Preference Shocks, Liquidity Shocks, and Price Dynamics

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Directions

- Motivation
- Literature
- Model
- Extracting Shocks
Motivation
Short-run determinants of price dynamics

According to classical monetary business model,

\[ P_t = \frac{vM_t}{c_t}. \]

Lucas (1980, AER) : Quantity theory of money holds only in the long-run.

Segmented market model of Alvarez., Atkeson and Edmond (2009, QJE) deliver the endogenous velocity dynamics.

AAE with shocks to money supply and goods supply explain only half of the velocity variation in the data.

Role of other types of shocks

Is there room that shocks other than those to money and goods affect price variation?

Are these “other shocks” quantitatively important?
**Motivation II**

- **Velocity in long run and short run**

![Graphs showing velocity](image)

- **Graphs**
  - Title: Velocity
  - X-axis: Date
  - Y-axis: Level
  - Legend:
    - Original Series
    - Business Cycle Component

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We develop a DSGE model that focuses on the source of price variations.

- Extension of the model of AAE (2009, QJE).
- Shocks to transaction (liquidity shocks) and shocks to preference are considered.

**Liquidity shock (adverse shocks to credit service)**
- A positive liquidity shock increases money demand in all agents in the economy, causing a decline of price and an upsurge of interest rate.

**Preference shock**
- A positive discount factor shock decreases the velocity of agents with much money holdings and increases that of agents with less money holdings, reducing aggregate velocity and price. It leads to a decline of interest rate.
We distilled the liquidity shocks and preference shocks using the Japanese data from 1971Q1 to 2007Q4.

We evaluate the contribution of shocks to money supply, goods supply and these two shocks.

Throughout the period, about half of price variations are explained by shocks to liquidity and shocks to discount factor.

In 70s and 80s, shocks to discount factor are relatively important.

In 90s and 00s, shocks to liquidity are relatively important.
Literature
Empirical studies for money and price
Analysis on frequency domain: Money supply is responsible for price variation in low frequency, but not in high frequency (Assenmacher-Wesche and Gerlach, 2007, JEEA; Assenmacher-Wesche, Gerlach and Sekine, 2008, JJIE).

Theory of money demand
Inventory model of money demand: Market segmentation generates the liquidity effect (Grossman and Weiss, 1983, AER; Lucas and Weber, 2001, AER; and AAE).
Liquidity shocks

Shocks to the credit service provided by financial sector and money demand: Improvement in the productivity of financial sector makes the credit-based transaction cheaper than money-based transaction (Benk, Gillman, and Kejak, 2005, JMCB, 2008, REDS; Ireland, 1994, AER).

Shocks to the preference

Christiano, Motto and Rostagno (2007, JMCB) : HH starts to accumulate currency at the expense of demand deposits and other liabilities (time deposits).

Christiano, Eichenbaum and Rebelo (2009, WP) : HH attaches a larger utility weight on the consumption tomorrow.
Model
Model: Overview I


- Endowment economy where aggregate goods $Y_t$ and aggregate money $M_t$ are exogenously supplied.

- There are $N$ agents in the economy, categorized by its type $s$. Each type of agent consumes $c_t(s)$ and holds $Z_t(s)$ of money.

\[
\sum_{s=1}^{N} y_t(s) = Y_t = C_t = \sum_{s=1}^{N} c_t(s),
\]

\[
\sum_{s=1}^{N} Z_t(s) = M_t.
\]

- Agents purchase goods using money holdings in his wallet.

- Agents are allowed to go to the ATM once a $N$ periods to withdraw money.
Key feature of the model

$N$ agents have different size of money holdings and different pattern of consumption expenditure.

Consequently, $N$ agents have different size of individual velocity.

Because agents have to use money over $N$ periods,

\[
Z_t(1) > Z_t(2) > ... > Z_t(N).
\]

Individual velocity is written as

\[
\frac{P_t c_t(1)}{Z_t(1)} < \frac{P_t c_t(2)}{Z_t(2)} < ... < \frac{P_t c_t(N)}{Z_t(N)}.
\]

The aggregate velocity changes because of the compositional effect.
Model: Household I

- Maximization problem of agent that is $s = 1$ at period $t$ is written as

$$\max_{\tau = t} \sum_{\tau = t}^{\infty} \beta_{\tau} \log c_{\tau} (s),$$

s.t.

(i) Budget constraint in the wallet

$$\sum_{j=0}^{N-1} \theta_{t+j} P_{t+j} c_{t+j} (s + j) \leq M_t (1).$$

(ii) Budget constraint in the ATM at period for $\forall \tau$ and for all $s$ except $s = 1$.

$$\frac{B_{\tau}}{1 + i_{\tau}} \leq B_{\tau-1} + P_{\tau} y_{\tau} (s) - P_{\tau} c_{\tau} (s) (1 - \theta_{\tau}).$$
Eular equation for households $s = 2, \ldots, N$.

$$\beta_{t+1} \left[ \frac{1}{c_{t+1}(s + 1)} - \theta_{t+1} \lambda_{t+1}(1) \right] = \left[ \frac{1}{c_t(s)} - \theta_t P_t \lambda_t(1) \right] \pi_{t+1}.$$  

Note that $\lambda_t(1)$ equals to the value of a dollar in the ATM for all agents.

For $\theta_t = 1$, we have

$$\frac{\beta_{t+1}}{\pi_{t+1}} = \frac{c_{t+1}(s + 1)}{c_t(s)}.$$

Because (i) agents $s = 2, \ldots, N$ cannot access to the ATM, and (ii) transaction requires cash, slope of consumption tilted with inflation rate $\pi_t$. 
Model: Aggregate variables

- Nominal interest rate $1 + i_t$

\[
\frac{1}{1 + i_t} = \frac{\beta_{t+1} c_t (1)}{c_{t+1} (1)} \frac{P_t}{P_{t+1}}.
\]

Nominal interest rate reflects the price of money in the ATM market.

- Velocity $v_t$

\[
v_t = \frac{P_t \sum_{s=1}^{N} c_t (s)}{\sum_{s=1}^{N} M_t (s)}.
\]
Money supply shock $\mu^m_t$.

\[ M_t = \mu^m_t M_{t-1} \]

Money supply shock is market operation $\neq$ helicopter money. Central bank supplies newly printed money into the ATM.

Goods shock $\mu^y_t$.

\[ Y_t = \mu^y_t Y_{t-1} = \sum_{s=1}^{N} \mu^y_t y_{t-1}(s). \]
Model: Shocks II

- Liquidity shock $\mu^\theta_t$.

$$\theta_{t+1} (s + 1) = \mu^\theta_t \theta_t (s).$$

It rises the transaction based on money.

- Preference shock $\mu^\beta_t$.

$$\beta_{t+1} (s + 1) = \mu^\beta_t \beta_t (s).$$

A rise in the discount factor increases the value of consumption tomorrow, reducing that of consumption today.
Suppose $N = 2$. Then we have

\[ M_t = \underbrace{Z_t(1)}_{\text{Money held by agent 1}} + \underbrace{Z_t(2)}_{\text{Money held by agent 2}}. \]

Aggregate velocity is written as

\[ v_t = \frac{P_t Y_t}{M_t} = \frac{P_t c_t(1) + P_t c_t(2)}{M_t} \]

\[ = \sum_{s=1}^{2} \frac{Z_t(s)}{M_t} \times \frac{P_t c_t(s)}{Z_t(s)}. \]

Note that because $\theta_t P_t c_t(2) = Z_t(2)$,

\[ \frac{\theta_t P_t c_t(1)}{Z_t(1)} = \frac{\theta_t P_t c_t(1)}{Z_{t+1}(2) + \theta_t P_t c_t(1)} < \frac{\theta_t P_t c_t(2)}{Z_t(2)}. \]
A negative shock to money supply increases aggregate velocity. It reduces a portion of money held by agents with low velocity.

\[
\Delta v_{t+1} \approx \frac{\Delta Z_{t+1} (1) + Z (1)}{M + \Delta Z_{t+1} (1)} \times \frac{Pc (1)}{Z (1)}
\]

- Portion of money held by agent 1 < 0
- Velocity of agent 1 < 1

\[
+ \frac{Z_t (2)}{M + \Delta Z_{t+1} (1)} \times \frac{Pc (2)}{Z (2)}
\]

- Portion of money held by agent 2 > 0
- Velocity of agent 2 = 1
A positive shock to goods supply lowers aggregate velocity.
It reduces velocity of agents with low velocity.

\[ \Delta v_{t+1} \approx \frac{Z(1)}{M} \times \Delta \left[ \frac{P_{t+1}c_{t+1}(1)}{Z(1)} \right] \]

\( \Delta P_t \) drops to clear the market.
Under our parametrization, drop of \( \Delta P_t \) is larger than an increase in \( \Delta c_{t+1}(1) \).
A positive shock to liquidity lowers aggregate velocity.

It reduces a velocity of all agents.

\[ \Delta \nu_{t+1} \approx \frac{Z(1)}{M} \times \Delta \left[ \frac{P_{t+1}c_{t+1}(1)}{Z(1)} \right] \]

\[ + \frac{Z(2)}{M} \times \Delta \left[ \frac{P_{t+1}c_{t+1}(2)}{Z(2)} \right] \]

Given \( Z(1) \) and \( Z(2) \), an increase in \( \theta_{t+1} \) reduces the expenditure.

\[ P_{t+1}c_{t+1}(1) = \frac{Z(1) - \theta_{t+2}P_{t+2}c_{t+2}(2)}{\theta_{t+1}} \]

\[ P_{t+1}c_{t+1}(2) = \frac{Z(2)}{\theta_{t+1}} \]
Model: Working mechanism V

- A positive shock to discount factor lowers aggregate velocity.
- It reduces a velocity of agent that possess higher portion of money, and increases a velocity of agent that possess smaller portion of money.
- Because of the composition of money holdings, the former effect dominates the latter.

\[ \Delta v_{t+1} \approx \begin{align*}
\left[ \frac{Z(1)}{M} \right] & \times \Delta \left[ \frac{P_{t+1} c_{t+1}(1)}{Z(1)} \right] \\
\left[ \frac{Z(2)}{M} \right] & + \left[ \frac{Z(1)}{M} \right] \\
\end{align*} \times \Delta \left[ \frac{P_{t+1} c_{t+1}(2)}{Z(2)} \right].\]
Response to a contractionary money supply shock
Response to a positive goods supply shock

- Goods
- Nominal Interest Rate
- Price
- Velocity
Response to a positive preference shock
Response to a positive liquidity shock

![Diagram showing Cash Requirement, Nominal Interest Rate, Price, and Velocity responses to a positive liquidity shock.](image-url)
Summary of IRFs I

- **Contractionary money supply shock**: $P_t$ declines. $V_t$ and $i_t$ increase.
  - $M_t$ is scarce while goods supply are constant, reducing $P_t$.
  - $M_t$ is scarce in the ATM, raising interest rate.
  - Most of money is held by agents with higher velocity $v_t (s)$, raising $V_t$.

- **Positive goods supply shock (level shock)**: $P_t$ declines. $V_t$ and $i_t$ increase.
  - Goods supply increases at the initial period, reverting to the steady state with persistency.
  - $M_t$ is scarce, reducing $P_t$.
  - Growth rate of consumption falls. $i_t$ declines to clear the market.
Summary of IRFs II

- **Positive preference shock**: $P_t$ and $V_t$ decline. $i_t$ decreases.
  - Agents postpone consumption, less money prevails in the market while $Y_t$ unchanged, reducing $P_t$.
  - Given consumption growth rate, $i_t$ falls to clear the market.

- **Positive liquidity shock**: $P_t$ and $V_t$ decline. $i_t$ increases.
  - $M_t$ is scarce because transaction becomes cash intensive, reducing $P_t$.
  - Given money supply, $i_t$ raises to clear the market.
Simulation

- Linearly detrend “private consumption” and “M2+CD” to obtain the deviation of exogenous variables \( \{ Y_t, M_t \}_{t=1970Q1}^{2009Q2} \).

- Feed through these observable exogenous variables into the model.

- Examine the portion of velocity and price variations explained by shocks to goods supply \( \mu^Y_t \) and money supply \( \mu^m_t \).

- Recover shocks to transaction \( \mu^\theta_t \) and shocks to preference \( \mu^\beta_t \), using the discrepancy between model-generated velocity \( \tilde{V}_t \) and interest rate \( \tilde{i}_t \), and their data counterparts.
Baseline simulation I: Time path of Model-generated series

- $\mu^y_t$ and $\mu^m_t$ are fed into the model.
Baseline simulation II: Baseline Statistics

- Model-generated velocity and price, with money supply shocks and goods supply shocks, are highly correlated with data.
- Model underpredicts velocity variations throughout the period.
- Model underpredicts price variations before 90s and over-predicts them after 90s. It implies that other two shocks help to offset the effect of money shocks and goods shocks.

<table>
<thead>
<tr>
<th></th>
<th>Corr, $V_t$</th>
<th>Corr, $P_t$</th>
<th>Vol, $V_t$</th>
<th>Vol, $P_t$</th>
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</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td>.62</td>
<td>.64</td>
<td>.44</td>
<td>.78</td>
</tr>
<tr>
<td>70s</td>
<td>.68</td>
<td>.63</td>
<td>.36</td>
<td>.62</td>
</tr>
<tr>
<td>80s</td>
<td>.67</td>
<td>.70</td>
<td>.80</td>
<td>.63</td>
</tr>
<tr>
<td>90s</td>
<td>.59</td>
<td>.75</td>
<td>.76</td>
<td>1.49</td>
</tr>
<tr>
<td>After 2000s</td>
<td>.41</td>
<td>.78</td>
<td>.42</td>
<td>1.50</td>
</tr>
</tbody>
</table>
We have two observable shocks $\mu^m_t$ and $\mu^y_t$, and two unobservable shocks $\mu^\theta_t$ and $\mu^\beta_t$.

Equilibrium system of the economy is written as

$$K_t = AK_{t-1} + B \begin{bmatrix} \mu^m_t \\ \mu^y_t \\ \mu^\theta_t \\ \mu^\beta_t \\ \mu_t \end{bmatrix},$$

where $K_t$ is endogenous variables, such as $P_t$ and $i_t$. We can recover $\mu^\theta_t$ and $\mu^\beta_t$ using the discrepancy between model-generated $P_t$ and $i_t$ and the data.
Recovering shocks II: Time path of the Two shocks

Discount Factor

Cash Requirement

Date

Deviation from Trend

Discount Factor

Goods Supply

Date

Deviation from Trend

Discount Factor

Goods Supply

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Recovering shocks III: Cyclicality of the Two shocks

- Movement of discount factor is cyclical. $\beta_t$ increases with $Y_t$.
- Movement of cash share in payment is cyclical in the first sub-sample period and counter cyclical in the latter sub-sample period. In 90s and 00s, $\theta_t$ increases when $Y_t$ drops (more money is needed in the recession).

<table>
<thead>
<tr>
<th></th>
<th>Corr $(Y_t, \beta_t)$</th>
<th>Corr $(Y_t, \theta_t)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td>.53</td>
<td>.12</td>
</tr>
<tr>
<td>70s</td>
<td>.63</td>
<td>.34</td>
</tr>
<tr>
<td>80s</td>
<td>.47</td>
<td>.13</td>
</tr>
<tr>
<td>90s</td>
<td>.26</td>
<td>-.31</td>
</tr>
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<td>.41</td>
<td>-.44</td>
</tr>
</tbody>
</table>
Contribution of Shocks in Price Variations
Contribution of Shocks in Price Variations

QE, 01Q1:06:Q3

Financial Crisis, 97Q4

Money Goods Liquidity Preference

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Contribution of Shocks in Velocity Variations

Money Goods Liquidity Preference

QE; 01Q1:06:Q3
Financial Crisis, 97Q4

(BOJ)

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Contribution of Shocks in Interest Rate Variations

The diagram illustrates the contribution of shocks in interest rate variations over time. The x-axis represents years from 1971 to 2006, while the y-axis measures the impact of shocks ranging from -0.03 to 0.03. The chart is color-coded to distinguish between different categories: Goods (dark grey), Liquidity (light grey), Money (black), and Preference (white).
Contribution of Shocks in Interest Rate Variations

QE, 01Q1:06:Q3
Financial Crisis, 97Q4

Money Goods Liquidity Preference

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Variance Decomposition over sample period (Velocity)

Variance Decomposition of Velocity Variations

Money
Goods
Liquidity
Preference

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Variance Decomposition over sample period (Price)

Variance Decomposition of Price Variations

Money
Goods
Liquidity
Preference


Variance Decomposition of Price Variations

Money
Goods
Liquidity
Preference

(BOJ)

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Variance Decomposition over sample period (Interest Rate)
Conclusion
Conclusion I

- We develop a DSGE model that focuses on the source of price variations.
  - Extension of the model of AAE (2009, QJE).
  - Shocks to transaction (liquidity shocks) and shocks to preference are considered.

- Liquidity shock
  - A positive liquidity shock increases money demand, causing a decline of price and an upsurge of the interest rate.

- Preference shock
  - A positive preference shock causes delayed consumption, reducing money supply used for transaction and price level. It leads to a decline of interest rate.
Conclusion II

- We distilled the liquidity shocks and preference shocks using the Japanese data.

- Roughly half of price variations is attributed to shocks to money supply and goods supply. The rest is explained by other two shocks.

- In the current sub-sample period, role of liquidity shocks becomes increasingly important in price variations.

- In the current sub-sample period, realization of liquidity shocks are counter-cyclical, helping price to go down during the recession.