

Relative Price Shocks and Inflation

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¹The views here are those of the authors alone. They do not represent the views of any part of the Federal Reserve System.

- ▶ There are large monthly relative price changes across consumption categories.
- ▶ What role do the factors driving those *relative* price changes play in the behavior of inflation in a stable monetary regime?
- ▶ Study U.S. from 1995 to 2019, multi-sector NK model.
 - ▶ overall contrib'n of relative price shocks to inflation
 - ▶ in sample application to inflation shortfall (2012-2019)
 - ▶ out of sample applications to 2020-2025 (maintained assumption regime remained stable)

Outline

1. Motivation and literature
2. Model
3. General properties of model
4. Estimated parameters
5. Properties of estimated model
6. Applications: post-GFC inflation shortfall;
post-2020 high inflation
7. Conclusion

Motivation

- ▶ Practical central banking question: to what extent is inflation driven by real sectoral shocks when CB is following a stable policy?
- ▶ To answer that question we need two things:
 - ▶ A model with multiple sectors
 - ▶ Data from a stable regime
- ▶ We have a model, and arguably data from a stable regime.

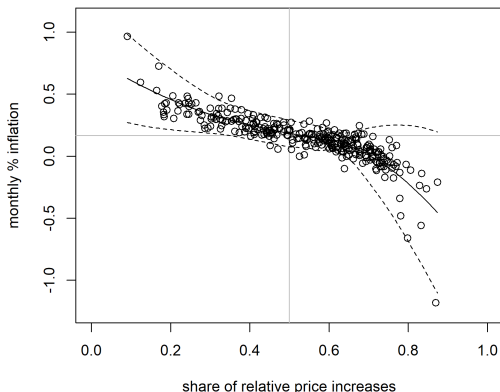
Literature

Among the most relevant of the many, many papers:

- ▶ Models in which distribution of “relative price shocks” important for inflation:
 - ▶ Ball and Mankiw (1995): fixed costs, so firms only adjust if large desired price change
 - ▶ Balke and Wynne (2000): sectoral productivity shocks interact with flexible prices, constant money growth
- ▶ Multi-sector NK models with input-output: e.g. Pasten, Schoenle, Weber ('20,'24), Carvalho, Lee and Park ('21), Ghassibe ('21), Baqaee and Farhi ('22), Rubbo ('23,'26), Ferrante, Graves, Iacoviello ('23).
- ▶ Reis and Watson (2010) factor model, argue inflation associated to a large extent with relative price changes.

More motivation: Hornstein, Ruge-Murcia & Wolman (2024)

- ▶ U.S. data 1995-2019
- ▶ Monthly inflation (y-axis) closely related to monthly share of relative price increases (x-axis).
- ▶ To understand inflation, need to understand distrib'n of relative price changes (*in a stable monetary regime*).



The model in one slide

- Consumption is Cobb-Douglas across-, CES within sectors:

$$C_t = \prod_{s=1}^{15} (\xi_s)^{-\xi_s} (c_{s,t} - u_t - u_{s,t})^{\xi_s}, \quad (1)$$

$$c_{s,t} = \left(\int (c_{s,t}(i))^{(\theta-1)/\theta} di \right)^{\theta/(\theta-1)}, \quad (2)$$

- Production uses labor and intermediates:

$$y_{s,t}(i) = (e^{z_t} e^{z_{s,t}} (n_{s,t}(i))^\alpha (M_{s,t}(i))^{1-\alpha})^\nu, \quad (3)$$

$$M_{s,t}(i) = \prod_{j=1}^S (\kappa_s^j)^{-\kappa_s^j} \left(m_{s,t}^j(i) \right)^{\kappa_s^j}, \quad (4)$$

$$m_{s,t}^j(i) = \left(\int \left(m_{s,t}^j(i, l) \right)^{(\theta-1)/\theta} dl \right)^{\theta/(\theta-1)}, \quad (5)$$

- Rotemberg pricing; Standard Taylor-type rule
- Local analysis around balanced growth path, inflation rate π^* .

Notable features of the model

- Trends in sectoral productivity to match trends in rel. prices

$$y_{s,t}(i) = (e^{z_t} e^{z_{s,t}} (n_{s,t}(i))^{\alpha} (M_{s,t}(i))^{1-\alpha})^{\nu},$$

- Sectoral demand shock specification

$$C_t = \prod_{s=1}^{15} (\xi_s)^{-\xi_s} (c_{s,t} - u_t - u_{s,t})^{\xi_s},$$

and DRTS so the demand shocks move relative prices.

- Sources of sectoral heterogeneity:
 - Size (expenditure share)
 - I/O structure
 - Productivity and demand shock volatility
 - Price stickiness parameter (Rotemberg), ϕ_j

General properties of model (1)

- ▶ Sectoral relative productivity trends and sectoral supply and demand shocks mean cannot (and should not) stabilize ALL prices.
- ▶ But no problem *in the model* to hit π^* every period: policy rule $\pi_t = \pi^*$.
- ▶ Intuition from flex price model: real shocks determine relative prices and monetary policy determines inflation.
- ▶ With sticky prices, no dichotomy, but monetary policy can still choose inflation (*in the model*).

General properties of model (2)

For a “typical” policy rule, relative price shocks move inflation:

- ▶ Sectoral shocks are aggregate shocks, and as such, they move the inflation rate.
- ▶ Under a perfect inflation peg $\pi_t = \pi^*$, equilibrium function for R_t involves large responses to all sectoral productivity shocks.
- ▶ In contrast, with Taylor type rule, equilibrium R_t has small responses to all sectoral shocks (*but not zero*).

- ▶ Calibrate parameters that determine balanced growth path (heroic use of PCE bridge tables and NAICS to get I/O parameters κ_i^j)
- ▶ Maximum likelihood using Kalman filter.
- ▶ Observables: sectoral price changes, sectoral real consumption growth. ~~nominal interest rate~~
- ▶ U.S. data, 1995-January 2020.
- ▶ Linearize *detrended* model around balanced growth path:
 - ▶ Inflation target $\pi^* \approx 2\%$.
 - ▶ Sectoral productivity growth from sectoral relative price trends.
 - ▶ Detrending a bit tricky: stochastic trends in relative prices

Estimation: stochastic processes and detrending

- Sectoral productivity processes ($z_{j,t}$):

$$(dz)_{j,t} = \rho_j (dz)_{j,t-1} + \epsilon_{j,t}, \quad (6)$$

where

$$(dz)_{j,t} \equiv (z_{j,t} - z_{j,t-1} - \mu_j). \quad (7)$$

- Sectoral and aggregate demand shocks: conditionally mean zero, but trend in variance so they stay relevant.
- Example of detrending, relative price ($\tilde{z}$ is vector of z_j):

$$\tilde{p}_{j,t} \equiv \frac{p_{j,t}}{e^{\alpha \nu (\tilde{\xi}' A - A_j) \tilde{z}_t}}, \quad j = 1, \dots, S. \quad (8)$$

Estimated sectoral parameters

	Price Rigid.	S.D. Innovations to	
		Prod. $\times 10^2$	Dem. $\times 10^4$
Motor veh., parts	91.3*	4.9*	9.9*
Frnshngs, hhld dur.	9.4*	2.4*	1.3*
Rec. goods	9.8*	2.5*	2.2*
Other durables	0.7	2.9*	0.8*
Food home	15.8*	2.3*	1.9*
Clothg & footwr	7.5*	2.1*	2.0*
Gas, energy goods	0.0	5.2*	9.1*
Other nondur	3.9*	1.2*	1.8*
Housing, utlts	35.9*	1.1*	2.7*
Health care	11.0*	0.6*	1.2*
Transp. svcs	0.9	1.8*	1.7*
Rec. svcs	8.9*	1.0*	1.1*
Food svcs, acom	33.5*	1.3*	1.8*
Fin. svcs, ins.	0.0 ,	1.0*	2.5*
Other svcs	40.4*	1.5*	2.2*
Wald test (p -value)	< 0.001	< 0.001	< 0.001

Properties of estimated model: summary

1. Fits sectoral and aggregate price change data, by construction.
2. Sectoral prod. and dem. shocks drive own relative prices, small opposite effect on other relative prices (by definition, zero effect on average relative price).
3. Sectoral productivity and demand shocks primary driver of inflation ($\approx 78\%$), mon. policy 10%..
4. Model matches empirical relationship between inflation and share of relative price increases.
5. Clear heterogeneity in price stickiness, but heterogeneity in shock volatility more important for matching relationship between relative price changes and inflation.

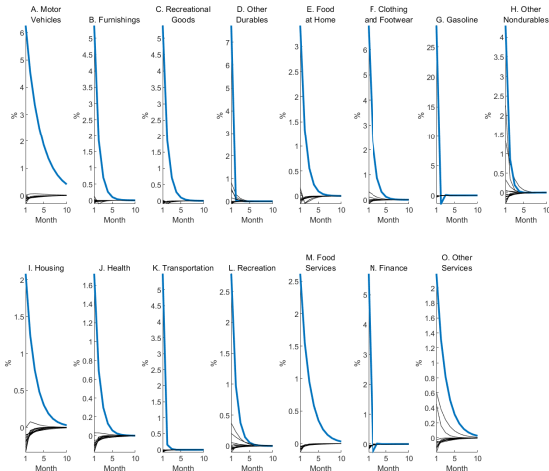
Properties of estimated model: 2nd moments

Variable	Price Changes			
	Std. Deviation		Autocorrelation	
	Data	Model	Data	Model
	(1)	(2)	(3)	(4)
Motor vehicles and parts	3.8	12.5	0.3	0.7
Furnishings and household durables	4.6	6.4	−0.0	0.3
Recreational goods	4.4	6.6	−0.0	0.4
Other durable goods	7.1	8.7	−0.2	0.0
Food at home	3.2	4.4	0.3	0.4
Clothing and footwear	5.9	8.4	0.0	0.3
Gasoline and other energy goods	59.9	41.6	0.3	−0.0
Other nondurable goods	3.6	5.0	−0.1	0.2
Housing and utilities	1.7	3.1	0.3	0.6
Health care	1.8	2.3	0.1	0.4
Transportation services	6.1	6.5	−0.0	0.1
Recreation services	2.5	3.6	0.1	0.3
Food services and accommodations	2.1	3.8	−0.1	0.6
Financial services and insurance	8.7	7.9	−0.2	−0.0
Other services	2.1	3.1	0.3	0.6
Correlation	0.98		0.52	
R^2	0.95		0.27	

IRFs of all relative prices to 1-stdev sectoral prod shocks

► Large own response (blue)

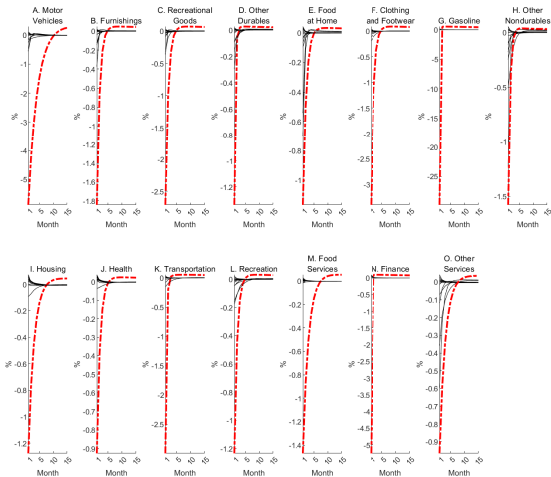
► Small other responses (black)



IRFs of all rel. prices to 1-stdev sectoral demand shocks

► Large own response (red)

► Small other responses (black)

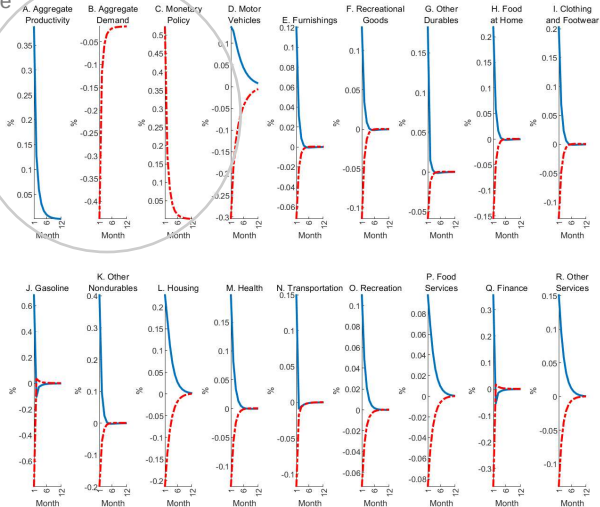


Response of inflation to all shocks

Red = demand

Blue = productivity

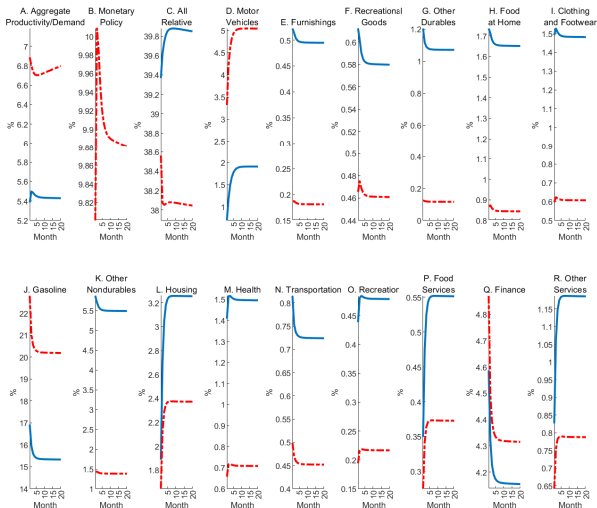
Aggregate shocks



Variance decomposition of inflation (scales differ)

Red = demand

Blue = productivity



Variance decomposition of inflation

	Aggregate Shocks	Sectoral Shocks	
		Productivity	Demand
	(1)	(2)	(3)
Aggregate productivity	5.4		
Aggregate demand	7.6		
Monetary policy	9.8		
Motor vehicles and parts		1.9	5.0
Furnishings and household durables		0.5	0.2
Recreational goods		0.6	0.5
Other durable goods		1.1	0.1
Food at home		1.6	0.8
Clothing and footwear		1.5	0.6
Gasoline and other energy goods		15.2	20.0
Other nondurable goods		5.4	1.4
Housing and utilities		3.2	2.4
Health care		1.5	0.7
Transportation services		0.7	0.4
Recreation services		0.5	0.2
Food services and accommodations		0.5	0.4
Financial services and insurance		4.1	4.3
Other services		1.2	0.8

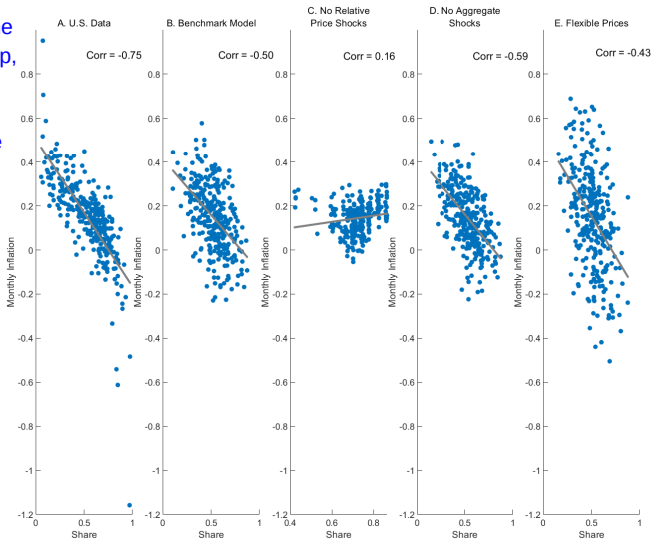
Estimated model: inflation & share rel. price increases

Data

Est'd
modelOnly agg
shocksNo agg
shocks

Flex prices

For matching the empirical rel'ship, heterogeneous shock variance important, more than het. price stickiness.

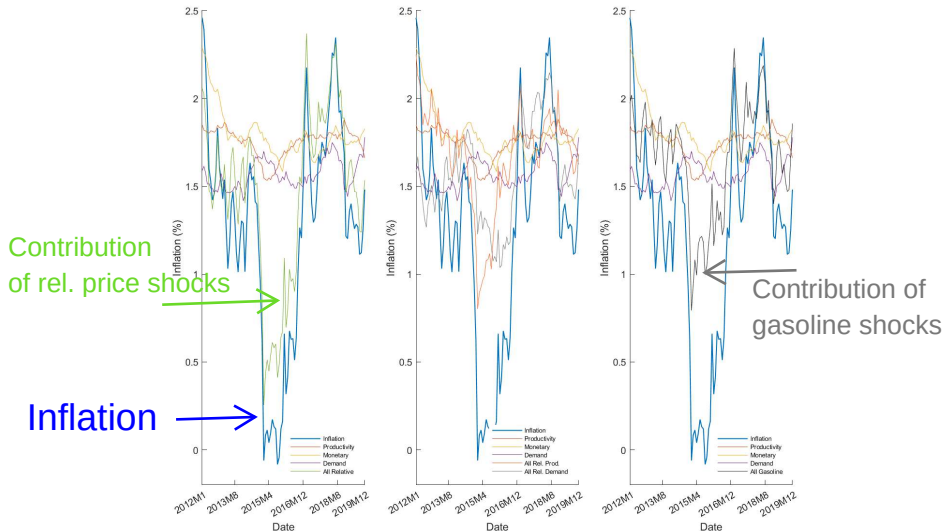


Inflation undershoot, 2012-2019: mainly rel. price shocks ²²

Guide to the illegible figure on the next slide:

- ▶ 3 panels with 12m inflation from 2012-2019 and the inflation paths implied by subsets of shocks.
- ▶ Each panel, blue line is inflation.
- ▶ Left panel: green line shows that all relative price shocks accounted for majority of inflation shortfall.
- ▶ Right panel: red/black line shows that gasoline accounted for (only) about half of the relative price shock contribution.
- ▶ Ignore middle panel.

Inflation undershoot, 2012-2019: mainly rel. price shocks



COVID: inflation post-Feb.2020 (out of sample)

- ▶ Decompose COVID inflation into contrib'ns of various shocks, notably including sectoral supply and demand
- ▶ Strong caveats!
 - ▶ COVID is not in the sample.
 - ▶ We filter inflation and price change data under assumption the estimated parameters still apply: inflation anchored at target and only effect of policy is through shocks that are expected to fade.
 - ▶ Etc.

COVID inflation, 2020-2023 (out of sample)

Guide to the illegible figure on the next slide:

- ▶ Same format as before
- ▶ Left panel shows that initial inflation associated with agg. demand shock, then relative price shocks took over.
- ▶ Model attributes small role to monetary policy shocks. Can the estimation procedure distinguish well between monetary policy and demand shocks?

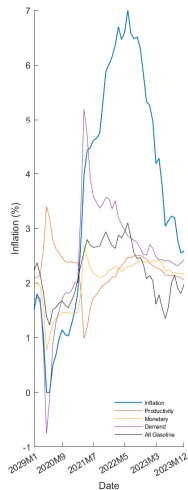
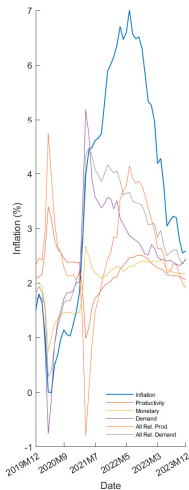
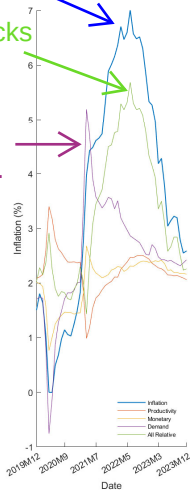
COVID inflation, 2020-2023 (out of sample)

Contribution of all shocks

Inflation

Rel. price shocks
contribution

Agg. demand
shock contrib.



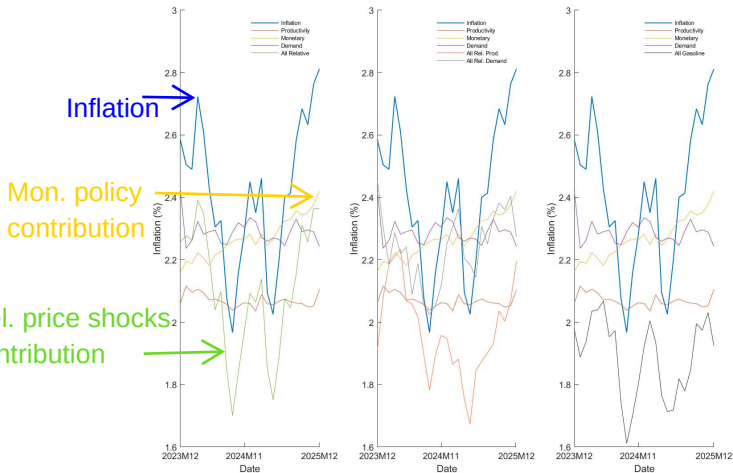
Recent inflation, 2024-2025 (out of sample)

Guide to the illegible figure on the next slide:

- ▶ Same format
- ▶ Left panel: contribution of monetary policy shocks to inflation steadily increased from late '23 to late '25, about equal to relative price shock contribution.

Recent inflation, 2024-2025 (out of sample)

Contribution of all shocks



Conclusion

- ▶ With typical monetary policy rules, “relative price shocks” can move around the inflation rate.
- ▶ We quantify this effect in an estimated 15-sector NK model:
 - ▶ relative price shocks account for majority of volatility in U.S. monthly inflation, 1995-2019
- ▶ Use the framework to decompose inflation shortfall (in sample) and COVID inflation (out of sample)
 - ▶ The high inflation 2021-2023 is primarily caused by relative price shocks, given assumption of fixed policy rule
 - ▶ In 2024 and 2025, monetary policy shocks accounted for an increasing and nontrivial portion of the inflation overshoot. (need update with more recent data)