Inflation Dynamics During the Financial Crisis

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Exhibit 1: Introduction

What accounts for the resilience of inflation in the face of significant and long-lasting economic slack?

The question of why inflation has been so sticky despite prolonged economic weakness is particularly challenging.

Core producer prices*

Industrial production*

* Deviations from a linear trend estimated over the 24 months preceding the specified recession.

Economic forces that dampen the response of inflation to adverse demand or financial shocks reflect the interaction between customer markets and financial frictions:

Customer markets:

- markets in which customer base is "sticky" and an important determinant of firm's assets and firm's ability to generate profits

Financial frictions:

- systematic countercyclical wedge between the cost of external and internal finance due to asymmetric information or moral hazard problems in financial markets
What accounts for the resilience of inflation in the face of significant and long-lasting economic slack?

In particular, the absence of more substantial deflationary pressures during the “Great Recession” is difficult to square with the Phillips curve common to most macroeconomic models (including standard financial accelerator models).

In a customer-markets model with financial frictions, firms have the incentive to raise prices to increase cash flow at the cost of future market share (Gottfries [1991]; Chevalier and Scharfstein [1996]).
Monthly **good-level** price data underlying the PPI.
(Nakamura & Steinsson [2008]; Goldberg & Hellerstein [2009]; Bhattarai & Schoenle [2010])

- Match 584 PPI respondents to their income and balance sheet data from Compustat.

- Sample period: Jan2005–Dec2012
NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.
ACCUMULATED INDUSTRY-ADJUSTED PPI INFLATION
By selected financial characteristics as of 2006

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

\[
\begin{align*}
\Pr(p_{i,j,t+3} - p_{i,j,t}) &= \begin{cases} 
  +  & \text{0 (base)} = \Lambda(X_{jt}; \beta_t) \\
  - & \end{cases}
\end{align*}
\]

Price change regression:

\[
\log(p_{i,j,t+3}) - \log(p_{i,j,t}) = \beta X_{j,t} + \epsilon_{i,j,t+3}
\]

- \(X_{j,t}\) = liquidity ratio and other controls.
  - Includes fixed time effects and 3-digit inflation.
  - Estimated using four-quarter rolling window.
### Directional Price Change Regressions

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>+</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{LIQ}<em>{j,t} \times 1 [\text{CRISIS}</em>{t} = 1]$</td>
<td>-0.433***</td>
<td>-0.012</td>
</tr>
<tr>
<td></td>
<td>(0.107)</td>
<td>(0.072)</td>
</tr>
<tr>
<td>$\text{LIQ}<em>{j,t} \times 1 [\text{CRISIS}</em>{t} = 0]$</td>
<td>-0.143**</td>
<td>-0.044</td>
</tr>
<tr>
<td></td>
<td>(0.068)</td>
<td>(0.050)</td>
</tr>
<tr>
<td>$\log(\frac{S_{j,t}}{S_{j,t-12}})$</td>
<td>-0.020</td>
<td>-0.042*</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>$\log(\frac{C_{j,t}}{C_{j,t-12}})$</td>
<td>0.017</td>
<td>0.020*</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>$[N/S]_{j,t}$</td>
<td>-0.022</td>
<td>-0.020</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>$\pi_{t}^{\text{IND}(3m)}$</td>
<td>1.182***</td>
<td>-0.127</td>
</tr>
<tr>
<td></td>
<td>(0.333)</td>
<td>(0.170)</td>
</tr>
</tbody>
</table>
**Directional Price Change Regressions**

Coefficient on liquidity ratio (4-quarter rolling window estimates)

- **Negative price changes**
  - Coefficient: $-0.8, -0.6, -0.4, -0.2, 0.0, 0.2, 0.4$

- **Positive price changes**
  - Coefficient: $-0.2, -0.1, 0.0, 0.1, 0.2, 0.3, 0.4$

Quantitative implication: a two std. dev. reduction in liquidity implies a 33% higher probability of a price increase.
### Inflation Regressions

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$LIQ_{j,t} \times 1[CRISIS_{t} = 1]$</td>
<td>-0.029***</td>
<td>(0.009)</td>
</tr>
<tr>
<td>$LIQ_{j,t} \times 1[CRISIS_{t} = 0]$</td>
<td>-0.012***</td>
<td>(0.004)</td>
</tr>
<tr>
<td>$\log(S_{j,t}/S_{j,t-12})$</td>
<td>0.004</td>
<td>(0.003)</td>
</tr>
<tr>
<td>$\log(C_{j,t}/C_{j,t-12})$</td>
<td>-0.002</td>
<td>(0.002)</td>
</tr>
<tr>
<td>$[N/S]_{j,t}$</td>
<td>0.001</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\pi_{t}^{IND(3m)}$</td>
<td>0.134**</td>
<td>(0.055)</td>
</tr>
</tbody>
</table>
Quantitative implication: A two std. dev. reduction in liquidity implies a 5% increase in annualized inflation.
Examine sensitivity of 6-digit industry-level PPI inflation to changes in aggregate financial conditions.

Regress industry-specific year-ahead inflation on
- Current and lagged inflation and industrial production.
- Current financial conditions – excess bond premium (EBP)

Coefficient on EBP varies across 4-digit industry groups.
- Is variation in industry-specific EBP coefficient related to financial constraints across industries?
- Measure severity of financial constraints using size-age index.
Inflation Response to EBP

**Exhibit 4: Is This a One-Off Event?**

- Use detailed industry-level PPIs to examine the sensitivity of inflation to changes in aggregate financial conditions during the 1973-2013 period.
  - Current and lagged inflation
  - Current and lagged growth in industry-level industrial production
  - Current commodity price inflation measured by GSCI

- Coefficients on EBP and commodity price inflation vary across 4-digit industry groups.
- Is variation in industry-specific EBP coefficients related to the likelihood of financial constraints across industries?

**Empirical approach**

Regress industry-specific year-ahead inflation on:
- Indicator of current financial conditions - excess bond premium (EBP)
- Use industry-specific size-age index to identify the likelihood of financial constraints

![Graph showing 12-month PPI inflation and financial conditions by industry-specific indicator of financial constraints](image)

- Coefficient on EBP (4-digit NAICS):
  - \( \beta = 1.11 \)
  - \(|t| = 4.88\)
  - \(R^2 = 0.29\)

- Coefficient on GSCI (4-digit NAICS):
  - \( \beta = 0.01 \)
  - \(|t| = 1.39\)
  - \(R^2 = 0.03\)

Note: Smaller values of the size-age index indicate a smaller likelihood of financial constraints.
Output Response to the EBP

Figure 7: Sensitivity of Industry-Level Output to Financial Conditions, 1973–2013
(By Industry-Specific Indicator of Financial Constraints)

Median Size-Age Index

Coefficient on EBP

$p < .10$

$p >= .10$

$\hat{\beta} = -1.88$

$|t| = -3.77$

$R$-sq $= 0.22$

Note: No. of (4-digit NAICS) industries $= 52$. The figure shows the relationship between the median SA-index of financing constraints at the 4-digit NAICS level during the 1973–2013 period and the corresponding industry-specific estimates of the coefficient on the EBP; the dependent variable is $\Delta \log IP_{i,t+12}$, the log-difference of IP in (5- or 6-digit NAICS) industry $i$ from $t$ to $t+12$ (see the text and notes to Table 3 for details). Observations plotted as diamonds (♦) indicate coefficients that are different from zero at the 10-percent, or lower, significance level; observations plotted as stars (∗) are statistically not different from zero at the 10-percent level. Smaller values of the size-age index indicate a smaller likelihood of financial constraints.

3.1.1 Subsample Stability

The results reported in Table 2 are based on the behavior of producer prices from 1973 to 2013, a period encompassing several distinct inflation regimes. This period also saw significant changes in the conduct of monetary policy, which—in addition to breaking the inflationary spiral of the 1970s—have ultimately led to the stabilization of inflation expectations, a crucial determinant of the firms' pricing behavior. To ensure that our results are robust to this change in inflation expectations, this section repeats the above analysis for post-1985 period. As shown in Table 4, the effect of changes in financial conditions on the subsequent behavior of producer prices during the 1985–2013 period is very similar to that estimated over the full sample period. Imposing a restriction of a common coefficient on the EBP (Panel (a)) yields estimates that

Moreover, as emphasized by Dynan, Elmendorf, and Sichel (2006), the rapid pace of financial innovation since the mid-1980s—namely, the deepening and emergence of lending practices and credit markets that have enhanced the ability of households and firms to borrow and changes in government policy such as the demise of Regulation Q—may have also changed the way economic agents respond to changes in financial conditions.
Customer markets imply that firms trade off current profits for future market share.

Financial market frictions imply that firms discount the future more when demand is low—and therefore charge high markups.

Embed this intuition into a GE model with nominal price rigidities.
Demand for monopolistically competitive good:

\[ c_{it} = \left( \frac{p_{it}}{\tilde{p}_t} \right)^{-\eta} s_{i,t-1} \theta(1-\eta) c_t \]

where

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

- Firms are forward looking – set low price today to build future stock of customer base.
Firms make production decisions prior to realization of marginal cost.

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

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

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

Expected shadow value of internal funds:

\[ E_t^a [\xi_{it}] > 1 \]
Assume flexible prices and no customer markets.

When $\alpha = 1$, optimal pricing $\Rightarrow$

$$p_{i,t} = \left(\frac{\eta}{\eta - 1}\right) \times \left(\frac{E^a_t[\xi_{it}a_{it}]}{E^a_t[\xi_{it}]}\right) \times \left(\frac{w_t/p_t}{A_t}\right)$$

- accounting markup
- economic markup
- real marginal cost

Financial frictions $\Rightarrow$

$$\frac{E^a_t[\xi_{it}a_{it}]}{E^a_t[\xi_{it}]} = 1 + \text{Cov}[\xi_{it}a_{it}] \geq 1$$
Optimal Pricing with Deep Habits

- Bring back customer markets (still flexible prices!)
- Growth-adjusted, compounded discount rate:

\[
\tilde{\beta}_{t,s} \equiv m_{s,s+1} \frac{s_{s+1}/s_s - \rho}{1 - \rho} \\
\times \prod_{j=1}^{s-t} \left[ \rho + \chi \frac{s_{t+j}/s_{t+j-1} - \rho}{1 - \rho} \right] m_{t+j-1,t+j}
\]

- Optimal pricing ⇒

\[
p_{i,t} = \frac{\eta}{\eta - 1} \frac{E_t^a[\xi_{it}a_{it}]}{E_t^a[\xi_{it}]} \left[ \frac{w_t/p_t}{A_t} \right] \\
- \frac{\chi}{\eta - 1} E_t \left[ \sum_{s=t+1}^{\infty} \tilde{\beta}_{t,s} \frac{E_s^a[\xi_{i,s}]}{E_t^a[\xi_{i,t}]} \left( p_{h,s} - \frac{w_s/p_{h,s}}{A_s} \right) \right]
\]
Optimal Pricing with Deep Habits

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\]

- Optimal pricing \( \Rightarrow \)

\[
p_{i,t} = \frac{\eta}{\eta - 1} \frac{\mathbb{E}_t^a[\xi_{i,t} a_{i,t}]}{\mathbb{E}_t^a[\xi_{i,t}]} \left[ \frac{w_t/p_t}{A_t} \right] \\
- \frac{\chi}{\eta - 1} \mathbb{E}_t \left[ \sum_{s=t+1}^{\infty} \tilde{\beta}_{t,s} \frac{\mathbb{E}_s^a[\xi_{i,s}]}{\mathbb{E}_t^a[\xi_{i,t}]} \left( p_{h,s} - \frac{w_s/p_{h,s}}{A_s} \right) \right]
\]
\[ \hat{\pi}_t = -\frac{\omega(\eta - 1)}{\gamma_p} \left[ \hat{\mu}_t + \mathbb{E}_t \sum_{s=t}^{\infty} \chi^s \delta^{s-t+1} \hat{\mu}_{s+1} \right] + \beta \mathbb{E}_t [\hat{\pi}_{t+1}] \\
+ \frac{1}{\gamma_p} [\eta - \omega(\eta - 1)] \mathbb{E}_t \sum_{s=t}^{\infty} \chi^s \delta^{s-t+1} \left[ (\hat{\xi}_t - \hat{\xi}_{s+1}) - \hat{\beta}_{t,s+1} \right] \]

- \( \hat{\mu}_t \) = (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”

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

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

- \(\hat{\mu}_t\) = (financially-adjusted) mark-up
- \(\hat{\beta}_{t,s+1}\) = capitalized growth of customer base
- \(\hat{\xi}_t\) = shadow value of internal funds
Log-Linearized Phillips Curve
The role of financial frictions

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

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

Benchmark model: homogeneous firms

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preferences and Technology</strong></td>
<td></td>
</tr>
<tr>
<td>Relative risk aversion: ( \gamma_x )</td>
<td>1.00</td>
</tr>
<tr>
<td>Deep habit: ( \theta )</td>
<td>-0.80</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>
</tr>
<tr>
<td>Fixed operating costs: ( \phi )</td>
<td>0.21</td>
</tr>
<tr>
<td>Idiosyncratic volatility (a.r.): ( \sigma )</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Financial Frictions</strong></td>
<td></td>
</tr>
<tr>
<td>Equity dilution costs: ( \varphi )</td>
<td>0.30</td>
</tr>
<tr>
<td>Persistence of financial shock: ( \rho_\varphi )</td>
<td>0.90</td>
</tr>
</tbody>
</table>
Demand Shock: Financial Crisis ($\varphi = 0.5$)

(a) Output

(b) Hours worked

(c) Inflation

(d) Real wage

(e) Markup

(f) Value of internal funds

(g) Value of marginal sales

(h) Interest rate
Financial Shock: ($\varphi = 0.3$)

With vs Without Customer Markets

(a) Output

(b) Hours worked

(c) Inflation

(d) Real wage

(e) Markup

(f) Value of internal funds

(g) Value of marginal sales

(h) Interest rate
Alternative monetary policy rules

Policy Implications: “Divine Coincidence” breaks down!
- Sectors differ by operating efficiency: $0 \leq \phi_1 < \phi_2$
- Fixed measures of firms: $\Xi_1 = \Xi_2 = \frac{1}{2}$
- Equilibrium dispersion of relative prices:

$$\pi_t = \left[ \sum_{k=1}^{2} \Xi_k p_k^{1-\eta} p_{k,t-1}^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

- $p_{k,t} \equiv \frac{P_{k,t}}{P_t}$ = sector-specific relative price
- $\pi_{k,t} \equiv \frac{P_{k,t}}{P_{k,t-1}}$ = sector-specific inflation rate

- Benchmark case:
  - $\phi_1 = 0 \Rightarrow$ financially “strong” firms
  - $\phi_1 = 0.3 \Rightarrow$ financially “weak” firms
“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 $\omega_1 = \omega_2 = 0.5$
**PARADOX OF FINANCIAL STRENGTH**

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 $\omega_1 = \omega_2 = 0.5$
Empirical results imply that financially healthy firms decreased prices, while financially weak firms increased prices during the financial crisis.

Industry-level and Eurozone evidence suggest this is a regular feature of business cycles.

DSGE model: financial theory of countercyclical markups

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

Implications for monetary policy:

- Tradeoff between inflation and output in response to demand and financial shocks.