)} \times \left(\log\left(\frac{\text{PPI energy}_t}{\text{PPI}_t}\right) - \log\left(\frac{\text{PPI energy}_{t-1}}{\text{PPI}_{t-1}}\right)\right) \\
+ \beta_2^{(h)} \times \left[\frac{a_{j,\text{energy}}}{1-a_{jj}} \frac{\xi_j}{\xi_j + \xi_{\text{energy}}}\right] \times \left(\log\left(\frac{\text{PPI energy}_t}{\text{PPI}_t}\right) - \log\left(\frac{\text{PPI energy}_{t-1}}{\text{PPI}_{t-1}}\right)\right) \\
+ \sum_{k=1}^{12} \text{Controls}_{j,t-k} + \epsilon_{jt}
\end{aligned}$$

- Instrumental Variable: Känzig (2021) oil supply news shock
- Model prediction: $\beta_2^{(h)} > 0$
- Time Window: 1998:01 - 2023:06

Results in line with model predictions: $\beta_2^{(h)} > 0$

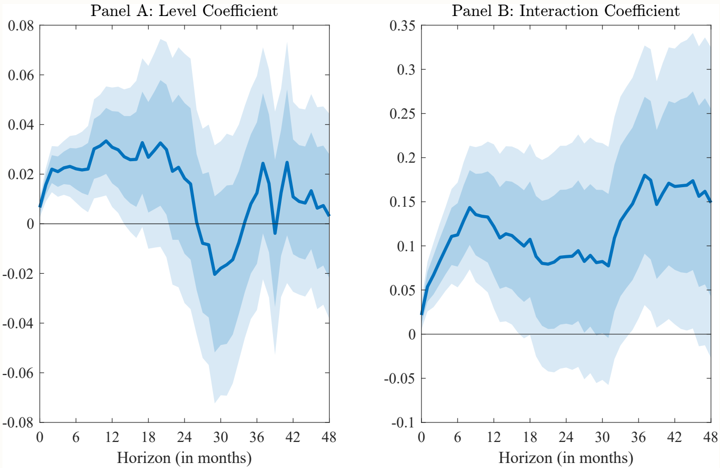


Figure 2: Panel A: Level. Panel B: Interaction. F-stat: 49.96. Ex-PCE categories with positive energy sectors in it. Period: 1998:01-2023:06. Driscoll-Kraay SE. 68% and 90% CI. Pre-COVID

Agg. Spec Magnitudes

Robustness

- Quantities Qty
- Kanzig shock as independent variable Kanzig shock
- Placebo Placebo
- Time FE Time FE
- Sector FE Sector FE
- Oil and gas extraction as the oil sector Oil and gas extraction
- GSCPI GSCPI prices GSCPI quantities

Conclusion

Conclusion

- Two-sector model with IO linkages and heterogeneity of price stickiness:
    - Helps understand *inflation dynamics* in the aftermath of COVID-19
    - Even with *zero* GDP gap, relative price changes can generate aggregate inflation dynamics
- Empirical results suggest:
    - *Relative price of energy* shocks can act as negative aggregate supply shocks
    - *Sectoral consumer price* responses are consistent with model predictions

Thank you!

References

Afrouzi, H. and S. Bhattarai (2022). Inflation and gdp dynamics in production networks: A sufficient statistics approach. Manuscript.

Aoki, K. (2001). Optimal monetary policy responses to relative-price changes. *Journal of monetary economics 48*(1), 55–80.

Ball, L. and N. G. Mankiw (1995). Relative-price changes as aggregate supply shocks. *The Quarterly Journal of Economics 110*(1), 161–193.

Benigno, P. (2004). Optimal monetary policy in a currency area. *Journal of international economics 63*(2), 293–320.

Carvalho, C., J. W. Lee, and W. Y. Park (2021). Sectoral price facts in a sticky-price model. *American Economic Journal: Macroeconomics 13*(1), 216–56.

Känzig, D. R. (2021, April). The macroeconomic effects of oil supply news: Evidence from opec announcements. *American Economic Review 111*(4), 1092–1125.

La'O, J. and A. Tahbaz-Salehi (2022). Optimal monetary policy in production networks. *Econometrica 90*(3), 1295–1336.

Lorenzoni, G. and I. Werning (2023). Inflation is conflict. Technical report, National Bureau of Economic Research.

Minton, R. and B. Wheaton (2022). Hidden inflation in supply chains: Theory and evidence. Manuscript.

Pasten, E., R. Schoenle, and M. Weber (2020). The propagation of monetary policy shocks in a heterogeneous production economy. *Journal of Monetary Economics 116*, 1–22.

Rubbo, E. (2023). Networks, phillips curves and monetary policy. Econometrica (Forthcoming).

Ruge-Murcia, F. J. and A. L. Wolman (2022, May). Relative Price Shocks and Inflation. Working Paper 22-07, Federal Reserve Bank of Richmond.

Woodford, M. (2003). *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton University Press.

Relative price of energy shocks are expansionary for prices

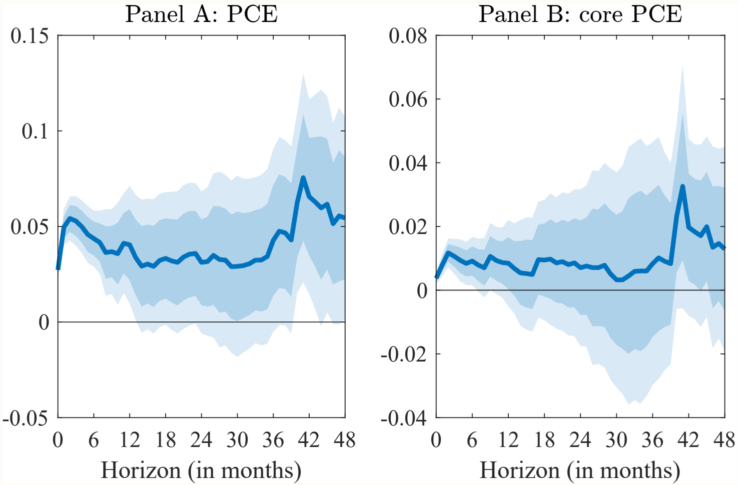


Figure 3: Panel A: PCE. F-stat: 111.08. **Panel B: PCE core.** F-stat: 105.69. Sample: 1986:01-2020:03. HAC robust standard errors. 68% and 90% CI. back

Relative price of energy shocks are contractionary for real economic activity

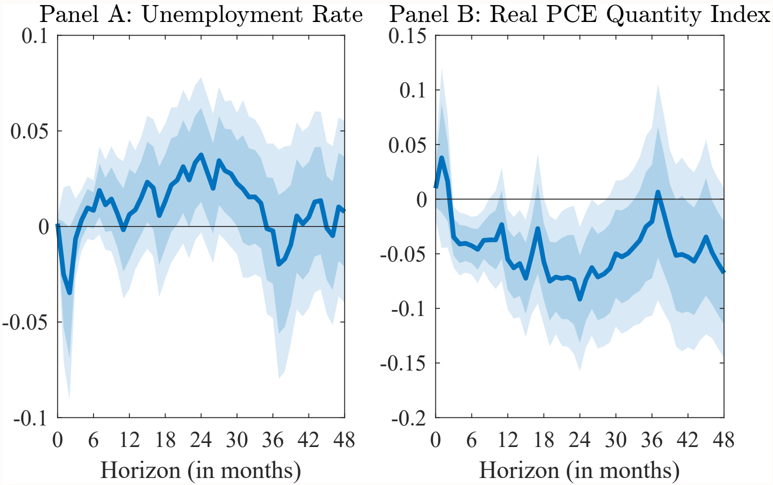


Figure 4: Panel A: Unemployment rate. F-stat: 113.75. **Panel B: Real PCE quantity.** F-stat: 135.43. Sample: 1986:01-2020:03. HAC robust standard errors. 68% and 90% CI. back

Placebo

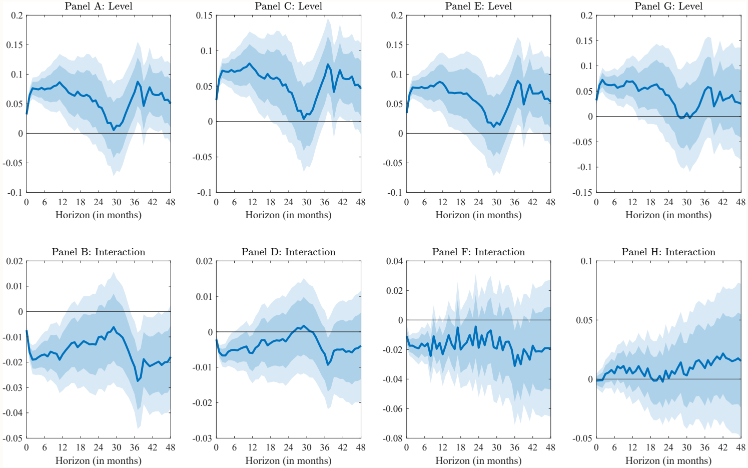


Figure 5: Panel A, B: Ambulatory health care serv. Panel C, D: Hospitals. Panel E, F: Insurance carriers and rel. activ. Panel G, H: Legal services. Period: 1998:01-2023:06. Driscoll-Kraay SE. 68% and 90% CI. F-Stat > 10. All PCE categories. Back

Time Fixed-Effects

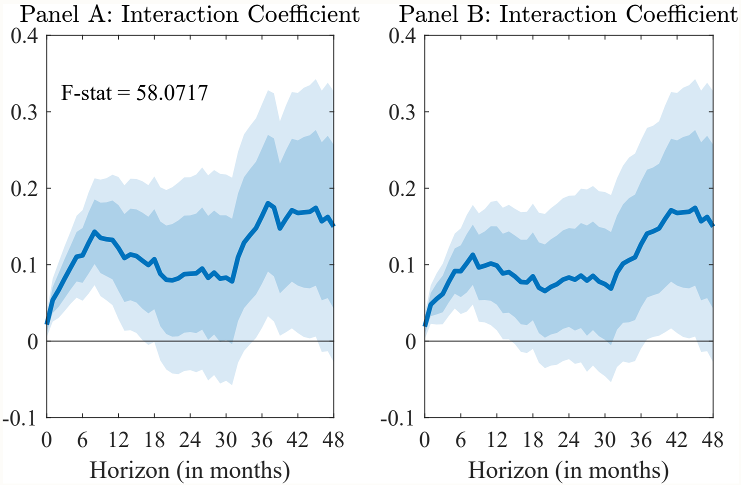


Figure 6: Panel A: 1998:01-2023:06. Panel B: 1998:01-2020:03. F-Stat: 58.07. Ex-PCE categories with positive energy sector in it. Driscoll-Kraay SE. 68% and 90% CI. Back

Sector Fixed-Effects

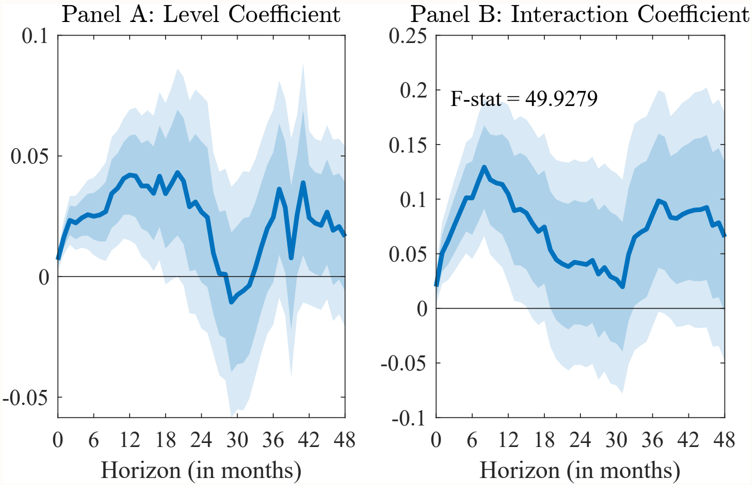


Figure 7: Panel A: Level. Panel B: Interaction. F-Stat (Interaction): 49.92. Ex-PCE categories with positive energy sector in it. Driscoll-Kraay SE. 68% and 90% CI. Back

Oil and gas extraction

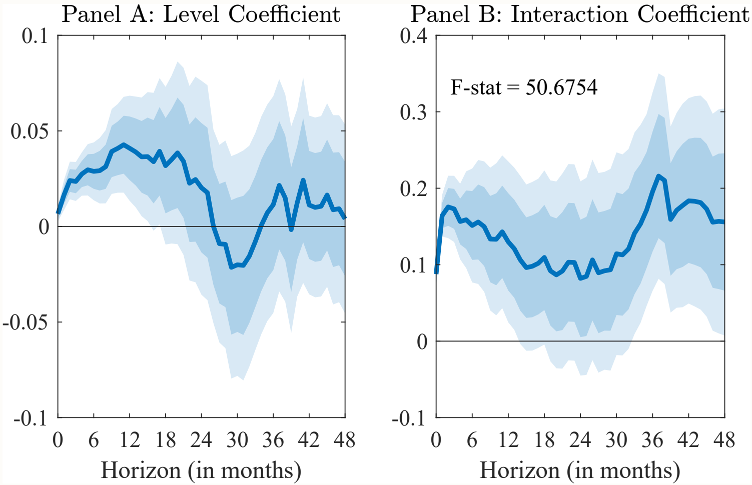


Figure 8: Panel A: Level. Panel B: Interaction. F-Stat (Interaction): 50.67. All PCE categories. Driscoll-Kraay SE. 68% and 90% CI. Back

Calibration–Upstream sector

Name	IO Code
Oil and gas extraction	211
Petroleum and coal products	324
Utilities	22
Primary metals	331
Wholesale trade	42
Farms	111CA
Other real estate	ORE
Federal Reserve banks, credit intermediation, and related activities	521CI

Back

Results in line with model predictions: $\beta_2^{(h)} > 0$, Pre-COVID-19

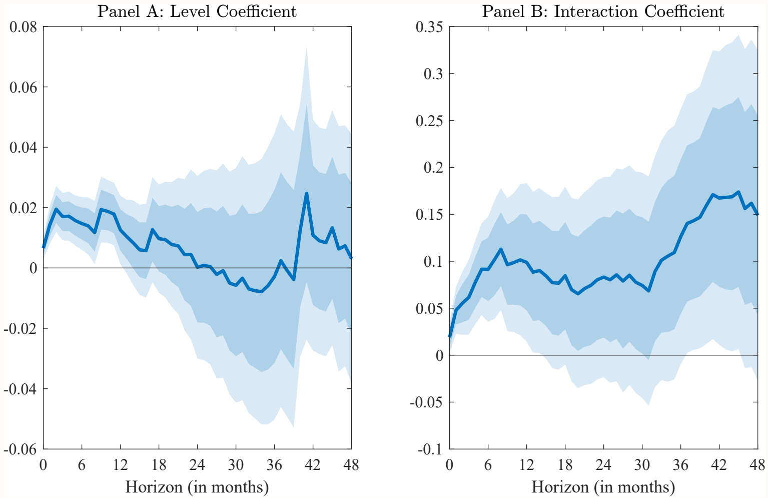


Figure 9: Panel A: Level. Panel B: Interaction. F-stat: 49.96. Ex-PCE categories with positive energy sectors in it. Period: 1998:01-2020:03. Driscoll-Kraay SE. 68% and 90% CI. Back

PCE Inflation in the data

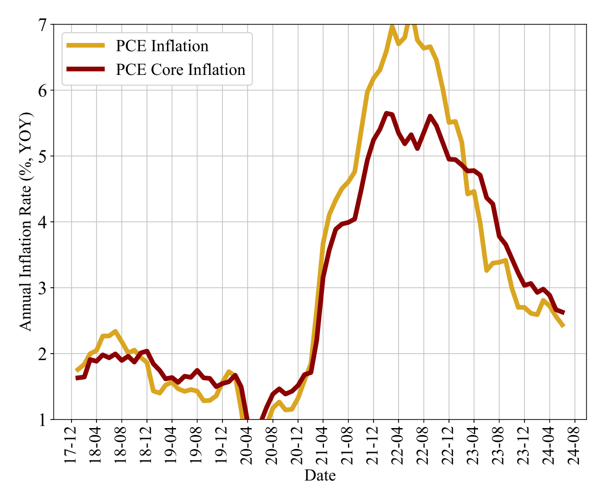


Figure 10: PCE Inflation, YOY change. back

Results–Kanzig as independent variable

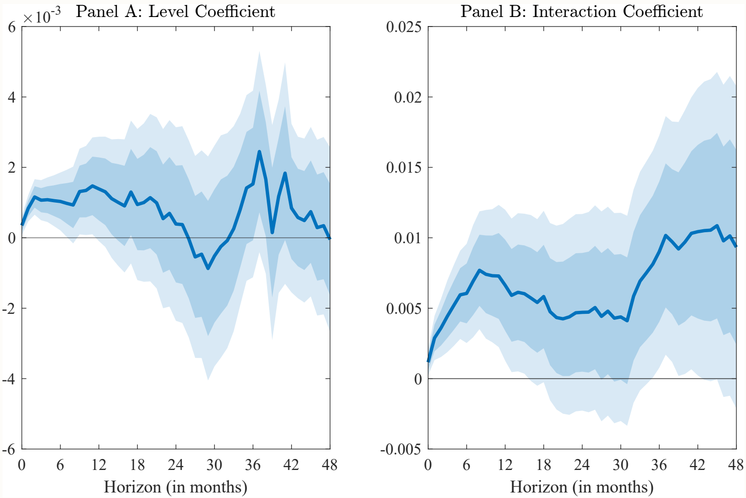


Figure 11: Panel A: Level. Panel B: Interaction. Ex-PCE categories with positive energy sectors in it. Period: 1998:01-2023:06. Driscoll-Kraay SE. 68% and 90% CI. Back

Domar weights

$$\lambda_1 = \frac{1}{1 - a_{11}} \left(\beta + (1 - \beta) \frac{a_{21}}{1 - a_{22}} \right)$$

$$\lambda_2 = \frac{1 - \beta}{1 - a_{22}}$$

- β : Consumption share of sector 1

Back

Sectoral price paths after permanent shock to relative prices

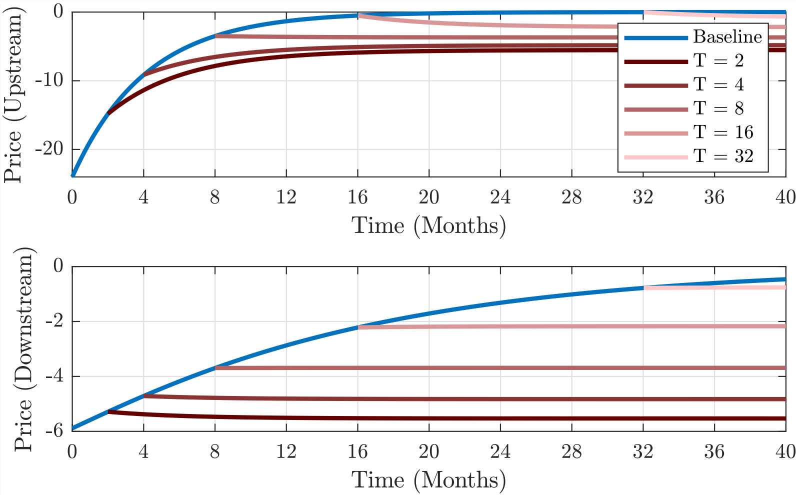


Figure 12: Blue: price path under no monetary response. Red: price path contingent on monetary policy switching to soft-landing at T. Back

Sectoral Inflation Responses to a Relative Price Shock under $i_t = \dot{m}_t = 0$

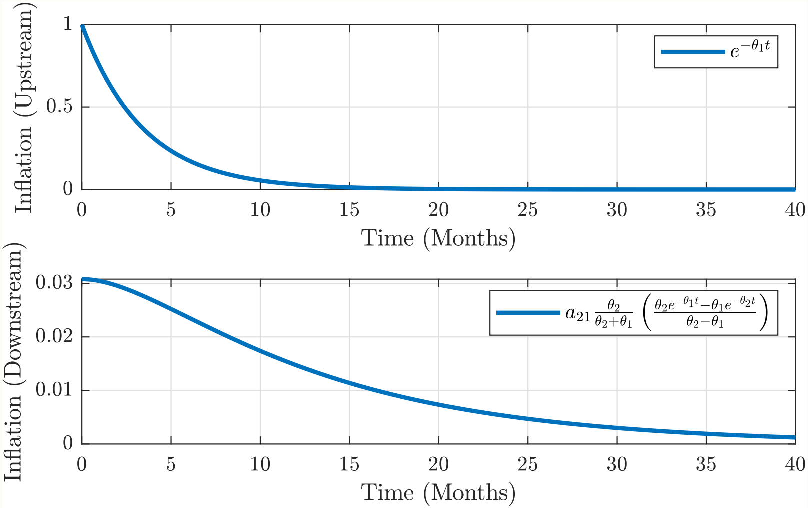


Figure 13: Shock to the upstream sector such that $\pi_{1,0} = 1$. Back

GDP gap stabilization price index

- To implement $x_t = 0, \forall t \geq 0$, the Central Bank can target the following price index:

$$\zeta p_{1,t} + (1 - \zeta) p_{2,t} = 0, \qquad \zeta \equiv \frac{\lambda_1 \theta_2^2}{\lambda_1 \theta_2^2 + \lambda_2 \theta_1^2}$$

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Model–Intermediate Good Producers

- **Pricing**: In sector $i \in \{1, 2\}$, i.i.d. price changes arrive at Poisson rate $\theta_i > 0$
- A firm ij that gets to change its price at time t maximizes

$$\max_{P_{ij,t}} \int_0^\infty \theta_i e^{-(\theta_i h + \int_0^h i_{t+s} \mathrm{d}s)} [\underbrace{(1 - \tau_{i,t}) P_{ij,t} \mathcal{D}(P_{ij,t}/P_{i,t+h}; Y_{i,t+h})}_{\text{total revenue at time } t} - \underbrace{\mathcal{C}_i(Y^S_{ij,t+h}; \mathbf{P}_{t+h}, Z_{i,t+h})}_{\text{total cost at time } t}] \mathrm{d}h$$

$$\text{subject to} \quad Y^S_{ij,t+h} \geq \mathcal{D}(P_{ij,t}/P_{i,t+h}; Y_{i,t+h}), \quad \forall h \geq 0$$

Back

Quantity Relative Responses

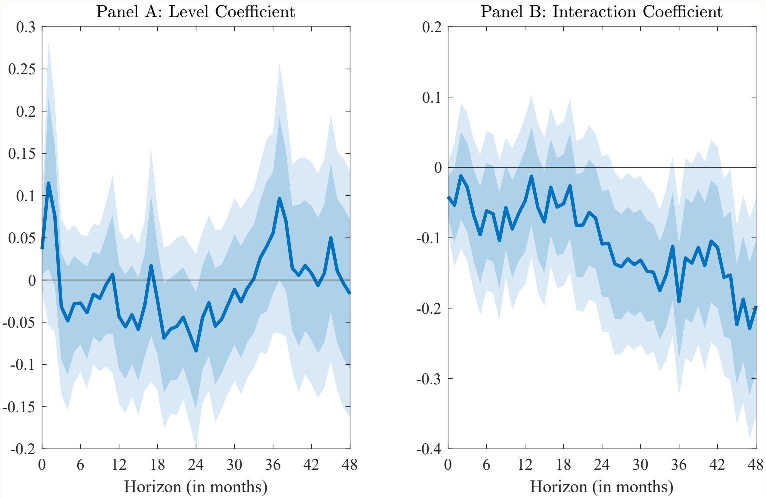

Figure 14: Panel A: Level. Panel B: Interaction. F-stat: 49.96. Ex-PCE categories with positive energy sectors in it. Period: 1998:01-2020:03. Driscoll-Kraay SE. 68% and 90% CI. Back

12-Month Change in Relative Prices

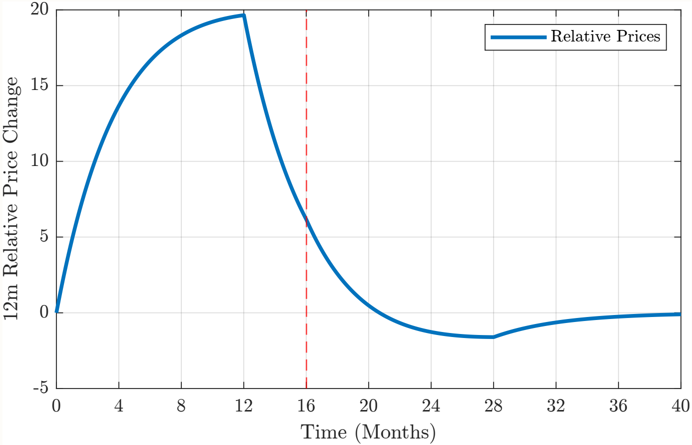

Figure 15: 12m relative price change. At $t = 16$, soft-landing. Back

Sectoral Inflation Responses to a Relative Price Shock under $x_t = 0$

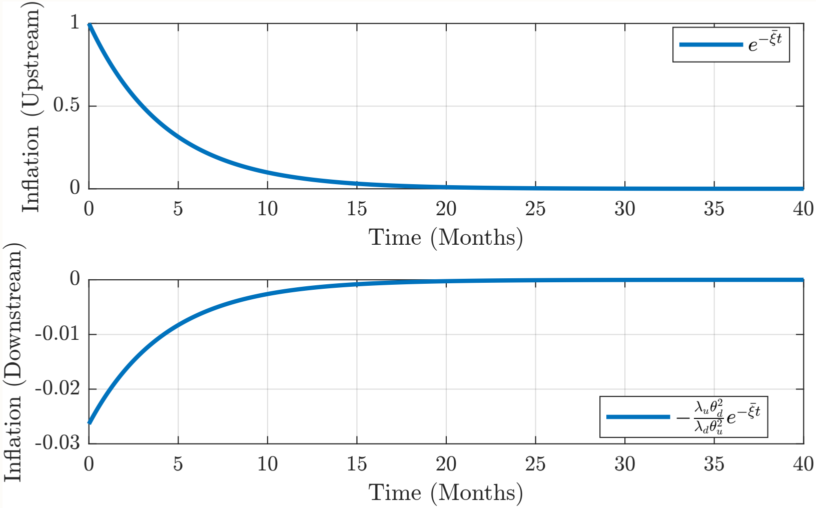

Figure 16: Shock to the upstream sector such that $\pi_{1,0} = 1$. Back

Results–Sectoral Inflation Cumulative Impulse Response

Corollary

Under $i_t = \dot{m}_t = 0$, the sectoral inflation cumulative impulse responses (CIR) are given by

$$\mathrm{CIR}_u^\pi = \theta_u^{-1} \qquad \text{(Upstream Sector Inflation CIR)}$$

$$\mathrm{CIR}_d^\pi = a_{du} \times \mathrm{CIR}_u^\pi \qquad \text{(Downstream Sector Inflation CIR)}$$

- Total spillover from upstream to downstream sector depends on
  - Input share of downstream sector from upstream sector, a_{du}

Back

Results–Impact response

Corollary

Under $i_t = \dot{m}_t = 0$, the impact response of downstream sector is given by

$$\frac{\partial \pi_{d,0}}{\partial \pi_{u,0}} = \underbrace{a_{du}}_{\substack{\text{Long-run} \\ \text{pass-through}}} \times \underbrace{\frac{\theta_u^{-1}}{\theta_d^{-1} + \theta_u^{-1}}}_{\substack{\text{Relative duration of} \\ \text{price stickiness}}}$$

- Impact response of downstream sector depends on relative price stickiness
  - The more flexible the upstream sector, the more dampened the response

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Aggregate effects of relative price of energy shocks

- Local projections IV specification:

$$
\begin{aligned}
\log(Y_{t+h}) - \log(Y_{t-1}) = \alpha^{(h)} + \beta^{(h)} \times \Big(\log(\frac{\text{PPI energy}_t}{\text{PPI}_t}) - \log(\frac{\text{PPI energy}_{t-1}}{\text{PPI}_{t-1}}) \Big) \\
+ \sum_{k=1}^{12} \gamma_k^{(h)} \Big(\log(Y_{t-k}) - \log(Y_{t-k-1}) \Big) \\
+ \sum_{k=1}^{12} \zeta_k^{(h)} \Big(\log(\frac{\text{PPI energy}_{t-k}}{\text{PPI}_{t-k}}) - \log(\frac{\text{PPI energy}_{t-k-1}}{\text{PPI}_{t-k-1}}) \Big) + \varepsilon_t
\end{aligned}
$$

- Instrumental variable: Känzig (2021) oil supply news shock
- Time Window: 1986:01 - 2023:06

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Relative price of energy shocks are *expansionary* for prices

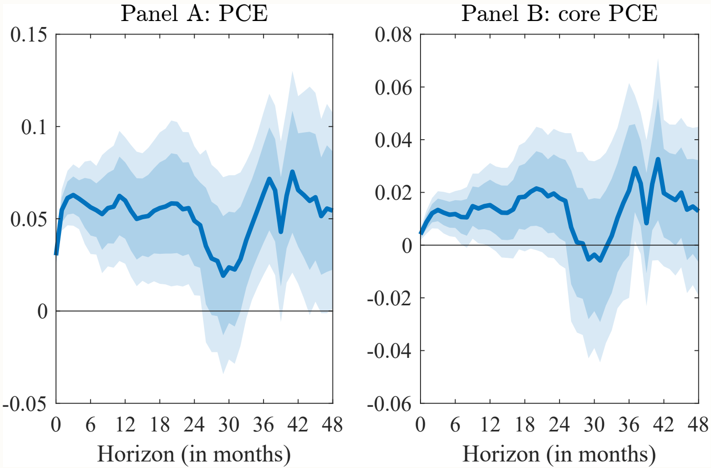

Figure 17: Panel A: PCE. F-stat: 111.08. **Panel B: PCE core.** F-stat: 105.69. Sample: 1986:01-2023:06. HAC robust SE. 68% and 90% CI. Pre-COVID Back

Relative price of energy shocks are *contractionary* for real economic activity

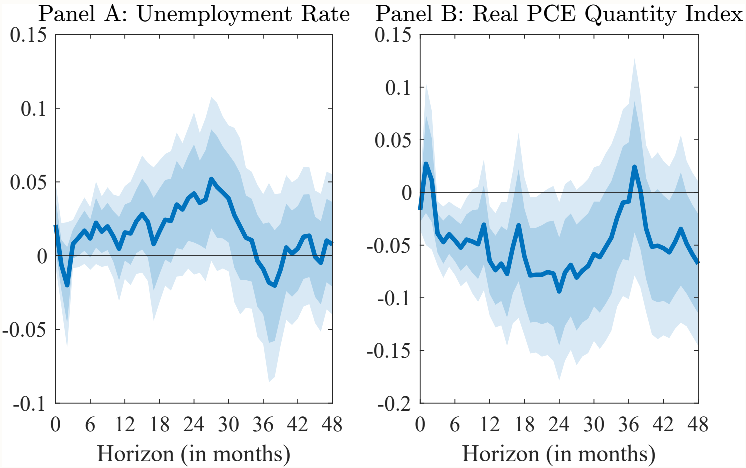

Figure 18: Panel A: Unemployment rate. F-stat: 113.75. **Panel B: Real PCE qty.** F-stat: 135.43. Sample: 1986:01-2023:06. HAC robust standard errors. 68% and 90% CI. Pre-COVID Back

Quantitative relevance of the interaction effects

- Moving from the 25th to the 75th pct of the distribution of the sufficient statistic leads the response to a 1% increase in the relative price of energy to increase
  - 0.07 bps on impact
  - 0.28 bps after 3 months
  - 0.55 bps after 36 months
- The responses of the 25th, 50th, and the 75th percentiles of the distribution of the sufficient statistic are, respectively,
  - 0.67, 0.69, and 0.75 bps on impact
  - 2.16, 2.23, and 2.44 bps after 3 months
  - 1.37, 1.50, and 1.93 bps after 36 months

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Global Supply Pressure Index expansionary for prices

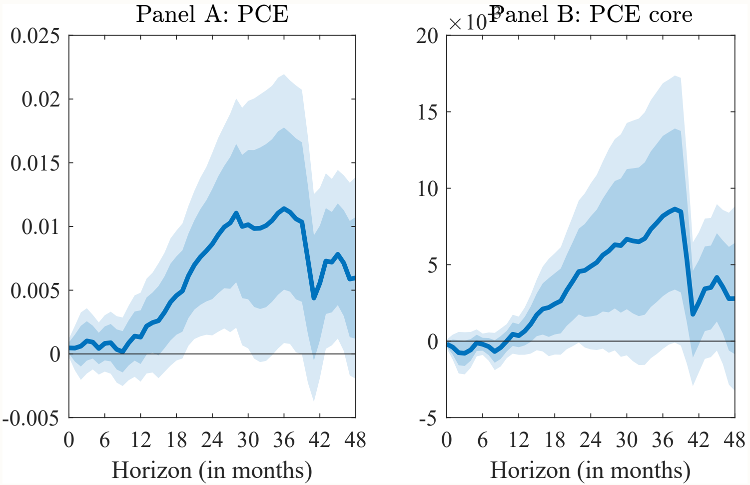

Figure 19: Panel A: PCE. Panel B: PCE core. Independent Variable: NY GSCPI. Period: 1998:01-2020:03. HAC robust SE. 68% and 90% CI. With Controls. Back

Global Supply Pressure Index contractionary for economic activity

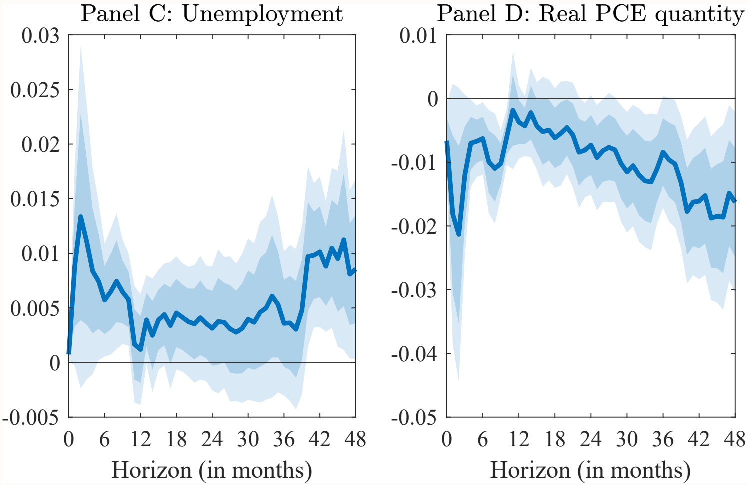

Figure 20: Panel A: Unemployment Rate. Panel B: Real PCE quantity. Independent Variable: NY GSCPI. Period: 1998:01-2020:03. HAC robust SE. 68% and 90% CI. With Controls. Back

Quantity Relative Responses

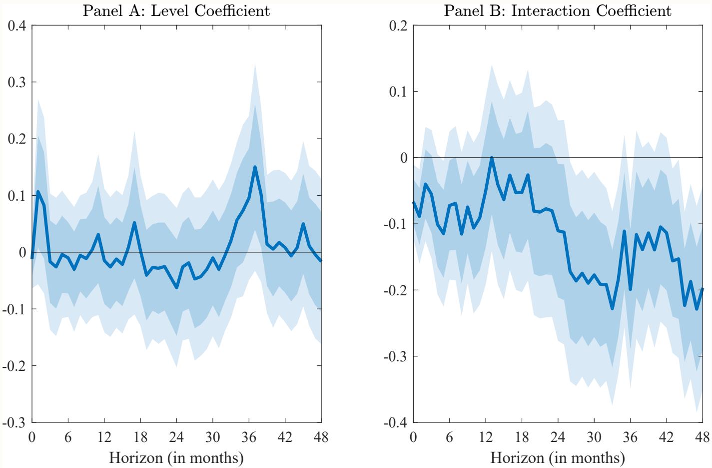

Figure 21: Panel A: Level. Panel B: Interaction. F-stat: 49.96. Ex-PCE categories with positive energy sectors in it. Period: 1998:01-2023:06. Driscoll-Kraay SE. 68% and 90% CI.

Pre-COVID Back