Relative Price Shocks and Inflation

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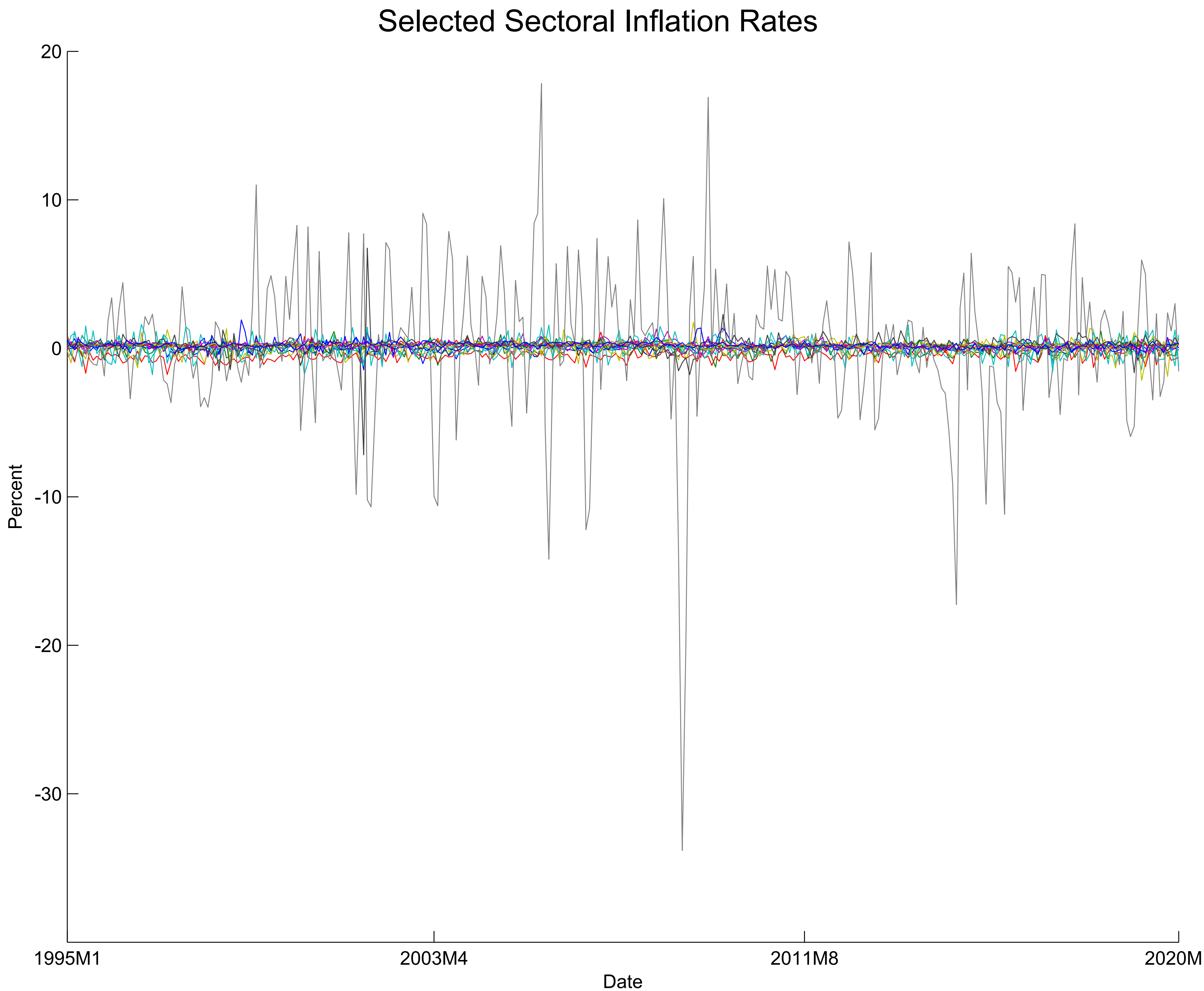
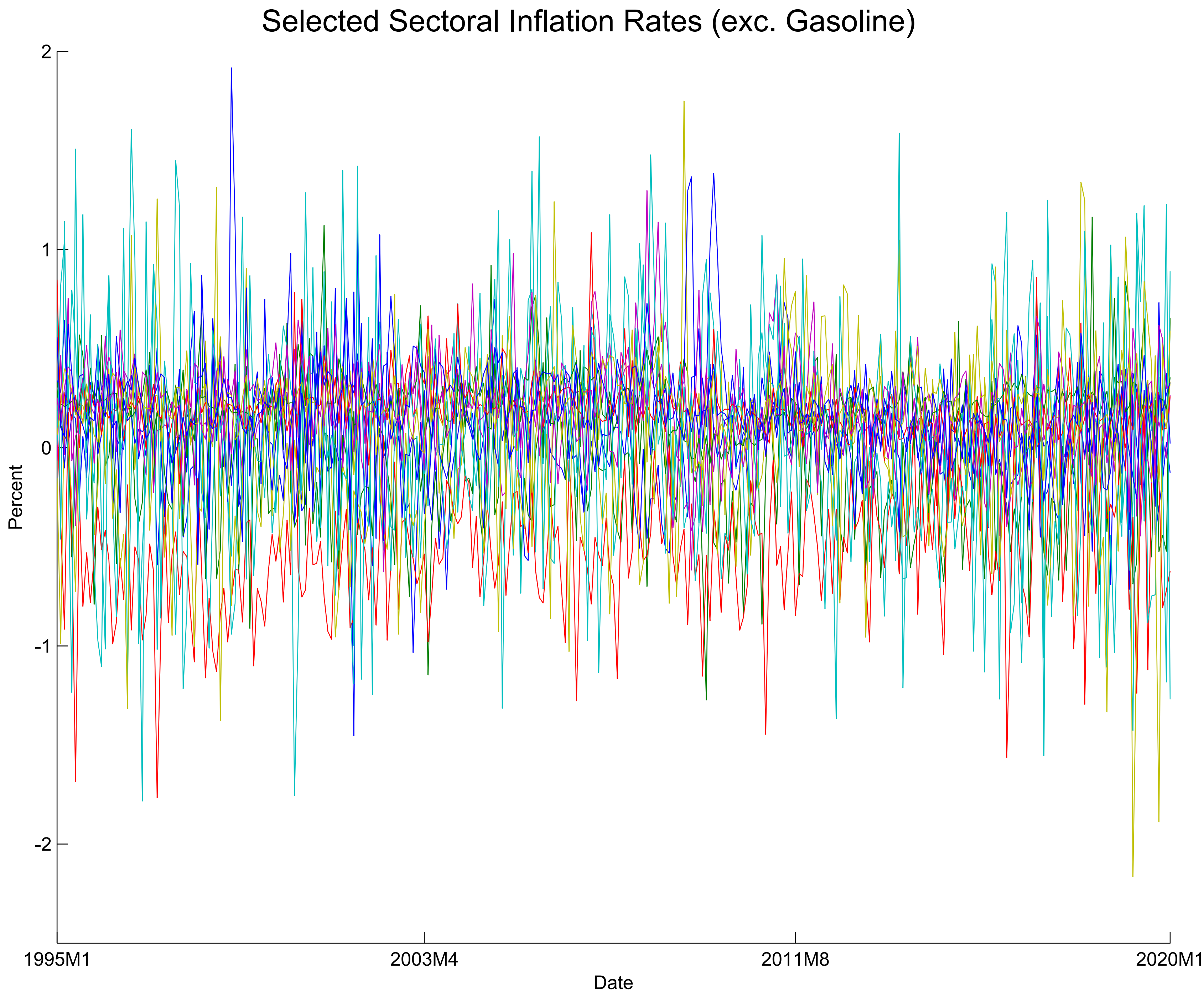
Motivation

By definition

$$\pi_t = \sum_{s=1}^{S} \xi^s \pi_{s,t}$$

In order to understand the inflation dynamics, it is important to study the dynamics of sectoral inflation


Selected Sectoral Inflation Rates
20
10
0
-10
-20
-30
Percent
1995M1
2003M4
2011M8
2020M1
Date



Selected Sectoral Inflation Rates (exc. Gasoline)
2
1
0
-1
-2
Percent
1995M1
2003M4
2011M8
2020M1
Date

Motivation (cont.)

We want to evaluate the relative role of sectoral and monetary shocks in general and in specific events

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Events of interest are:

- The inflation shortfall in 2012-2019
- The increase in inflation following the pandemic

The Model

Economic Agents

Monopolistic-competitive firms in S sectors

A representative household

A monetary authority

Firms

Firm i in sector $s \in S$ produces output using the technology

$$y_{i,s,t} = e^{z_t} e^{z_{s,t}} n_{i,s,t}$$

where $n_{i,s,t}$ is labor input and e^{z_t} and $e^{z_{s,t}}$ are aggregate and sectoral productivity, respectively

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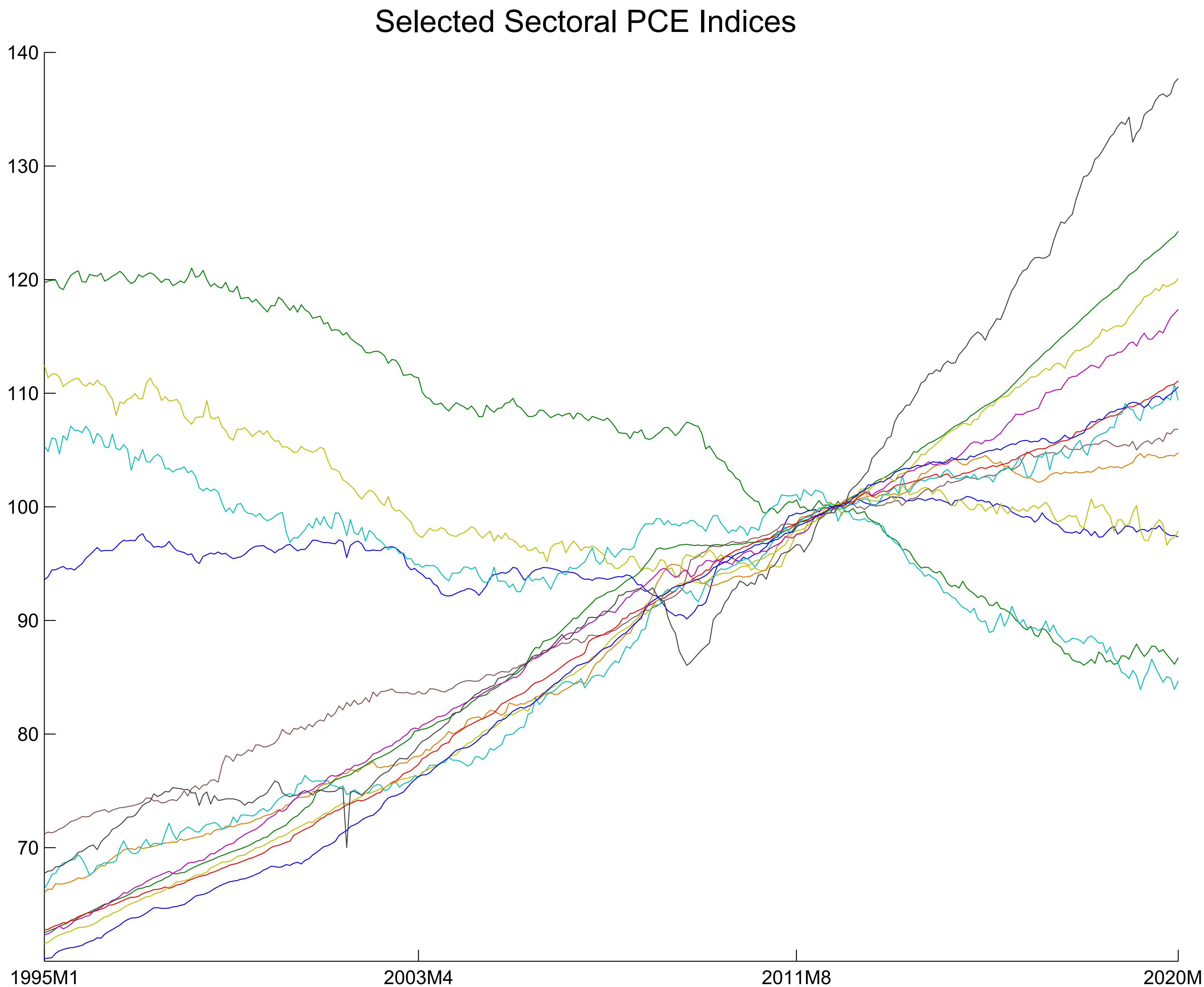
Sectoral productivity follows the trend-stationary process

$$\begin{aligned} z_{s,t} &= \mu_s t + a_{s,t} \\ a_{s,t} &= \rho_s a_{s,t-1} + \varepsilon_{s,t} \\ \varepsilon_{s,t} &\sim i.i.d. N(0, \sigma_s^2) \end{aligned}$$

The trend and the stochastic deviations from the trend are sector-specific


Selected Sectoral PCE Indices
140
130
120
110
100
90
80
70
1995M1
2003M4
2011M8
2020M1

Firms (cont.)

Aggregate productivity follows the process

$$z_t = \rho z_{t-1} + \varepsilon_t$$

$$\varepsilon_t \sim i.i.d. N(0, \sigma^2)$$

where $\rho \in (-1, 1)$

Firms (cont.)

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Per-unit price adjustment costs

$$\Phi_{i,s,t} = \Phi(P_{i,s,t}, P_{i,s,t-1}) = \frac{\zeta_{s,t}\phi_s}{2}\left(\frac{1}{e^{\alpha\pi+\alpha_s\pi_s}}\frac{P_{i,s,t}}{P_{i,s,t-1}} - 1\right)^2$$

where $\phi_s \geq 0$ and

$$\zeta_{s,t} = (1/e^{\mu_s})^t\left(\prod_{k=1}^{S}(e^{\mu_k})^{\xi_k}\right)^t$$

Households

The household maximizes

$$E_\tau \sum_{t=\tau}^{\infty} \beta^{t-\tau} \left(\ln(C_t) + \psi \frac{(1-N_t)^{1-\eta}}{1-\eta} \right),$$

where C_t is consumption and N_t is hours worked

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Consumption is an aggregate of all goods

$$C_t = \prod_{s=1}^{S} (\xi^s)^{-\xi^s} (c_{s,t})^{\xi^s}$$

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

with $\sum_{s=1}^{S} \xi^s = 1$

Households (cont.)

Budget constraint

$$P_t C_t + B_t \leq P_t w_t N_t + (1 + R_{t-1}) B_{t-1} + D_t$$

where

P_t is the aggregate price level

B_t is nominal bonds

w_t is the real wage

R_t is the net nominal interest rate

D_t are dividends from all firms

Monetary Policy

Interest-rate rule

$$1 + R_t = \delta(1 + R_{t-1}) + (1 - \delta)(1/\beta)\exp(\pi + \gamma_y + \lambda_\pi(\pi_t - \pi) + \lambda_y(\ln(Y_t) - \ln(Y)) + u_t)$$

where

$$u_t = \kappa u_{t-1} + \varsigma_t$$

$$\varsigma_t \sim i.i.d. N(0, \sigma_\varsigma^2)$$

Equilibrium and Balanced Growth Path

The equilibrium of the model is symmetric within sectors but asymmetric across sectors

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Sectoral Phillips curve

$$\left(\frac{\theta-1}{\theta}\right)\frac{P_{s,t}}{P_t} = \frac{w_t}{e^{z_t}e^{t\mu_s}e^{a_{s,t}}} + \zeta_{s,t}\phi_s\left(\frac{\pi_{s,t}}{e^{\alpha\pi+\alpha_s\pi_s}} - 1\right)\left(\left(\frac{1}{2}-\frac{1}{\theta}\right)\frac{\pi_{s,t}}{e^{\alpha\pi+\alpha_s\pi_s}} - \frac{1}{2}\right)$$
$$+ \zeta_{s,t+1}\left(\frac{\phi_s}{\theta}\right)\left(\frac{1}{e^{\alpha\pi+\alpha_s\pi_s}}\right)E_t\left(\left(\frac{1}{1+R_t}\right)\pi_{t+1}\pi_{s,t+1}\left(\frac{\pi_{s,t+1}}{e^{\alpha\pi+\alpha_s\pi_s}} - 1\right)\frac{y_{s,t+1}}{y_{s,t}}\right),$$

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Growth rates of consumption and the real wage along the balanced growth path

$$\gamma_c = \gamma_w = \sum_{s=1}^{S}\xi_s\mu_s$$

Equilibrium and Balanced Growth Path (cont.)

The trend growth (or decline) in sectoral *relative* prices is determined entirely by sectoral relative productivity growth

$$\pi_s - \pi = \sum_{k=1}^{S} \xi_k \mu_k - \mu_s$$

Data and Estimation

Data

Nominal interest rate and rates of price change for fifteen consumption expenditure categories of the U.S. economy

The fifteen categories comprise the entirety of PCE

Nominal interest rate is quadratically detrended to statistically account for the secular decline in the real rate

Sample: 1995M1 to 2020M1

Estimation

Estimation by Maximum Likelihood (ML)

Hansen and Sargent (2013, ch. 8) show that the ML estimator is consistent and asymptotically efficient

Estimation (cont.)

Likelihood function evaluated using Kalman filter

The transition equation and observation equations are respectively

$$X_{t+1} = HX_t + v_{t+1}$$
$$Q_t = GX_t$$

where

$$X_t = (z_t, a_{1,t}, \ldots, a_{S,t}, u_t, R_{t-1}, P_{1,t-1}, \ldots, P_{S,t-1})'$$

are the state variables of the model and

$$Q_t = (R_t, \pi_{1,t}, \ldots, \pi_{S,t})'$$

Calibrated Parameters

Parameter	Notation	Value
Weight of leisure in the utility function	ψ	1.8
Elasticity parameter	θ	10.0
Price indexation	α, α_s	0.5
Discount rate	β	0.998

Consumption weights:

$$\xi_s = \frac{P_{s,t} c_{s,t}}{P_t C_t}$$

Sectoral productivity trends:

$$\mu_s = \pi + \gamma_c - \pi_s$$

Consumption Weights and Productivity Trends

Sector	Consumption Weight	Productivity Trend $\times 10^2$
Motor vehicles and parts	0.0488	0.2605
Furnishings and household durables	0.0296	0.3936
Recreational goods	0.0311	0.7428
Other durable goods	0.0166	0.3076
Food at home	0.0878	0.1710
Clothing and footwear	0.0414	0.3487
Gasoline and other energy goods	0.0308	0.1343
Other nondurable goods	0.0801	0.1564
Housing and utilities	0.1877	0.0891
Health care	0.1509	0.0464
Transportation services	0.0343	0.1586
Recreation services	0.0371	0.0983
Food services and accommodations	0.0661	0.1003
Financial services and insurance	0.0738	0.0978
Other services	0.0840	0.1041

ML Estimates: Other Sectoral Paramaters

	Price Rigidity	AR Coefficient	SD $\times 10^2$
Motor vehicles and parts	7.316*	0.990*	0.460*
Furnishings and household durables	0.186	0.991*	0.386*
Recreational goods	0.676	0.998*	0.376*
Other durable goods	< 0.001	0.995*	0.584*
Food at home	4.229*	0.997*	0.324*
Clothing and footwear	0.516	0.995*	0.547*
Gasoline and other energy goods	3.673*	0.962*	6.144*
Other nondurable goods	0.030	0.990*	0.315*
Housing and utilities	8.485*	0.997*	0.192*
Health care	4.090*	0.997*	0.184*
Transportation services	0.255	0.975*	0.530*
Recreation services	2.094*	0.997*	0.243*
Food services and accommodations	111.121*	0.455*	1.989*
Financial services and insurance	< 0.001	0.991*	0.710*
Other services	12.883*	0.998*	0.272*
Aggregate productivity		–0.819	< 0.001

ML Estimates: Taylor Rule

Parameter	Model Estimate	Model s.e.	Unrestricted Estimate	Unrestricted s.e.
Smoothing parameter	0.733^{*}	0.146	0.989^{*}	0.261
Inflation coefficient $\times 10^2$	4.312	2.725	1.007^{*}	0.249
Output coefficient $\times 10^2$	0.310	0.227	$0.146^{\dagger}$	0.079
AR coefficient	0.673^{*}	0.176	0.456^{*}	0.038
Standard deviation $\times 10^2$	$0.049^{\dagger}$	0.027	0.011^{*}	< 0.001

Model Evaluation

Predicted Second Moments

Variable	Standard Deviation		Autocorrelation	
	Data	Model	Data	Model
Nominal interest rate	0.110	0.043	0.992	0.939
Aggregate inflation	0.187	0.252	0.387	0.139
Sectoral price changes:				
Motor vehicles and parts	0.315	0.348	0.307	0.325
Furnishings and household durables	0.377	0.432	–0.019	0.000
Recreational goods	0.355	0.415	0.026	0.047
Other durable goods	0.597	0.628	–0.170	–0.013
Food at home	0.263	0.307	0.266	0.228
Clothing and footwear	0.517	0.566	0.016	0.039
Gasoline and other energy goods	4.986	4.828	0.349	0.211
Other nondurable goods	0.303	0.382	–0.140	–0.024
Housing and utilities	0.140	0.197	0.338	0.324
Health care	0.148	0.224	0.116	0.207
Transportation services	0.511	0.558	–0.045	0.005
Recreation services	0.208	0.273	0.097	0.127
Food services and accommodations	0.169	0.211	–0.056	0.288
Financial services and insurance	0.722	0.762	–0.236	–0.012
Other services	0.171	0.221	0.356	0.410

Relative Price Shocks and Inflation Over the Entire Sample

Impulse Responses

Figure 1: Responses of Relative Prices to Negative Productive Shock in Own Sector

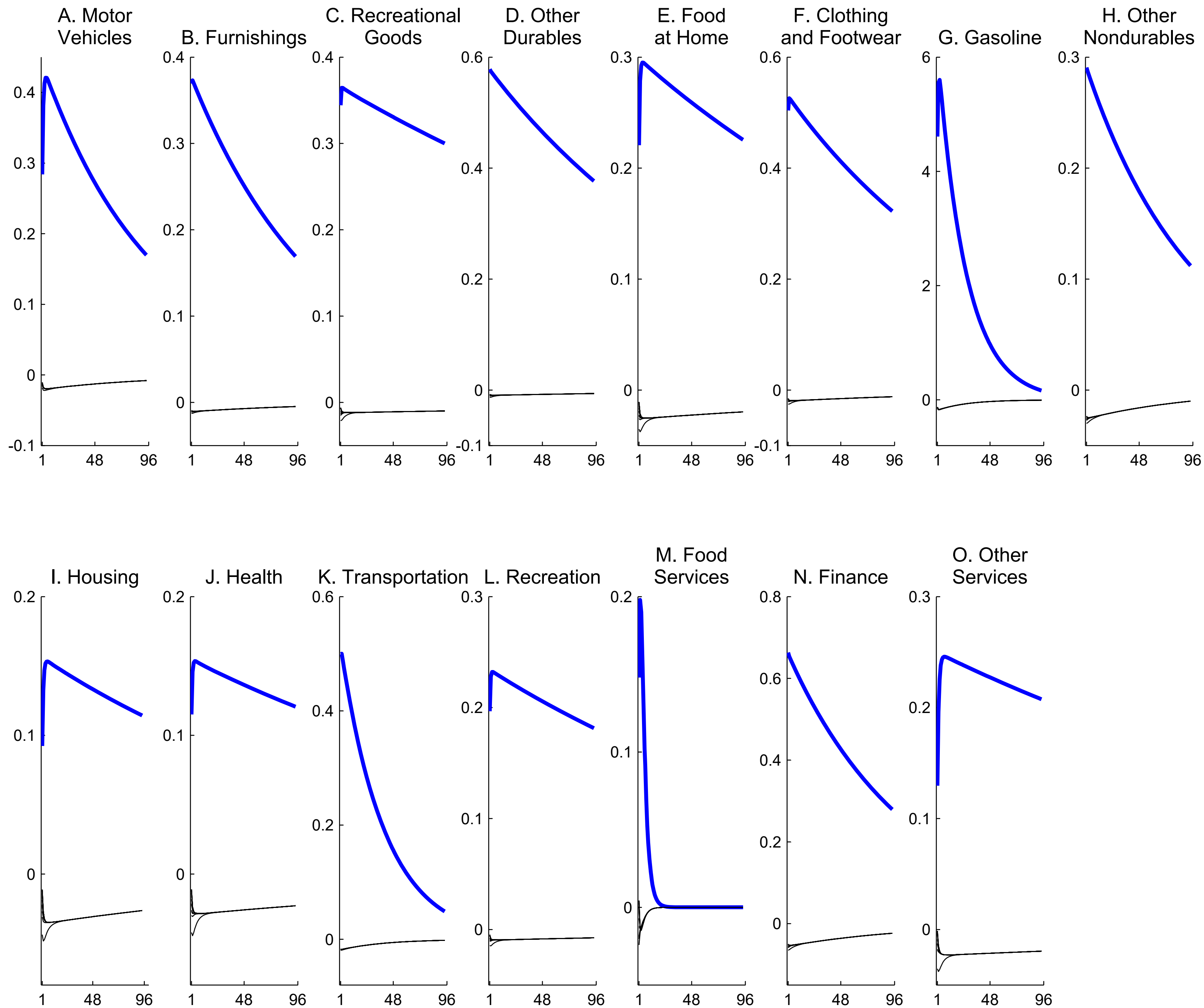
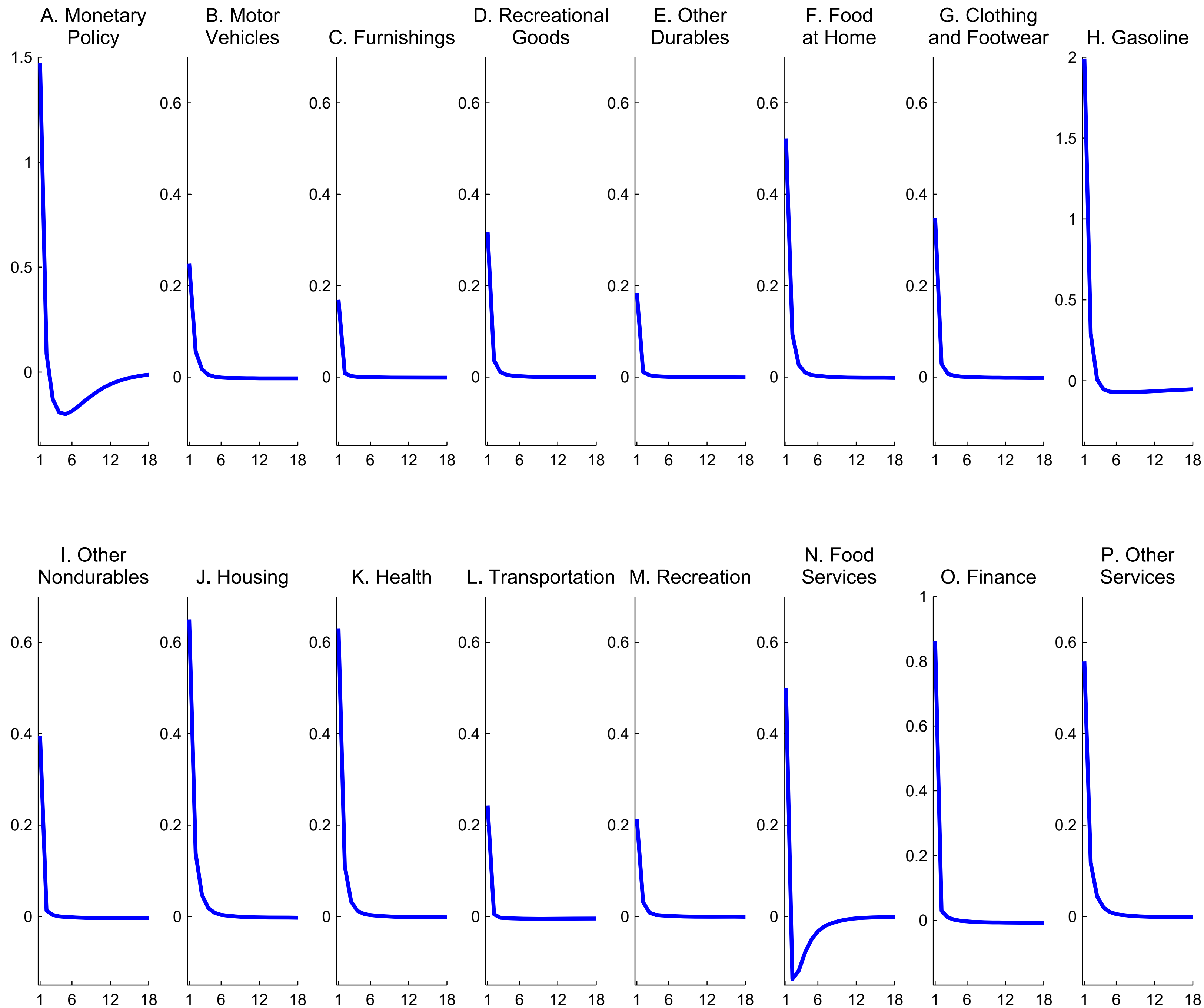


Figure 2: Inflation Responses



Impulse Responses

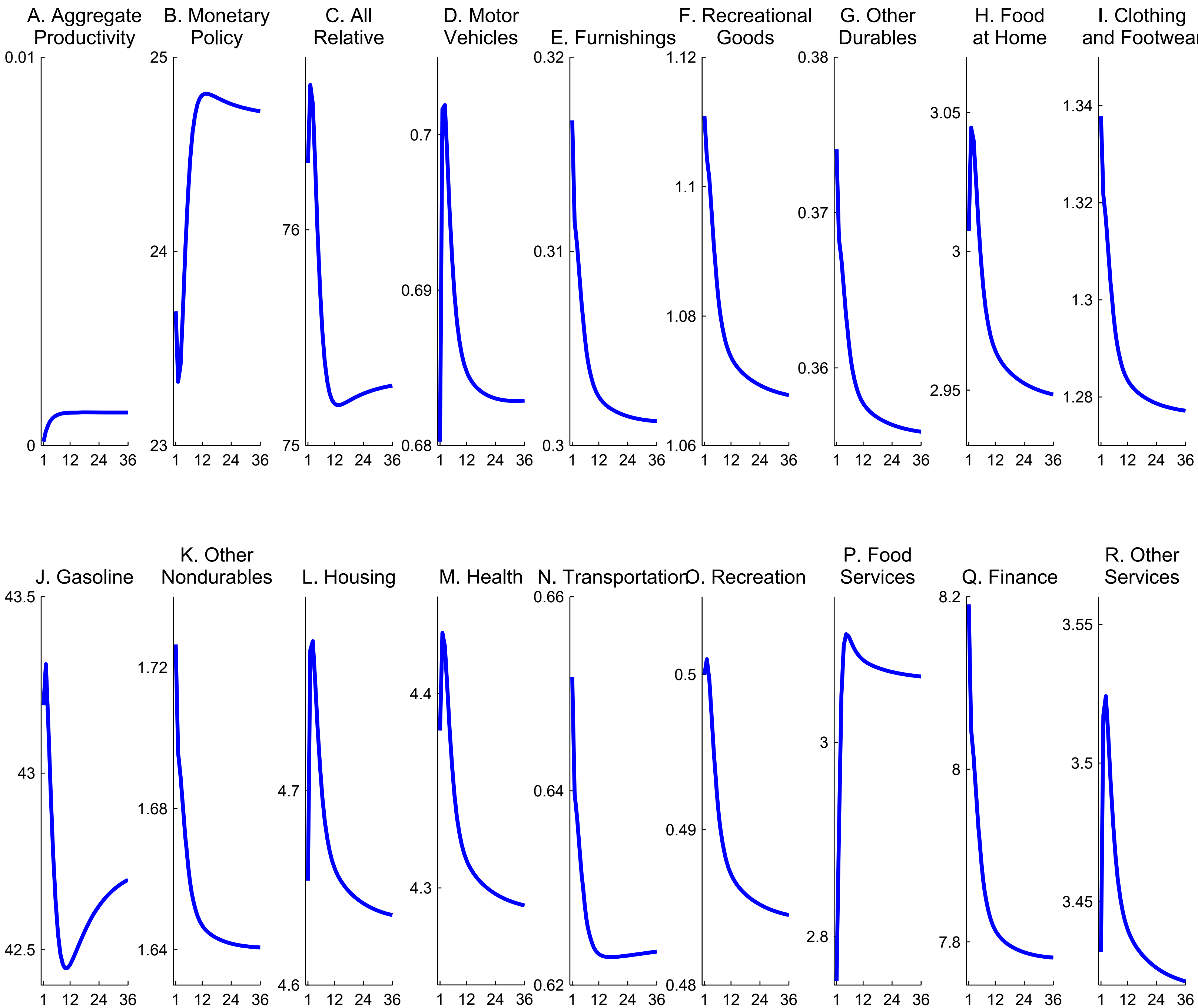
Sectoral productivity shocks are basically relative-price shocks

The difference in sectoral shock volatility and, to some extent, the difference in price stickiness deliver heterogeneity in the effects of relative price shocks on inflation

Quantitatively, the largest effects are due to relative price shocks to gasoline, finance and insurance, and housing and utilities

Accounting for the Variance of Inflation

Figure 3: Variance Decomposition of the Inflation Rate



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Aggregate productivity accounts for less than 0.001% of the variance of the inflation forecast error at all horizons

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Monetary policy accounts for around 25% of the variance of the inflation forecast error

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Relative price shocks account for around 75% of the variance of the inflation forecast error with large contributions from:

Gasoline: 42%

Finance and insurance: 8%

Housing and utilities: 5%

Health: 4%

Variance Decomposition Sectoral Inflation

Variable	Own Shock	Monetary Policy
Motor vehicles and parts	86.481	9.988
Furnishings and household durables	78.458	15.438
Recreational goods	79.421	14.980
Other durable goods	89.216	7.711
Food at home	77.909	16.674
Clothing and footwear	88.414	8.372
Gasoline and other energy goods	99.904	0.072
Other nondurable goods	71.308	20.537
Housing and utilities	62.428	28.985
Health care	58.413	31.883
Transportation services	87.256	9.139
Recreation services	62.771	27.274
Food services and accommodations	94.805	3.060
Financial services and insurance	92.735	5.240
Other services	77.021	17.813

Variance Decomposition Sectoral Inflation

The “own” relative price shock accounts for most of the variance of all sectoral price changes (in line with Boivin et al. (2009) and Mackowiak et al. (2009)

The contribution of the monetary policy shock is also substantial

There is basically no relationship between price rigidity and the proportion of the variance that is accounted for by the monetary policy shock

The correlation is -0.287 and not statistically significant

Inflation Shortfall 2012-2019

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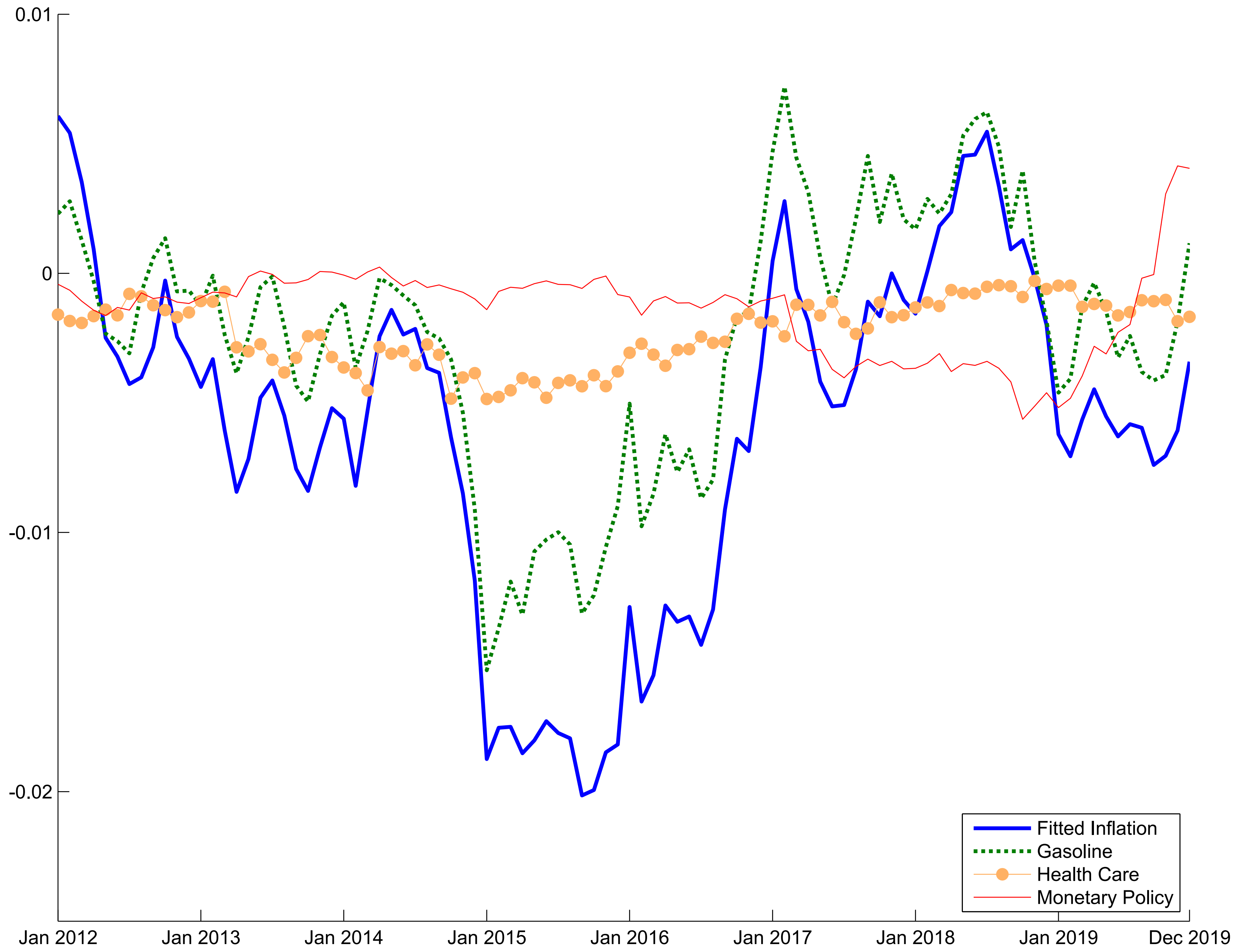
Since 2012, the Federal Reserve has a formal 2% target for PCE inflation

But from 2012 to 2019, PCE inflation averaged only 1.4%

What accounts for this inflation shortfall?

Compute the contribution from each component based on the smoothed inferences of each shock from the Kalman filter with our estimated parameters

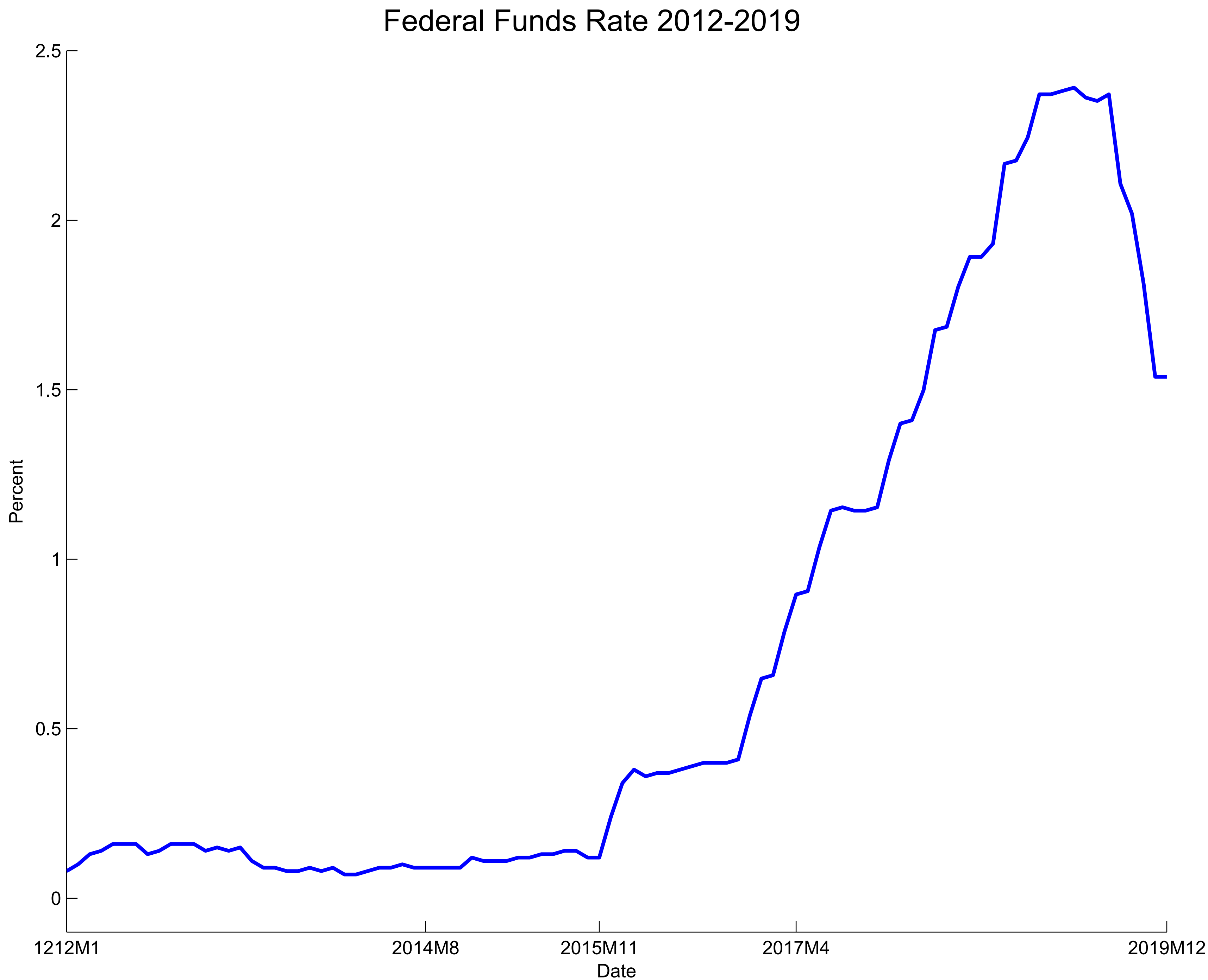
Figure 5: Undershooting: Inflation and Contributions from Gasoline, Health Care, and Monetary Policy



Inflation Shortfall 2012-2019 (cont.)

The early part of the undershoot was driven mainly by health care shocks, and then somewhat later by gasoline shocks

Monetary policy became more important starting in late 2016



Federal Funds Rate 2012-2019
Percent
2.5
2
1.5
1
0.5
0
1212M1
2014M8
2015M11
2017M4
2019M12
Date

Inflation Shortfall 2012-2019 (cont.)

The early part of the undershoot was driven mainly by health care shocks, and then somewhat later by gasoline shocks

Monetary policy became more important starting in late 2016

That period coincided with the Fed's increase in interest rates

While that rate increase was gradual by historical standards, it represented a contractionary policy according to our estimated model

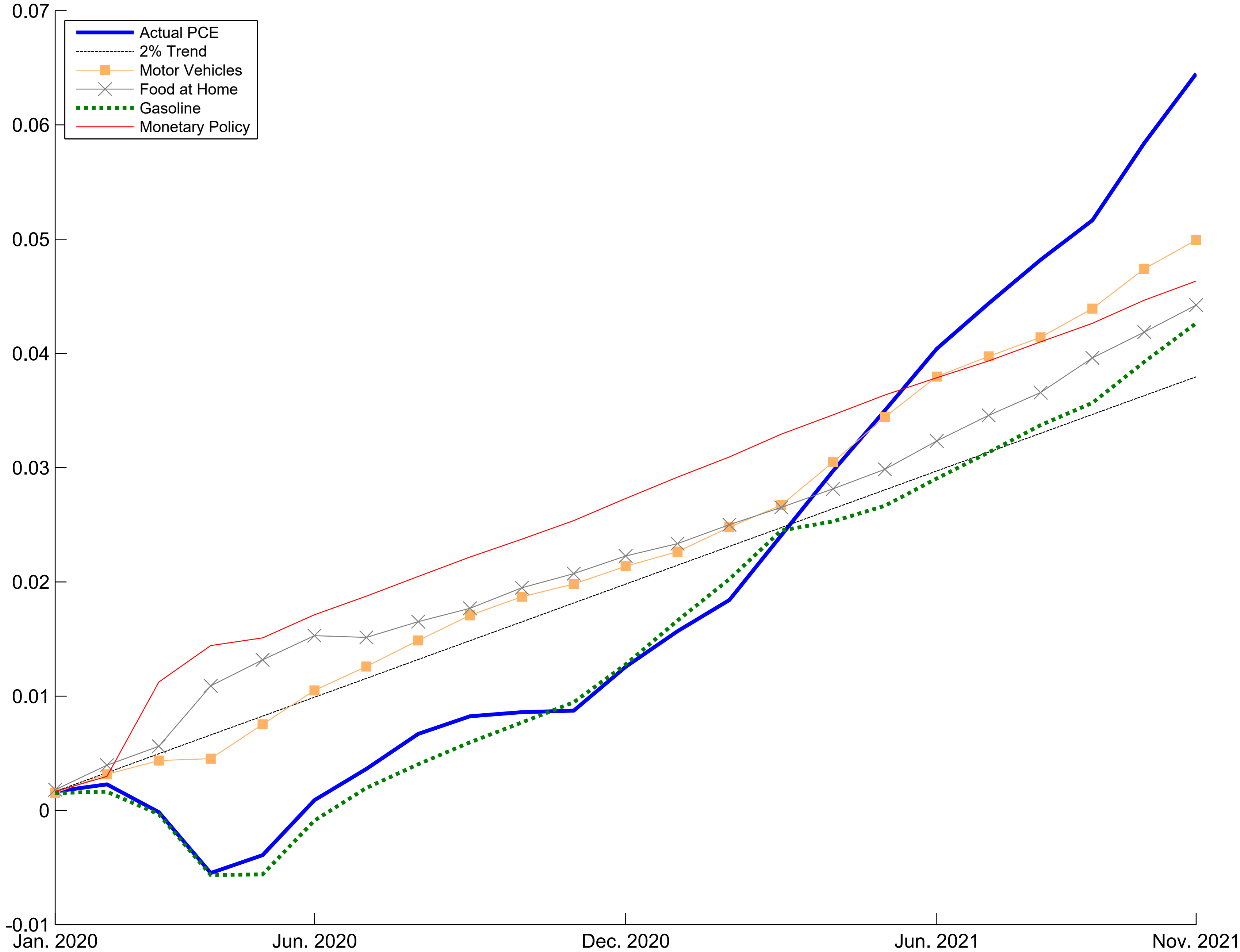
COVID Inflation

Covid Inflation

Again, decompose observed inflation into the contributions of the various shocks

Filter data through November 2021 assuming a stable policy regime

Figure 6: COVID Period: Price Level and Contribution from Selected Shocks



Covid Inflation (cont.)

Expansionary monetary policy and (to a lesser extent) food at home were significant contributors to inflation initially

But a few sectoral shocks, especially motor vehicles, were the main cause of the subsequent increase in inflation

Conclusions

Inflation is indeed a monetary phenomenon but . . .

in an environment where monetary policy delivers low and stable inflation, inflation fluctuations that remain appear to be mostly driven by sectoral shocks

In particular, shocks to specific sectors, in addition to monetary policy, account for the inflation undershooting in 2012-2019 and the increase in inflation after COVID