Decomposing Supply and Demand Driven Inflation

Adam Shapiro

Federal Reserve Bank of San Francisco

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- 1970's high inflation $\rightarrow$ Oil-related supply factors (Blinder and Rudd 2013) and monetary-policy related demand factors (Primiceri 2006))
- Post-covid inflation surge $\rightarrow$ both supply and demand factors appear responsible (Jorda et al. 2021) and (Ball et al. 2022)

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"What [the Fed] can control is demand, we can't really affect supply with our policies... so the question whether we can execute a soft landing or not, it may actually depend on factors that we don't control." -Jerome Powell

Motivation

Is there a way to measure, in real time, the extent to which supply or demand is driving inflation?

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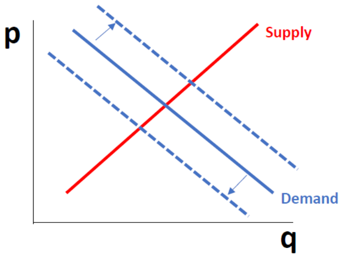
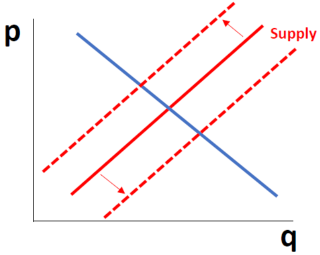
This study $\Rightarrow$ two new data series:

Supply-driven inflation:	categories where prices $\uparrow\downarrow$ due to a supply surprise
Demand-driven inflation:	categories where prices $\uparrow\downarrow$ due to a demand surprise

Identification based on Economics 101:

- Supply shock: price and quantity move in the opposite direction
- Demand shock: price and quantity move in the same direction





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Issue:

- Aggregate data $\rightarrow$ non-sign restrictions needed to infer *magnitude* of shocks

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Solution:

- Sectoral data $\rightarrow$ **continuous** measure of *magnitude* of shocks
  - Aggregating over binary information using category weights

Methodology

Upward sloping supply curve and a downward sloping demand curve applied to each sector i:

$$\begin{aligned} \text{Supply curve:} \quad q_i &= \sigma^i p_i + \alpha^i \\ \text{Demand curve:} \quad p_i &= -\delta^i q_i + \beta^i \end{aligned}$$

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$$\begin{aligned} \text{Supply shock:} \quad \varepsilon_i^s &= (q_{i,t} - \sigma^i p_{i,t}) - (q_{i,t-1} - \sigma^i p_{i,t-1}) \\ \text{Demand shock:} \quad \varepsilon_i^d &= (\delta^i q_{i,t} + p_{i,t}) - (\delta^i q_{i,t-1} + p_{i,t-1}) \end{aligned}$$

Methodology

Translating it into a structural VAR:

$$A^i z_{i,t} = \sum_{j=1}^{N} A^i_j z_{i,t-j} + \varepsilon_{i,t}$$

Price & quantity: $z_i = \begin{bmatrix} q_i \\ p_i \end{bmatrix}$

Sign restrictions: $A^i = \begin{bmatrix} 1 & -\sigma^i \\ \delta^i & 1 \end{bmatrix}$

Structural shocks: $\varepsilon_i = \begin{bmatrix} \varepsilon_i^s \\ \varepsilon_i^d \end{bmatrix}$

Methodology

Recovering the structural shocks from reduced-form estimation:

$$z_{i,t} = [A^i]^{-1} \sum_{j=1}^{N} A^i_j z_{i,t-j} + \nu_{i,t}$$

Reduced-form residuals: $\nu_i = \begin{bmatrix} \nu_i^q \\ \nu_i^p \end{bmatrix}$

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Reduced-form residuals: $\nu_i = \begin{bmatrix} \nu_i^q \\ \nu_i^p \end{bmatrix}$

Structural shocks can be recovered from reduced-form residuals:

$$\varepsilon_{i,t} = A^i \nu_{i,t}$$

Methodology

$$A^i \nu_{i,t} = \varepsilon_{i,t}$$

This means $\rightarrow$

$$\nu^p_{i,t} > 0, \nu^q_{i,t} > 0 \rightarrow \varepsilon^d_{i,t} > 0 \quad \text{(+ Demand Shock)}$$
$$\nu^p_{i,t} < 0, \nu^q_{i,t} < 0 \rightarrow \varepsilon^d_{i,t} < 0 \quad \text{(- Demand Shock)}$$
$$\nu^p_{i,t} < 0, \nu^q_{i,t} > 0 \rightarrow \varepsilon^s_{i,t} > 0 \quad \text{(+ Supply Shock)}$$
$$\nu^p_{i,t} > 0, \nu^q_{i,t} < 0 \rightarrow \varepsilon^s_{i,t} < 0 \quad \text{(- Supply Shock)}$$

Data

Publicly available price and quantity PCE data from the BEA.

I use the fourth level of disaggregation, for example:

- (1) services $\rightarrow$ (2) transportation services $\rightarrow$ (3) public transportation $\rightarrow$ (4) air transportation.

136 categories in the PCE price index
124 categories in the core PCE index
Available back to 1988

Estimation

Price & quantity regressions for each of the 136 categories, i, in the PCE:

$$
\begin{aligned}
q_{i,t} &= \sum_{j=1}^{12} \gamma_j^{qp} p_{i,t-j} + \sum_{j=1}^{12} \gamma_j^{qq} q_{i,t-j} + \nu_{i,t}^{q} \\
p_{i,t} &= \sum_{j=1}^{12} \gamma_j^{pp} p_{i,t-j} + \sum_{j=1}^{12} \gamma_j^{pq} q_{i,t-j} + \nu_{i,t}^{p}
\end{aligned}
$$

$q_{i,t} \rightarrow$ log quantity index of category i
$p_{i,t} \rightarrow$ log price index of category i

Estimation

Residuals, $\nu^q_{i,t}$ and $\nu^p_{i,t}$, are used to label each category i by month t:

$$\mathbb{1}_{i \in sup(+),t} = \begin{cases} 1 & \text{if } \nu^p_{i,t} < 0, \nu^q_{i,t} > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{1}_{i \in sup(-),t} = \begin{cases} 1 & \text{if } \nu^p_{i,t} > 0, \nu^q_{i,t} < 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{1}_{i \in dem(+),t} = \begin{cases} 1 & \text{if } \nu^p_{i,t} > 0, \nu^q_{i,t} > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{1}_{i \in dem(-),t} = \begin{cases} 1 & \text{if } \nu^p_{i,t} < 0, \nu^q_{i,t} < 0 \\ 0 & \text{otherwise} \end{cases}$$

Aggregating Supply and Demand Shocks

The share of spending with a supply or a demand shock:

$$\gamma_{s,t} = \sum_i \mathbb{1}_{i \in s,t} \omega_{i,t}$$

$s \in \{dem(+), dem(-), sup(+), sup(-)\}$.
$\omega_{i,t}$ is the **expenditure weight** of category i

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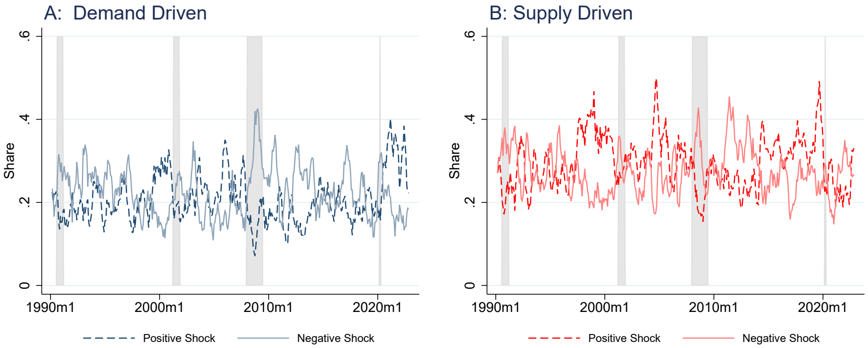

Shocks over the recent inflation surge

	Positive Demand Shocks (Share of Months)	
	2021m4-2023m7	Full Sample
Restaurants	0.68	0.53
Lotteries	0.64	0.40
Child Care	0.59	0.42
Higher Education	0.59	0.47
Rent (owner occupied)	0.59	0.49
Amusement Parks	0.59	0.38
Funeral & Burial Services	0.59	0.47
Water Supply & Sewage Maintenance	0.55	0.45
Electricity	0.55	0.29
Life Insurance	0.55	0.44

	Negative Supply Shocks (Share of Months)	
	2021m4-2023m7	Full Sample
New Light Trucks	0.73	0.33
Rent (tenant occupied)	0.68	0.51
Domestic Services	0.64	0.60
Tobacco	0.64	0.45
Food	0.64	0.43
Household Cleaning Products	0.64	0.35
Tires	0.64	0.33
Stationery & Misc Printed Mtls	0.64	0.35
Carpets & Other Floor Coverings	0.59	0.36
Dishes and Flatware	0.59	0.34

Supply- and demand-driven contributions to inflation

Two indicator functions defining whether category i experienced a supply shock or demand shock :

$$\mathbb{1}_{i \in sup,t} = \begin{cases} 1 & \text{if } \nu^p_{i,t} > 0, \nu^q_{i,t} < 0 \text{ or } \nu^p_{i,t} < 0, \nu^q_{i,t} > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbb{1}_{i \in dem,t} = \begin{cases} 1 & \text{if } \nu^p_{i,t} > 0, \nu^q_{i,t} > 0 \text{ or } \nu^p_{i,t} < 0, \nu^q_{i,t} < 0 \\ 0 & \text{otherwise} \end{cases}$$

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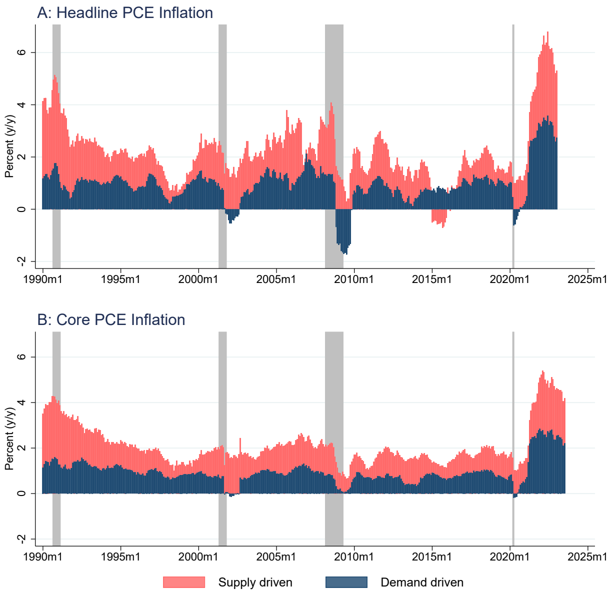
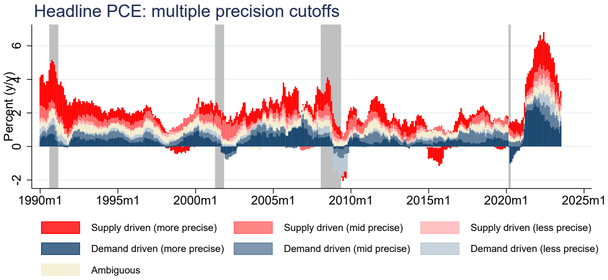
Monthly PCE inflation can be divided into two distinct components, the supply- and demand-driven contributions:

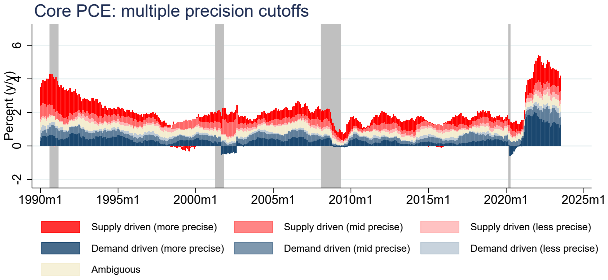
$$\pi_{t,t-1} = \underbrace{\sum_i \mathbb{1}_{i \in sup,t} \omega_{i,t} \pi_{i,t,t-1}}_{\text{supply-driven } (\pi^{sup}_{t,t-1})} + \underbrace{\sum_i \mathbb{1}_{i \in dem,t} \omega_{i,t} \pi_{i,t,t-1}}_{\text{demand-driven } (\pi^{dem}_{t,t-1})}$$

Supply- and demand-driven PCE Inflation



Precision Labeling





Probability Weights

"Weighted labels":

$$\pi_{t,t-1} = \underbrace{\sum_i \phi_{i,t}^{sup} \omega_{i,t} \pi_{i,t,t-1}}_{\text{supply-driven } (\pi_{t,t-1}^{sup})} + \underbrace{\sum_i \phi_{i,t}^{dem} \omega_{i,t} \pi_{i,t,t-1}}_{\text{demand-driven } (\pi_{t,t-1}^{dem})} .$$

$\phi_{i,t}^{sup}$: **probability** category *i* experienced a supply shock

$\phi_{i,t}^{dem}$: **probability** category *i* experienced a demand shock

Probability Weights

"Weighted labels":

$$\pi_{t,t-1} = \underbrace{\sum_i \phi_{i,t}^{sup}\omega_{i,t}\pi_{i,t,t-1}}_{\text{supply-driven } (\pi_{t,t-1}^{sup})} + \underbrace{\sum_i \phi_{i,t}^{dem}\omega_{i,t}\pi_{i,t,t-1}}_{\text{demand-driven } (\pi_{t,t-1}^{dem})}.$$

$\phi_{i,t}^{sup}$: **probability** category i experienced a supply shock

$\phi_{i,t}^{dem}$: **probability** category i experienced a demand shock

Bayesian weights: Bayesian VAR model $\Rightarrow$ collect the posterior estimates, results in distribution of indicator functions

$$\phi_{i,t}^{dem} = (1/S) * (\sum_{s=1}^{S} \mathbb{1}_{i \in dem,t}^{s}), \quad \phi_{i,t}^{sup} = 1 - \phi_{i,t}^{dem},$$

Parametric weights: Assume $\lambda_{i,t} = \nu_{i,t}^{p} \cdot \nu_{i,t}^{q}$ taken from a norm. dist.

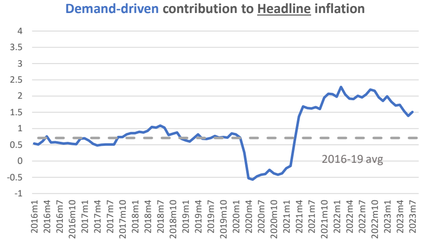
$$\phi_{i,t}^{dem} = P[z(\lambda_{i,t})], \quad \phi_{i,t}^{sup} = 1 - P[z(\lambda_{i,t})],$$

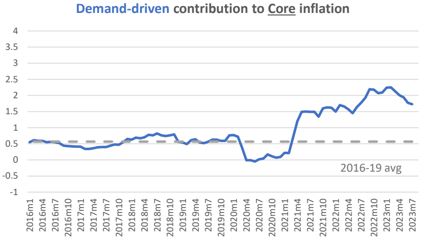
Robustness

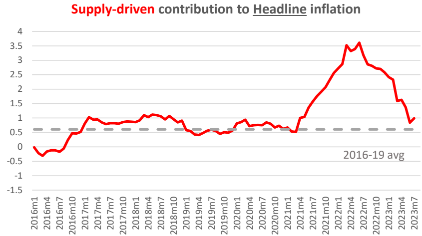
Table: Cross-correlations, alternative measures of supply- and demand-driven contributions to PCE inflation

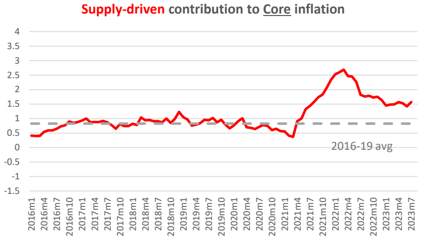
Variables	Baseline	Smooth-1	Smooth-2	Smooth-3	AR-3	AR-24	Wt. (Param.)	Wt. (Bayes.)	Rolling	Precision
					Supply-driven contribution					
Baseline	1.000									
Smooth-1	0.929	1.000								
Smooth-2	0.925	0.936	1.000							
Smooth-3	0.917	0.961	0.967	1.000						
AR-3	0.933	0.867	0.814	0.832	1.000					
AR-24	0.946	0.902	0.925	0.898	0.816	1.000				
Wt. (Param.)	0.958	0.923	0.939	0.938	0.897	0.925	1.000			
Wt. (Bayes.)	0.965	0.921	0.877	0.889	0.984	0.878	0.936	1.000		
Rolling	0.958	0.884	0.876	0.875	0.889	0.895	0.960	0.934	1.000	
Precision	0.963	0.889	0.845	0.854	0.954	0.868	0.895	0.966	0.909	1.000
					Demand-driven contribution					
Baseline	1.000									
Smooth-1	0.887	1.000								
Smooth-2	0.869	0.887	1.000							
Smooth-3	0.873	0.935	0.938	1.000						
AR-3	0.923	0.820	0.731	0.782	1.000					
AR-24	0.936	0.874	0.882	0.867	0.808	1.000				
Wt. (Param.)	0.937	0.858	0.861	0.887	0.891	0.908	1.000			
Wt. (Bayes.)	0.954	0.877	0.797	0.838	0.984	0.859	0.918	1.000		
Rolling	0.945	0.850	0.821	0.832	0.891	0.865	0.918	0.919	1.000	
Precision	0.989	0.890	0.873	0.879	0.907	0.925	0.922	0.942	0.946	1.000

Recent supply- and demand-driven inflation

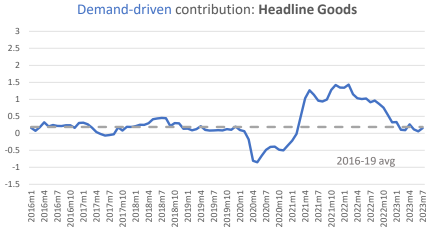


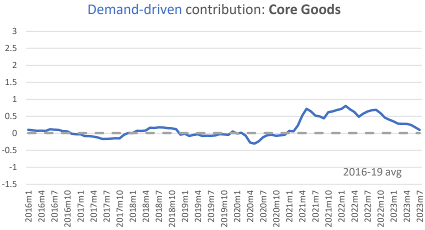


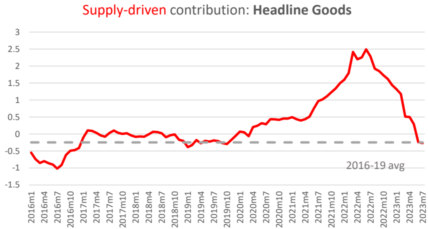


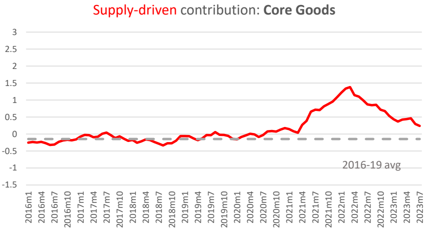


Supply factors heavily influenced goods inflation

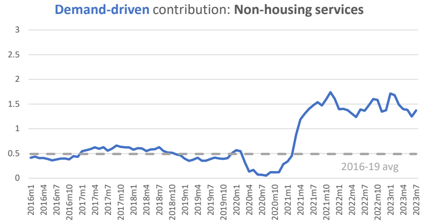


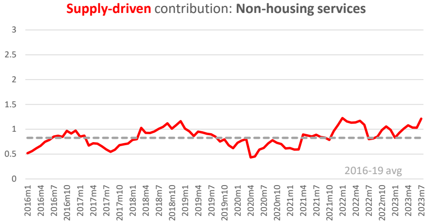






Demand factors continue to influence services inflation





Application: How do wages impact inflation?

- Do higher wages raise prices through supply (ie, cost) channel?
- Do higher wages raise prices through demand (ie, income) channel?

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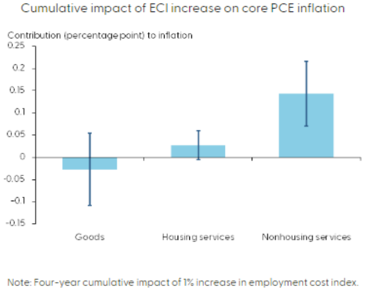

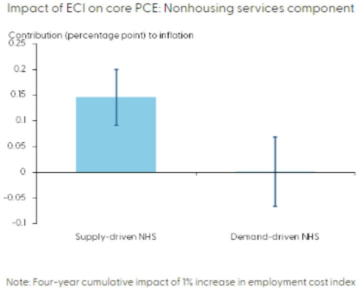

External Validation

How do known aggregate shocks impact the inflation decompositions?

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How do known aggregate shocks impact the inflation decompositions?

- MP tightening $\rightarrow$
  - $\downarrow$ demand-driven inflation (e.g. Smets and Wouters (2003))
  - $\uparrow$ supply-driven inflation (e.g. Barth and Ramey (2001))
- Oil supply decline $\rightarrow$
  - $\uparrow$ supply-driven inflation (e.g. Hamilton (1983))
  - $\downarrow$ demand-driven inflation (e.g. Hamilton (2008))

External Validation

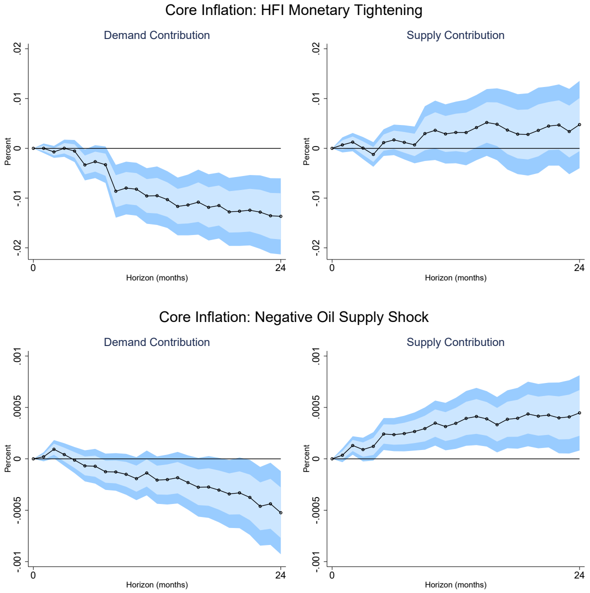
How do known aggregate shocks impact the inflation decompositions?

- high-frequency identified (HFI) monetary policy shocks
  - Gurkaynak et al. 2005
- externally-identified oil supply (OS) shocks
  - Baumeister and Hamilton 2019

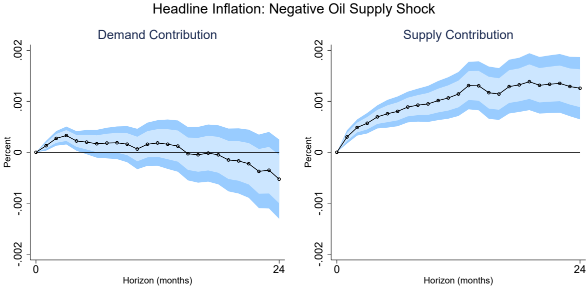
Local projections:

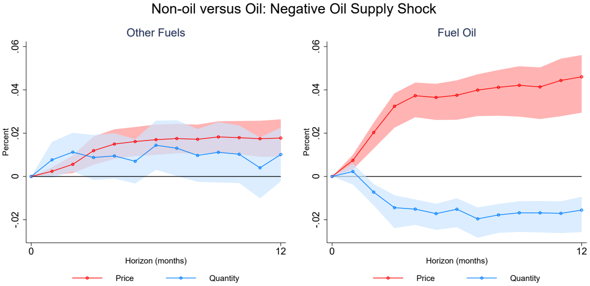
$$\pi^{j}_{t+h,t} = \alpha^{h}_{j} HFI_t + \beta^{h}_{j} OS_t + \mathrm{A}^{h}_{j} \sum_{\tau=1}^{6} \mathrm{Y}_{t-\tau} + \zeta_{j,t+h}.$$

Monetary and Oil Shocks



Interesting substitution effects



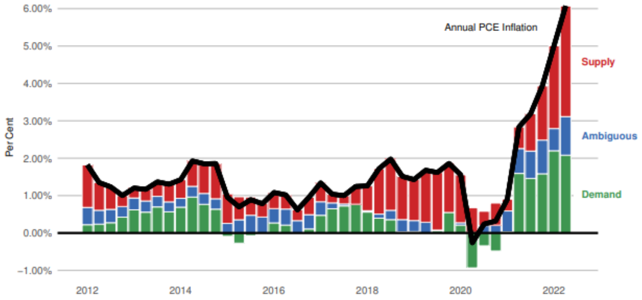


Replications currently being done...

Canada

Figure 4: Contribution of Supply and Demand Shocks to PCE Inflation, Q1 2012 to Q2 2022

(a) Annual PCE Inflation

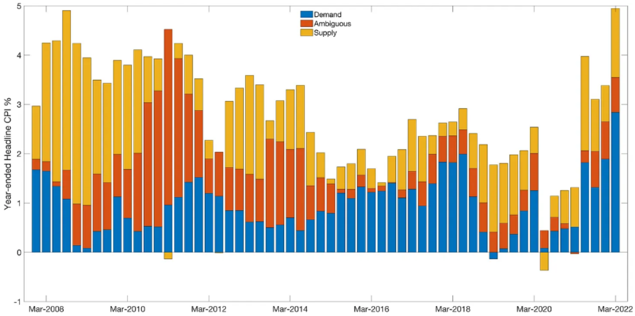


Chen, Yu, and Trevor Tombe. "The Rise (And Fall?) of Inflation in Canada: A Detailed Analysis of Its Post-Pandemic Experience."

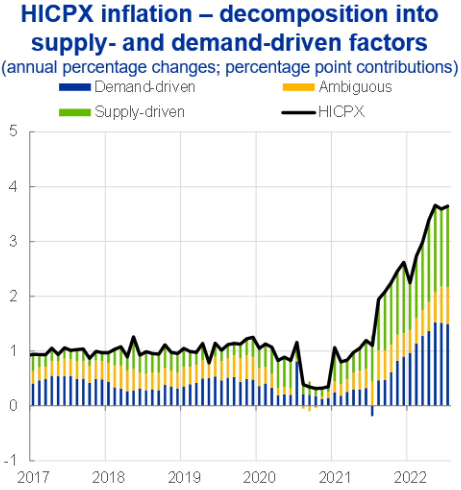
Replications currently being done...

Australia

With that caveat here is what the year-ended results look like for Australia:



Replications currently being done...



Sources: Eurostat and ECB staff calculations.
Notes: Seasonally adjusted series. Based on an application of Shapiro, A.H., "How Much Do Supply and Demand Drive Inflation?", *FRBSF Economic Letter* No 2022-15, Federal Reserve Bank of San Francisco, 21 June 2022; and Shapiro, A.H., "Decomposing Supply and Demand Driven Inflation", *Working Papers*, No 2022-18, Federal Reserve Bank of San Francisco, September 2022.See:Gonçalves, E. and Koester, G. (2022): "How much do supply and demand drive inflation – decomposing HICPX inflation item by item"- ECB Economic Bulletin Box issue 7 2022 (forthcoming) and also "Monetary policy in a cost-of-living crisis". Latest observations are for July 2022.

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Data available on FRBSF data page

Federal Reserve Bank of San Francisco

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ECONOMIC RESEARCH

INDICATORS AND DATA

Supply- and Demand-Driven PCE Inflation

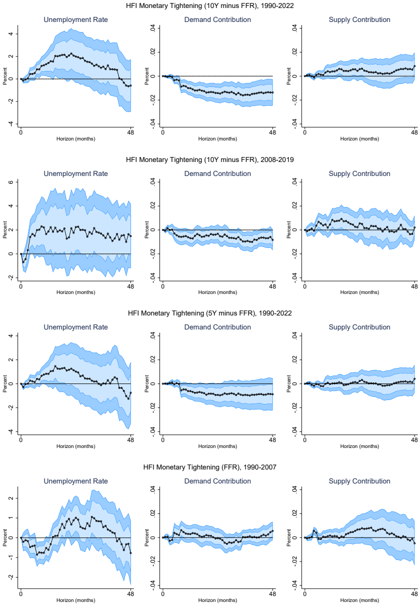
Supply- and Demand-Driven PCE Inflation updates data on the contributions to personal consumption expenditures (PCE) inflation from supply-driven versus demand-driven components. This tool is intended to track the changes in the extent to which either supply or demand factors are responsible for inflation levels. The methodology used for developing these data is detailed in Shapiro (2022b) and outlined in Shapiro (2022a).

The data on this page divide inflation rates into supply- and demand-driven groups of spending categories in the PCE basket of goods and services in the U.S. economy. *Demand-driven* categories are identified as those where an unexpected change in price moves in the same direction as the change in quantity in a given month. *Supply-driven* categories are identified as those where unexpected changes in price and quantity move in opposite directions. This methodology accounts for the evolving impact of supply- versus demand-driven factors on inflation from month to month.

and on my webpage: sites.google.com/site/adamshap/research

Additional slides

Robustness



HFI Monetary Tightening (10Y minus FFR), 1990-2022
Unemployment Rate
Demand Contribution
Supply Contribution
Percent
Horizon (months)
HFI Monetary Tightening (10Y minus FFR), 2008-2019
Unemployment Rate
Demand Contribution
Supply Contribution
Percent
Horizon (months)
HFI Monetary Tightening (5Y minus FFR), 1990-2022
Unemployment Rate
Demand Contribution
Supply Contribution
Percent
Horizon (months)
HFI Monetary Tightening (FFR), 1990-2007
Unemployment Rate
Demand Contribution
Supply Contribution
Percent
Horizon (months)