Inflation Dynamics During the Financial Crisis

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In spite of massive contraction in economic activity during the “Great Recession,” the general level of prices has remained surprisingly stable. (Hall [2011]; Ball & Mazumder [2011]; King & Watson [2012])

Can financial factors account for the absence of deflationary pressures?

We investigate the effect of financial conditions on firms’ price-setting behavior during the 2008–09 financial crisis.
Financial frictions distort pricing decisions in customer markets:

- price cut $\Rightarrow$ investment into customer base


**Implications:** In a customer-markets model with financial distortions, firms faced with a liquidity squeeze have an incentive to raise prices to bolster near-term cashflows at the expense of future market share.
Empirics:
- Merge good-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 during the 2008–09 financial crisis.

Theory:
- Study inflation and output dynamics in a GE model that embeds financial market frictions in a customer-markets framework.
Data Sources

- Monthly **good-level** price data underlying the PPI. ([Nakamura & Steinsson [2008]; Goldberg & Hellerstein [2009]; Bhattarai & Schoenle [2010])

- Match approx. 600 PPI respondents to their income and balance sheet data from Compustat.

- Sample period: Jan2005–Dec2012
\( i \in I \) items; \( j \in J \) firms; and \( k \in K \) industries.

- \( p_{i,j,k,t}^* = \) actual transaction price
- \( p_{i,j,k,t}^b = \) base price (controls for changes in item quality)
- \( p_{i,j,k,t} = p_{i,j,k,t}^* / p_{i,j,k,t}^b = \) quality-adjusted price

**Item-level inflation:** \( \pi_{i,j,k,t} \equiv \Delta \log p_{i,j,k,t} \)

**Industry-adjusted firm-level inflation:**

\[
\pi_{j,k,t} = \sum_{i=1}^{n_j} w_{i,j,k,t} (\pi_{i,j,k,t} - \pi_{k,t})
\]

- \( n_j = \) number of goods produced by firm \( j \)
- \( w_{i,j,k,t} = \) relative weight of good \( i \) in the production structure
- \( \pi_{k,t} = \) industry-level (2-digit NAICS) inflation rate
COMPARING DATA TO BROADER AGGREGATES

Weighted-average PPI inflation

NOTE: Seasonally adjusted monthly rate.

PPI-OIL
COMPARING DATA TO BROADER AGGREGATES
Weighted-average growth of real sales

NOTE: Deflated by the implicit nonfarm business sector GDP price deflator (2010 = 100); seasonally adjusted quarterly rate.
How do financial characteristics of firms influence their price-setting behavior?

- Descriptive analysis of aggregate relationships
- Multivariate analysis
Sorting procedure:

- In period \( t \), sort firms into financially \textbf{weak} and \textbf{strong} based on observable characteristics in periods \( t - 1, \ldots, t - 4 \).

Financial characteristics:

- \textbf{Liquidity}: \( \frac{\text{Cash}[t] + \text{LiquidAssets}[t]}{\text{TotalAssets}[t]} \)

Other characteristics:

- Customer markets vs. operating efficiency: \( \frac{\text{SGAX}[t]}{\text{Sales}[t]} \)  
  \cite{(Gourio & Rudanko [2008])}
- Durability of output: durable vs. nondurable goods
NOTE: Weighted-average inflation relative to industry (2-digit NAICS) inflation (seasonally adjusted monthly rate).
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NOTE: Weighted-average inflation relative to industry (2-digit NAICS) inflation (seasonally adjusted monthly rate).
INDUSTRY-ADJUSTED PPI INFLATION
By durability of output and liquidity condition

NOTE: Weighted-average inflation relative to industry (2-digit NAICS) inflation (seasonally adjusted monthly rate).
8 pps. difference in industry-adjusted inflation rates between financially **weak** and **strong** firms:
(Anderson, Nakamura, Simester & Steinsson [2014])
- Large immediate impact at the nadir of the financial crisis
- Long-lasting, persistent effect

6 pps. difference in industry-adjusted inflation rates between **high-intensity** and **low-intensity** SG&A expense firms.

Differences concentrated in the **nondurable** goods manufacturing sector.
Multinominal logit (3-month-ahead directional price change):

$$\Pr(\text{sgn}(\Delta^3 p_{ij,t+3})) = \begin{cases} + & = \Lambda(LIQ_{jt}, SGAX_{jt}, X_{jt}; \beta_1, \beta_2, \theta) \\ 0 & \\ - & \end{cases}$$

- $LIQ_{jt}$ = liquidity ratio
- $SGAX_{jt}$ = SG&A expense ratio
- $X_{jt}$ = four-quarter (nominal) sales growth; inventory-sales ratio (3-digit NAICS) industry inflation; time fixed effects

Coefficients $\beta_1$ (on $LIQ_{jt}$) and $\beta_2$ (on $SGAX_{jt}$) are allowed to differ across crisis (Apr2008–Mar2009) and no crisis periods.
Marginal effects of selected variables on the probability of a price change

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>w/o OIL Interactions</th>
<th>w/ OIL Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(−)</td>
<td>(+)</td>
</tr>
<tr>
<td>LIQ_{jt}</td>
<td>no crisis</td>
<td>0.078</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.055)</td>
</tr>
<tr>
<td>LIQ_{jt}</td>
<td>crisis</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.098)</td>
</tr>
<tr>
<td>SGAX_{jt}</td>
<td>no crisis</td>
<td>-0.259***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.073)</td>
</tr>
<tr>
<td>SGAX_{jt}</td>
<td>crisis</td>
<td>-0.382***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.098)</td>
</tr>
</tbody>
</table>

Cragg & Uhler’s $R^2$ 0.072 0.073

Note: Robust standard errors are clustered at the firm level; *** $p < .01$, ** $p < .05$, * $p < .10$. 
Regression (3-month-ahead inflation):

\[
\pi_{ij,t+3}^{3m} = \beta_{cLIQ} I_t[\text{crisis}] + \beta_{ncLIQ} I_t[\text{no crisis}]
\]
\[
+ \gamma_{cSGAX} I_t[\text{crisis}] + \gamma_{ncSGAX} I_t[\text{no crisis}]
\]
\[
+ \theta' X_{jt} + \eta + \lambda_t + \epsilon_{ij,t+3}
\]

- \( X_{jt} = \) four-quarter (nominal) sales growth; inventory-sales ratio (3-digit NAICS) industry inflation
### Effect of selected variables on item-level inflation

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>w/o OIL Interactions</th>
<th>w/ OIL Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$LIQ_{jt}$</td>
<td>no crisis</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>$LIQ_{jt}$</td>
<td>crisis</td>
<td>-0.029</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.020)</td>
</tr>
<tr>
<td>$SGAX_{jt}$</td>
<td>no crisis</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.002)</td>
</tr>
<tr>
<td>$SGAX_{jt}$</td>
<td>crisis</td>
<td>0.035***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td></td>
<td>0.029</td>
</tr>
</tbody>
</table>

**Note:** Robust standard errors are clustered at the firm level; *** $p < .01$, ** $p < .05$, * $p < .10$. 
NOTE: Robust standard errors are clustered at the firm level.
NOTE: Standard errors are clustered at the firm level.
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

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

Aggregator: \( x_t^j \equiv \left[ \int_0^1 \left( \frac{c_{it}^j}{s_{it-1}^j} \right)^{1-1/\eta} \, di \right]^{1/(1-1/\eta)} \)

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.
Price adjustment: \((\text{Rotemberg [1982]})\)

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

Taylor rule:

\[
r_t = \max \left\{ 0, (1 + r_{t-1})^{\rho_r} \left[ (1 + \bar{r}) \left( \frac{\pi_t}{\pi^*} \right)^{\rho_\pi} \left( \frac{y_t}{y^*} \right)^{\rho_y} \right]^{1-\rho_r} - 1 \right\}
\]
**Firm Problem**

- Maximize the expected present value of dividends:

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

- 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 \( a_{it} \).
Equity issuance

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:

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

where

\[
z_t^E = \sigma^{-1} (\log a_t^E + 0.5\sigma^2).
\]
Mark-ups

- **Aggregate markup:**

  \[ \mu(A_t, c_t, w_t) \equiv \alpha \left( \frac{A_t}{w_t} \right) (c_t + \phi)^{\frac{\alpha-1}{\alpha}} \]

- **Financially-adjusted mark-up**

  \[ \tilde{\mu}(A_t, c_t, w_t) \equiv \frac{\mathbb{E}_t^a [\xi_{it}]}{\mathbb{E}_t^a [\xi_{it} a_{it}]} \mu(A_t, c_t, w_t) \]

  where

  \[ \frac{\mathbb{E}_t^a [\xi_{it}]}{\mathbb{E}_t^a [\xi_{it} a_{it}]} = \frac{1 - \varphi \Phi(z_t^E)}{1 - \varphi \Phi(z_t^E - \sigma)} \leq 1. \]

- **Financial frictions increase marginal cost and hence lower the markup.**
\[ m_{t,t+1} = \beta \left[ \frac{U_x(x_{t+1} - \delta_{t+1}, h_{t+1})}{U_x(x_t - \delta_t, h_t)} \right] \left[ \frac{s_{t-1}}{s_t^*} \right] \]

\[ \frac{\omega_t}{\tilde{p}_t} = -\frac{U_h(x_t - \delta_t, h_t)}{U_x(x_t - \delta_t, h_t)} \]

\[ c_t = y_t - \sum_{k=1}^{N} \omega_k \frac{\gamma}{2} (\pi_t \pi_{kt} - 1)^2 c_t \]
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:

\[
r_t = \max \left\{ 0, (1 + r_{t-1})^{\rho_r} \left[ (1 + \bar{r}) \left( \frac{\pi_t}{\pi^*} \right)^{\rho_{\pi}} \left( \frac{y_t}{y^*_t} \right)^{\rho_y} \right]^{1-\rho_r} - 1 \right\}
\]
Price-setting without nominal rigidities

- No customer markets:

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

- With customer markets:

\[
1 = \eta \left[ \frac{\tilde{\mu}_t - 1}{\tilde{\mu}_t} \right] \\
+ \psi \mathbb{E}_t \left[ \sum_{s=t}^{\infty} \tilde{\beta}_{ts} \frac{\mathbb{E}_{s+1}^{a} [\xi_{i,s+1}]}{\mathbb{E}_t^{a} [\xi_{it}]} \left[ \frac{\tilde{\mu}_{s+1} - 1}{\tilde{\mu}_{s+1}} \right] \right]
\]
Log-Linearized Phillips Curve
New Keynesian model with cost channel

\[ \hat{\pi}_t = \frac{\omega(\eta - 1)}{\gamma_p} \left[ \hat{\mu}_t + \mathbb{E}_t \sum_{s=t}^{\infty} \chi \tilde{\delta}^{s-t+1} \hat{\mu}_{s+1} \right] + \beta \mathbb{E}_t[\hat{\pi}_{t+1}] \]

\[ + \frac{1}{\gamma_p} [\eta - \omega(\eta - 1)] \mathbb{E}_t \sum_{s=t}^{\infty} \chi \tilde{\delta}^{s-t+1} \left[ (\hat{\xi}_t - \hat{\xi}_{s+1}) - \hat{\beta}_{t,s+1} \right] \]

- \( \hat{\mu}_t = \) (financially-adjusted) mark-up
- \( \hat{\beta}_{t,s+1} = \) capitalized growth of customer base
- \( \hat{\xi}_t = \) shadow value of internal funds
The role of “deep habits”

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

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- \( \hat{\mu}_t = (\text{financially adjusted}) \text{ mark-up} \)
- \( \hat{\beta}_{t,s+1} = \text{capitalized growth of customer base} \)
- \( \hat{\xi}_t = \text{shadow value of internal funds} \)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferences and production</td>
<td></td>
</tr>
<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>
</tr>
<tr>
<td>Elasticity of labor supply, $1/\gamma_h$</td>
<td>5.00</td>
</tr>
<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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<td>Fixed operation cost, $\phi$</td>
<td>0.21</td>
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<td>Nominal rigidity and monetary policy</td>
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<td>Price adjustment cost, $\gamma_p$</td>
<td>10.0</td>
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<td>Wage adjustment cost, $\gamma_w$</td>
<td>30.0</td>
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<td>Monetary policy inertia, $\rho^r$</td>
<td>0.75</td>
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<td>Taylor rule coefficient for inflation gap, $\rho^\pi$</td>
<td>1.50</td>
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<td>Financial Frictions</td>
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<td>Equity issuance cost, $\phi$</td>
<td>0.30, 0.50</td>
</tr>
<tr>
<td>Idiosyncratic volatility (a.r.), $\sigma$</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Shocks

- Demand shock, $\varphi = 0.5$
- Demand shock and financial shock. $\varphi = 0.3, 0.375$
- Discount factor shock – ZLB
- Demand shock with heterogeneous firms
Demand Shock: Financial Crisis ($\varphi = 0.5$)

Economy with flexible prices

(a) Output

(b) Value of intnl. funds

(c) Mark-up

(d) Inflation

- w/o financial frictions
- w/ financial frictions
DEMAND SHOCK: FINANCIAL CRISIS ($\varphi = 0.5$)

Economy with sticky prices

(a) Output
(b) Value of intnl. funds
(c) Mark-up
(d) Inflation

- Inflation without financial frictions vs. with financial frictions
- Graphs show changes in output, value of international funds, mark-up, and inflation over time.
**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
Discounting Rate Shock: the ZLB

NOTE: Blue = model w/ financial frictions; Red = model w/o financial frictions.
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:

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

- $p_{kt} \equiv \frac{P_{kt}}{P_t}$ = 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 $\omega_1 = \omega_2 = 0.5$
- **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 $\omega_1 = \omega_2 = 0.5$
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 $\omega_1 = \omega_2 = 0.5$
Empirical results imply that financially healthy firms decreased prices, while financially weak firms increased prices during the financial crisis.

DSGE model implies attenuation of inflation dynamics in response to demand shocks and severe contraction in response to temporary financial shocks.

Implications for monetary policy: inflation-output tradeoff in response to demand or financial shocks.