Relative Price Shocks and Inflation

by

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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 (exc. Gasoline)
Motivation (cont.)

We want to evaluate the relative role of sectoral and monetary shocks in general and in specific events.
Motivation (cont.)

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

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.
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.

Sectoral productivity follows the trend-stationary process

$$z_{s,t} = \mu_s t + a_{s,t}$$

$$a_{s,t} = \rho_s a_{s,t-1} + \varepsilon_{s,t}$$

$$\varepsilon_{s,t} \sim i.i.d. N(0, \sigma_s^2)$$

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

Aggregate productivity follows the process

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

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

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

Per-unit price adjustment costs

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

where \( \phi_s \geq 0 \) and

\[ \zeta_{s,t} = (1/e^{\mu_s})^t \left( \prod_{k=1}^{S} (e^{\mu_k} \tilde{\xi}_k) \right)^t \]
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.
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

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

\[ P_tC_t + B_t \leq P_tw_tN_t + (1 + R_{t-1})B_{t-1} + D_t \]

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

\[ 1 + R_t = \delta(1 + R_{t-1}) + (1 - \delta)(1/\beta) \exp(\pi + \gamma \pi + \lambda \pi (\pi_t - \pi) + \lambda_y (\ln(Y_t) - \ln(Y)) + u_t) \]

where

\[ u_t = \kappa u_{t-1} + \zeta_t \]
\[ \zeta_t \sim i.i.d. N(0, \sigma_\zeta^2) \]
Equilibrium and Balanced Growth Path

The equilibrium of the model is symmetric within sectors but asymmetric across sectors.
Equilibrium and Balanced Growth Path

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

Sectoral Phillips curve

\[
\left( \frac{\theta - 1}{\theta} \right) \frac{P_{s,t}}{P_t} = \frac{w_t}{e^{z_t} e^{t \mu_s} e^{a_{s,t}}} + \zeta_{s,t} \phi_s \left( \frac{\pi_{s,t}}{e^{a \pi + a_s \pi_s}} - 1 \right) \left( \frac{1}{2} - \frac{1}{\theta} \right) \frac{\pi_{s,t}}{e^{a \pi + a_s \pi_s}} - \frac{1}{2} \\
+ \zeta_{s,t+1} \left( \frac{\phi_s}{\theta} \right) \left( \frac{1}{e^{a \pi + a_s \pi_s}} \right) E_t \left( \left( \frac{1}{1 + R_t} \right) \pi_{t+1} \pi_{s,t+1} \left( \frac{\pi_{s,t+1}}{e^{a \pi + a_s \pi_s}} - 1 \right) \frac{y_{s,t+1}}{y_{s,t}} \right),
\]
Equilibrium and Balanced Growth Path

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

Sectoral Phillips curve

\[
\left( \frac{\theta - 1}{\theta} \right) \frac{P_{s,t}}{P_t} = \frac{w_t}{e^{z_t} e^{\mu_s} e^{\delta_{s,t}}} + \zeta_{s,t}\phi_s \left( \frac{\pi_{s,t}}{e^{a\pi + \alpha_{s} \pi_s}} - 1 \right) \left( \frac{1}{2} - \frac{1}{\theta} \right) \frac{\pi_{s,t}}{e^{a\pi + \alpha_{s} \pi_s}} - \frac{1}{2} \\
+ \zeta_{s,t+1} \left( \frac{\phi_s}{\theta} \right) \left( \frac{1}{e^{a\pi + \alpha_{s} \pi_s}} \right) E_t \left( \left( \frac{1}{1 + R_t} \right) \pi_{t+1} \xi_{s,t+1} \left( \frac{\pi_{s,t+1}}{e^{a\pi + \alpha_{s} \pi_s}} - 1 \right) \frac{y_{s,t+1}}{y_{s,t}} \right),
\]

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.
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of leisure in the utility function</td>
<td>$\psi$</td>
<td>1.8</td>
</tr>
<tr>
<td>Elasticity parameter</td>
<td>$\theta$</td>
<td>10.0</td>
</tr>
<tr>
<td>Price indexation</td>
<td>$\alpha, \alpha_s$</td>
<td>0.5</td>
</tr>
<tr>
<td>Discount rate</td>
<td>$\beta$</td>
<td>0.998</td>
</tr>
</tbody>
</table>

Consumption weights:

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

Sectoral productivity trends:

$$\mu_s = \pi + \gamma_c - \pi_s$$
## Consumption Weights and Productivity Trends

<table>
<thead>
<tr>
<th>Sector</th>
<th>Consumption Weight</th>
<th>Productivity Trend $\times10^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicles and parts</td>
<td>0.0488</td>
<td>0.2605</td>
</tr>
<tr>
<td>Furnishings and household durables</td>
<td>0.0296</td>
<td>0.3936</td>
</tr>
<tr>
<td>Recreational goods</td>
<td>0.0311</td>
<td>0.7428</td>
</tr>
<tr>
<td>Other durable goods</td>
<td>0.0166</td>
<td>0.3076</td>
</tr>
<tr>
<td>Food at home</td>
<td>0.0878</td>
<td>0.1710</td>
</tr>
<tr>
<td>Clothing and footwear</td>
<td>0.0414</td>
<td>0.3487</td>
</tr>
<tr>
<td>Gasoline and other energy goods</td>
<td>0.0308</td>
<td>0.1343</td>
</tr>
<tr>
<td>Other nondurable goods</td>
<td>0.0801</td>
<td>0.1564</td>
</tr>
<tr>
<td>Housing and utilities</td>
<td>0.1877</td>
<td>0.0891</td>
</tr>
<tr>
<td>Health care</td>
<td>0.1509</td>
<td>0.0464</td>
</tr>
<tr>
<td>Transportation services</td>
<td>0.0343</td>
<td>0.1586</td>
</tr>
<tr>
<td>Recreation services</td>
<td>0.0371</td>
<td>0.0983</td>
</tr>
<tr>
<td>Food services and accommodations</td>
<td>0.0661</td>
<td>0.1003</td>
</tr>
<tr>
<td>Financial services and insurance</td>
<td>0.0738</td>
<td>0.0978</td>
</tr>
<tr>
<td>Other services</td>
<td>0.0840</td>
<td>0.1041</td>
</tr>
</tbody>
</table>
### ML Estimates: Other Sectoral Parameters

<table>
<thead>
<tr>
<th>Category</th>
<th>Price Rigidity</th>
<th>AR Coefficient</th>
<th>SD ×10²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicles and parts</td>
<td>7.316*</td>
<td>0.990*</td>
<td>0.460*</td>
</tr>
<tr>
<td>Furnishings and household durables</td>
<td>0.186</td>
<td>0.991*</td>
<td>0.386*</td>
</tr>
<tr>
<td>Recreational goods</td>
<td>0.676</td>
<td>0.998*</td>
<td>0.376*</td>
</tr>
<tr>
<td>Other durable goods</td>
<td>&lt; 0.001</td>
<td>0.995*</td>
<td>0.584*</td>
</tr>
<tr>
<td>Food at home</td>
<td>4.229*</td>
<td>0.997*</td>
<td>0.324*</td>
</tr>
<tr>
<td>Clothing and footwear</td>
<td>0.516</td>
<td>0.995*</td>
<td>0.547*</td>
</tr>
<tr>
<td>Gasoline and other energy goods</td>
<td>3.673*</td>
<td>0.962*</td>
<td>6.144*</td>
</tr>
<tr>
<td>Other nondurable goods</td>
<td>0.030</td>
<td>0.990*</td>
<td>0.315*</td>
</tr>
<tr>
<td>Housing and utilities</td>
<td>8.485*</td>
<td>0.997*</td>
<td>0.192*</td>
</tr>
<tr>
<td>Health care</td>
<td>4.090*</td>
<td>0.997*</td>
<td>0.184*</td>
</tr>
<tr>
<td>Transportation services</td>
<td>0.255</td>
<td>0.975*</td>
<td>0.530*</td>
</tr>
<tr>
<td>Recreation services</td>
<td>2.094*</td>
<td>0.997*</td>
<td>0.243*</td>
</tr>
<tr>
<td>Food services and accommodations</td>
<td>111.121*</td>
<td>0.455*</td>
<td>1.989*</td>
</tr>
<tr>
<td>Financial services and insurance</td>
<td>&lt; 0.001</td>
<td>0.991*</td>
<td>0.710*</td>
</tr>
<tr>
<td>Other services</td>
<td>12.883*</td>
<td>0.998*</td>
<td>0.272*</td>
</tr>
<tr>
<td>Aggregate productivity</td>
<td>−0.819</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
</tbody>
</table>
## ML Estimates: Taylor Rule

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model Estimate</th>
<th>Model s.e.</th>
<th>Unrestricted Estimate</th>
<th>Unrestricted s.e.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoothing parameter</td>
<td>0.733*</td>
<td>0.146</td>
<td>0.989*</td>
<td>0.261</td>
</tr>
<tr>
<td>Inflation coefficient</td>
<td>4.312</td>
<td>2.725</td>
<td>1.007*</td>
<td>0.249</td>
</tr>
<tr>
<td>Output coefficient</td>
<td>0.310</td>
<td>0.227</td>
<td>0.146†</td>
<td>0.079</td>
</tr>
<tr>
<td>AR coefficient</td>
<td>0.673*</td>
<td>0.176</td>
<td>0.456*</td>
<td>0.038</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.049†</td>
<td>0.027</td>
<td>0.011*</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
Model Evaluation
### Predicted Second Moments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Standard Deviation</th>
<th>Autocorrelation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Model</td>
</tr>
<tr>
<td>Nominal interest rate</td>
<td>0.110</td>
<td>0.043</td>
</tr>
<tr>
<td>Aggregate inflation</td>
<td>0.187</td>
<td>0.252</td>
</tr>
</tbody>
</table>

**Sectoral price changes:**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Standard Deviation</th>
<th>Autocorrelation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicles and parts</td>
<td>0.315</td>
<td>0.348</td>
</tr>
<tr>
<td>Furnishings and household durables</td>
<td>0.377</td>
<td>0.432</td>
</tr>
<tr>
<td>Recreational goods</td>
<td>0.355</td>
<td>0.415</td>
</tr>
<tr>
<td>Other durable goods</td>
<td>0.597</td>
<td>0.628</td>
</tr>
<tr>
<td>Food at home</td>
<td>0.263</td>
<td>0.307</td>
</tr>
<tr>
<td>Clothing and footwear</td>
<td>0.517</td>
<td>0.566</td>
</tr>
<tr>
<td>Gasoline and other energy goods</td>
<td>4.986</td>
<td>4.828</td>
</tr>
<tr>
<td>Other nondurable goods</td>
<td>0.303</td>
<td>0.382</td>
</tr>
<tr>
<td>Housing and utilities</td>
<td>0.140</td>
<td>0.197</td>
</tr>
<tr>
<td>Health care</td>
<td>0.148</td>
<td>0.224</td>
</tr>
<tr>
<td>Transportation services</td>
<td>0.511</td>
<td>0.558</td>
</tr>
<tr>
<td>Recreation services</td>
<td>0.208</td>
<td>0.273</td>
</tr>
<tr>
<td>Food services and accommodations</td>
<td>0.169</td>
<td>0.211</td>
</tr>
<tr>
<td>Financial services and insurance</td>
<td>0.722</td>
<td>0.762</td>
</tr>
<tr>
<td>Other services</td>
<td>0.171</td>
<td>0.221</td>
</tr>
</tbody>
</table>
Relative Price Shocks and Inflation Over the Entire Sample
Impulse Responses
Figure 1: Responses of Relative Prices to Negative Productive Shock in Own Sector

A. Motor Vehicles
B. Furnishings
C. Recreational Goods
D. Other Durables
E. Food at Home
F. Clothing and Footwear
G. Gasoline
H. Other Nondurables
I. Housing
J. Health
K. Transportation
L. Recreation
M. Food Services
N. Finance
O. Other Services
Figure 2: Inflation Responses

A. Monetary Policy

B. Motor Vehicles

C. Furnishings

D. Recreational Goods

E. Other Durables

F. Food at Home

G. Clothing and Footwear

H. Gasoline

I. Other Nondurables

J. Housing

K. Health

L. Transportation

M. Recreation

N. Food Services

O. Finance

P. Other Services
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
Accounting for the Variance of Inflation

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

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

Monetary policy accounts for around 25% of the variance of the inflation forecast error.
Accounting for the Variance of Inflation

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

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

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Own Shock</th>
<th>Monetary Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicles and parts</td>
<td>86.481</td>
<td>9.988</td>
</tr>
<tr>
<td>Furnishings and household durables</td>
<td>78.458</td>
<td>15.438</td>
</tr>
<tr>
<td>Recreational goods</td>
<td>79.421</td>
<td>14.980</td>
</tr>
<tr>
<td>Other durable goods</td>
<td>89.216</td>
<td>7.711</td>
</tr>
<tr>
<td>Food at home</td>
<td>77.909</td>
<td>16.674</td>
</tr>
<tr>
<td>Clothing and footwear</td>
<td>88.414</td>
<td>8.372</td>
</tr>
<tr>
<td>Gasoline and other energy goods</td>
<td>99.904</td>
<td>0.072</td>
</tr>
<tr>
<td>Other nondurable goods</td>
<td>71.308</td>
<td>20.537</td>
</tr>
<tr>
<td>Housing and utilities</td>
<td>62.428</td>
<td>28.985</td>
</tr>
<tr>
<td>Health care</td>
<td>58.413</td>
<td>31.883</td>
</tr>
<tr>
<td>Transportation services</td>
<td>87.256</td>
<td>9.139</td>
</tr>
<tr>
<td>Recreation services</td>
<td>62.771</td>
<td>27.274</td>
</tr>
<tr>
<td>Food services and accommodations</td>
<td>94.805</td>
<td>3.060</td>
</tr>
<tr>
<td>Financial services and insurance</td>
<td>92.735</td>
<td>5.240</td>
</tr>
<tr>
<td>Other services</td>
<td>77.021</td>
<td>17.813</td>
</tr>
</tbody>
</table>
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
Inflation Shortfall 2012-2019

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.
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