Inflation Dynamics During the Financial Crisis

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In spite of massive contraction in economic activity during the 2007–09 financial crisis, the general level of prices has remained surprisingly stable.

What accounts for the absence of deflationary pressures in light of the enormous and persistent resource slack in the economy?

This paper investigates the effect of financial conditions on firms’ price-setting behavior during the “Great Recession.”
Borrowing capacity of firms and households depends on borrower net worth. (Kyotaki & Moore [1997], Bernanke, Gertler and Gilchrist [1999], Christiano, Motto and Rostagno [2013])

Shocks to economy are amplified by endogenous movement in asset prices.

Positive comovement between inflation and output.
Financial frictions distort allocation of inputs across production units. (Kyotaki [1998], Basso, Cagetti & DeNardi [2010], Buera & Moll [2012])

- Shocks to the economy create endogenous movements in aggregate TFP.
- Negative comovement between inflation and output?
Financial frictions distort pricing decision in customer markets framework. (Gottfries [1991], Chevalier & Scharfstein [1996], Barth & Ramey [2001])

Shocks to the economy create endogenous movements in markups.

Negative comovement between inflation and output.
Overview

- Merge item-level prices of individual producers included in the Producers Price Index (PPI) to their income and balance sheet data from Compustat.
- Analyze how balance sheet conditions influence firm-level price-setting behavior.
- Study inflation and output dynamics in a DSGE model that embeds financial frictions in a customer-markets framework.
Monthly good-level price data underlying the PPI.
(Nakamura & Steinsson [2008]; Goldberg & Hellerstein [2009]; Bhattarai & Schoenle [2010])

Match 700+ PPI respondents to their income and balance sheet data from Compustat.

Sample period: Jan2005–Sep2012
Aggregate Inflation
All PPI respondents vs. publicly-traded firms

NOTE: Seasonally-adjusted weighted average inflation at a monthly rate.
Relative Inflation by Firm Characteristics

- Sort firms above/below median value based on observable characteristics in periods $t - 1 \ldots t - 4$.

- Financial characteristics:
  - Liquidity: $(\text{Cash}[t] + \text{LiquidAssets}[t])/\text{TotalAssets}[t]$
  - Cashflow: $\text{OperatingIncome}[t]/\text{TotalAssets}[t-1]$
  - Interest coverage: $\text{InterestExpense}[t]/\text{Sales}[t]$

- Other characteristics:
  - Customer markets vs. operating efficiency: $\text{SGAX}[t]/\text{Sales}[t]$
  - Durability of output: durable vs. nondurable goods
Relative Inflation
Financially unconstrained firms

NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.
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Relative Inflation
Effect of Financial Frictions, Cumulated Response

NOTE: Cumulated weighted average monthly inflation relative to industry (2-digit NAICS) inflation.
RELATIVE INFLATION
By durability of output and financial condition

NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.
Multinominal logit specification:

\[
\text{Pr}(\Delta p_{ij,t+1}) = \begin{cases} 
+ & (\text{base}) = \Lambda(X_{jt}; \beta_t) \\
0 & \\
- &
\end{cases}
\]

- \(X_{jt}\) = liquidity ratio and other controls
- Includes fixed industry (3-digit NAICS) effects.
- Estimated using four-quarter rolling window.
Elasticities of Price Changes
With Respect to SGAX

Downward Price Changes

Elasticity

2005 2007 2009 2011
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2

Upward Price Changes

Elasticity

2005 2007 2009 2011
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
Price change regression:

\[ \Delta p_{i,j,t+1} = \alpha_j + \beta X_{j,t} + \epsilon_{i,j,t} \]

- \( X_{j,t} \) = liquidity ratio and other controls.
- Includes firm-level fixed effects: controls for many aspects of firm heterogeneity such as productivity.
- Estimated using four-quarter rolling window.
PRICE CHANGE COEFFICIENTS

All Price Changes

- Estimated coefficient

NOTE: Estimated Coefficients on Liquidity Ratio.
Customer markets imply firms trade off current profits for future market share.

Financial frictions imply firms discount the future more when demand is low – therefore keep mark-up high.

Embed this into GE model with nominal price rigidities.
Maximization

\[
\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s U(x^j_{t+s} - \delta_{t+s}, h^j_{t+s}); \quad j \in [0, 1]
\]

Aggregator: \( x^j_t \equiv \left[ \int_0^1 \left( \frac{c^j_{it}}{s^j_{it-1}} \right)^{1-1/\eta} \frac{1-1/\eta}{1} \right]^{1/(1-1/\eta)} \)

Law of motion:

\[
s_{it} = \rho s_{i,t-1} + (1 - \rho) c_{it}; \quad 0 < \rho < 1
\]

\( \delta_t = \text{demand shock} \)
**Production function (labor input, fixed operating costs):**

\[ y_{it} = \left[ \frac{A_t}{a_{it}} h_{it} \right]^\alpha - \phi_i; \quad 0 < \alpha \leq 1 \]

- \( A_t \) = persistent aggregate technology shock
- \( a_{it} \) = i.i.d. idiosyncratic technology shock with
  \[ \log a_{it} \sim N(-0.5\sigma^2, \sigma^2) \]
Firms make production decisions prior to realization of marginal cost.

If realized operating income is negative, firms must raise costly equity finance:

\[ \varphi \in (0, 1) = \text{constant per-unit dilution costs of new equity} \]

**Implications:**

- A low mark-up is an aggressive, but risky investment.
- Exposes the firm to the risk of operating losses, which must be covered by external financing.
Nominal rigidities and monetary policy:

- **Price adjustment:** (Rotemberg [1982])

\[
\frac{\gamma}{2} \left( \frac{P_{it}}{P_{i,t-1}} - \bar{\pi} \right)^2 c_t = \frac{\gamma}{2} \left( \pi_t \frac{p_{it}}{p_{i,t-1}} - \bar{\pi} \right)^2 c_t; \quad p_{it} \equiv \frac{P_{it}}{P_t}
\]

- **Taylor rule:**

\[
r_t = \max \left\{ 0, (1 + r_{t-1})^{\rho_r} \left[ (1 + \bar{r}) \left( \frac{\pi_t}{\pi^*} \right)^{\rho_{\pi}} \left( \frac{y_t}{y^*_t} \right)^{\rho_y} \right]^{1-\rho_r} - 1 \right\}
\]
Maximize the expected present value of dividends:

\[ \mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t} \left\{ d_{it} + \kappa_{it} \left[ \left( \frac{A_t h_{it}}{a_{it}} \right)^\alpha - \phi_k - c_{it} \right] 
+ \xi_{it} \left[ p_{it} c_{it} - w_t h_{it} - \frac{\gamma}{2} \left( \pi_t \frac{p_{it}}{p_{i,t-1}} - \bar{\pi} \right)^2 c_t - \bar{\phi}(d_{it}) \right] 
+ \nu_{it} \left[ \left( \frac{p_{it}}{\tilde{p}_t} \right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} x_t - c_{it} \right] + \lambda_{it} [\rho s_{i,t-1} + (1 - \rho) c_{it} - s_{it}] \right\} \]

- **Externality-adjusted composite price index:**
  \[ \tilde{p}_t \equiv \left[ \int_0^1 (p_{it} s_{i,t-1}^{\theta})^{1-\eta} d\bar{i} \right]^{1/(1-\eta)} \]

- \( p_{it}, c_{it}, s_{it} \) chosen before the realization of idiosyncratic shock \( a_{it} \).
- \( d_{it}, h_{it} \) chosen after the realization of idiosyncratic shock \( a_{it} \).
The FOC for $d_{it}$:

$$
\xi(a_{it}) = \begin{cases} 
1 & \text{if } a_{it} \leq a_t^E \\
1/(1 - \varphi) & \text{if } a_{it} > a_t^E
\end{cases}
$$

where $a_t^E$ is the idiosyncratic productivity level when dividends are exactly zero:

$$
a_t^E = \frac{c_t}{(c_t + \phi)^{1/\alpha}} \frac{A_t}{w_t} \left[ 1 - \frac{\gamma}{2} (\pi_t - \bar{\pi})^2 \right]
$$
The expected cost of external funds is:

$$
\mathbb{E}_t^a[\xi_{it}] = \Phi(z_t^E) + \frac{1}{1 - \varphi} [1 - \Phi(z_t^E)]
$$

$$
= 1 + \frac{\varphi}{1 - \varphi} [1 - \Phi(z_t^E)] \geq 1
$$

where

$$
z_t^E = \sigma^{-1}(\log a_t^E + 0.5\sigma^2).
$$
Price-setting without nominal rigidities

- No customer markets:

\[ 1 = \left( \frac{\eta}{\eta - 1} \right) \frac{1}{\tilde{\mu}_t} \]

- With customer markets:

\[ 1 = \eta \left[ \frac{\tilde{\mu}_t - 1}{\tilde{\mu}_t} \right] + \psi \mathbb{E}_t \left[ \sum_{s=t}^{\infty} \tilde{\beta}_{ts} \frac{\mathbb{E}_{s+1}[\xi_{i,s+1}]}{\mathbb{E}_t[\xi_{it}]} \left[ \frac{\tilde{\mu}_{s+1} - 1}{\tilde{\mu}_{s+1}} \right] \right] \]
\[
\hat{\pi}_t = -\frac{\omega(\eta - 1)}{\gamma} \left[ \hat{\mu}_t + \mathbb{E}_t \sum_{s=t}^{\infty} \chi \delta^{s-t+1} \hat{\mu}_{s+1} \right] + \beta \mathbb{E}_t[\hat{\pi}_{t+1}]
\]
\[+ \frac{1}{\gamma} \left[ \eta - \omega(\eta - 1) \right] \mathbb{E}_t \sum_{s=t}^{\infty} \chi \delta^{s-t+1} \left[ (\hat{\xi}_t - \hat{\xi}_{s+1}) - \hat{\beta}_{t,s+1} \right] \]

- \( \hat{\mu}_t \) = (marginal) mark-up
- \( \hat{\xi}_t \) = shadow value of internal funds
- \( \hat{\beta}_{t,s+1} \) = capitalized growth of customer base
## Calibration

<table>
<thead>
<tr>
<th>Preferences and production</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant relative risk aversion, $\gamma_x$</td>
<td>1.00</td>
</tr>
<tr>
<td>Deep habit, $\theta$</td>
<td>0.95</td>
</tr>
<tr>
<td>Persistence of deep habit, $\rho$</td>
<td>0.95</td>
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<tr>
<td>Elasticity of labor supply, $1/\gamma_h$</td>
<td>5.00</td>
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<tr>
<td>Elasticity of substitution, $\eta$</td>
<td>2.00</td>
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<tr>
<td>Returns to scale, $\alpha$</td>
<td>0.80</td>
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<tr>
<td>Fixed operation cost, $\phi$</td>
<td>0.21</td>
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<thead>
<tr>
<th>Nominal rigidity and monetary policy</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price adjustment cost, $\gamma_p$</td>
<td>10.0</td>
</tr>
<tr>
<td>Wage adjustment cost, $\gamma_w$</td>
<td>30.0</td>
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<tr>
<td>Monetary policy inertia, $\rho^r$</td>
<td>0.75</td>
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<tr>
<td>Taylor rule coefficient for inflation gap, $\rho^\pi$</td>
<td>1.50</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Financial Frictions</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity issuance cost, $\varphi$</td>
<td>0.30, 0.50</td>
</tr>
<tr>
<td>Idiosyncratic volatility (a.r.), $\sigma$</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Demand Shock: Financial Crisis ($\varphi = 0.5$)

(a) Output

(b) Value of intnl. funds

(c) Mark-up

(d) Inflation

w/o financial frictions

w/ financial frictions
**Demand Shock**
With temporary increase in financial frictions

- **Fixed dilution cost:** $\varphi = 0.5$
- **Temporary increase:** $\varphi = 0.3 \rightarrow 0.37$
Taylor rule output gap coefficients: blue = 0; red = 0.125; green = 0.250
Heterogeneous Firms

- Sectors differ by operating efficiency: $0 \leq \phi_1 < \phi_2$
- Fixed measures of firms $\omega_1 = \omega_2 = \frac{1}{2}$
- Equilibrium dispersion of relative prices:

$$\pi_t = \left[ \sum_{k=1}^{2} \omega_k p_{k,t-1}^{1-\eta} \pi_{kt}^{1-\eta} \right]^{1/(1-\eta)}; \quad \pi_{kt} \equiv \frac{P_{kt}}{P_{k,t-1}}$$

- $p_{kt} \equiv P_{kt}/P_t = \text{sector-specific relative price}$
“Price War” in Response to Financial Shocks

Heterogeneous firms

Case I: $\phi_1 = 0.8 \bar{\phi}$, $\phi_2 = \bar{\phi}$ and $\omega_1 = \omega_2 = 0.5$

Case II: $\phi_1 = 0$, $\phi_2 = \bar{\phi}$ and $\omega_1 = \omega_2 = 0.5$
“Price War” in Response to Financial Shocks
Heterogeneous firms

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Case II: $\phi_1 = 0$, $\phi_2 = \bar{\phi}$ and $\omega_1 = \omega_2 = 0.5$
Balance sheet conditions played an important role in price-setting dynamics during the financial crisis:

- Financially healthy firms decreased prices, while financially weak firms increased prices.

DSGE model – customer markets and financial frictions implies

- Attenuation of inflation dynamics in response to demand shocks.
- Severe contraction in response to temporary financial shocks.
- Paradox of financial strength with heterogenous firms.

Monetary policy: inflation-output tradeoff in response to demand or financial shocks.