Recent Developments in Monetary Economics

Lawrence Christiano
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Overview

• A new consensus has emerged about the rough outlines of a model for the analysis of monetary policy.
  – Consensus influenced heavily by estimated impulse response functions from Structural Vector Autoregression (SVARs)

• Describe empirical SVAR results.

• Construction of the consensus models based on results from SVARs.
  – Christiano, Eichenbaum and Evans JPE (2005)
  – Smets and Wouters, AER (2007)

• Further developments of the consensus model
  – Labor market
  – Financial frictions
  – Open economy

• Policy analysis: how monetary policy may inadvertently contribute to excess asset market volatility.

Vector Autoregressions

• Proposed by Chris Sims in 1970s, 1980s

• Major subsequent contributions by others (Bernanke, Blanchard-Watson, Blanchard-Quah)

• Useful Way to Organize Data
  – VARs serve as a ‘Battleground’ between alternative economic theories
  – VARs can be used to quantitatively construct a particular model

• Question that can (in principle) be addressed by VAR:
  – ‘How does the economy respond to a particular shock?’
  – Current consensus model heavily guided by answers to this question

• VARs can’t actually address such a question
  – Identification problem
  – Need extra assumptions...Structural VAR (SVAR).

Outline of SVAR discussion

• What is a VAR?

• The Identification Problem

• Identification restrictions

• Results

• Historical Decompositions of Data
Shocks and Identification Assumptions

- Monetary Policy Shock
- Neutral Technology Shock
- Capital-Embodied Shock to Technology

Estimating the Effects of a Shock to the Economy

Identifier Problem

\[ \Lambda = \rho \Omega \]

\[ \text{Only } N \times (N+1)/2 \text{ equations in } C. \]

\[ \text{We know } F_s \text{ and } Y, \text{ we need } C. \]

\[ \Lambda = \Sigma \Omega = \sum^n_{i=1} C_{i} \cdot \hat{F}_{i} \cdot \hat{Y}_{i} = n \]

\[ \hat{Y}_{i} + d - 1 \hat{X}^d \hat{B} + \cdots + y \hat{X}^y \hat{B} = x \]

Vector Autoregression for a \( N \times 1 \) vector of observed variables
One strategy: estimate parameters of Fed's feedback rule that relates Fed's actions to state of the economy.

VAR estimation with the following data:

The data have been transformed to ensure stationarity

\[
\begin{pmatrix}
(\text{CDP deflator}) + (\text{GDP}) - e^t (\text{NP}) \\
\text{Fed Fund Rate} \\
(\text{GDP}) - e^t (\text{NP}) \\
(\text{GDP} / \text{Hours}) - e^t (\text{NP}) \\
(\text{NP}) \\
(\text{NP}) \\
\end{pmatrix}
\Rightarrow
\begin{pmatrix}
10 \\
1 \\
1 \\
1 \\
1 \\
1 \\
\end{pmatrix}
\]

VAR estimation:

- Regress X on et, etc.
- et estimated by OLS regression
- lagged study
- C contains current prices and wages, aggregate quantities,
- e orthogonal to Fed information, Z
- F linear

\( R = (T, T) + \varepsilon \)

Fed information set

Policy shock

One strategy: estimate parameters of Fed's feedback rule

Identifying Monetary Policy Shocks

Identification of Technology Shocks (Blanchard–Quiñonez, Fishe...)

The only shock which also has a long run effect on labor productivity in the long run:

- These are only shocks that can affect labor

\[
\begin{align*}
\Gamma' + \Delta \Gamma & = 0 \\
\Delta \Gamma & = X (\Gamma, T') \\
\end{align*}
\]

- There are two types of technology shocks: neutral
- The relative price of capital is a capital embodied technology shock

\( V \).

• The only shock which also has a long run effect on capital embodied technology shocks (V).

The sample period: 1959Q1-2007Q1

These shocks also have a long run effect on the relative price of capital.

\( K = (V) \)

The only shock which also has a long run effect on capital embodied technology shocks neutral.

\( K = (V) \)

Identifying Monetary Policy Shocks

- One strategy: estimate parameters of Fed's feedback rule

The data have been transformed to ensure stationarity
Interesting Properties of Monetary Policy Shocks

- Plenty of endogenous persistence:
  - Output, consumption, investment, hours worked and capacity utilization
  - Velocity comoves with the interest rate
  - Output, consumption, investment, hours worked and capacity utilization
  - Average output, consumption, investment, hours worked and capacity utilization
  - Money growth and interest rate over 1 year, but other variables keep
  - Plenty of endogenous persistence:

Results

- Hump-shaped
  - Velocity comoves with the interest rate
Observations on Neutral Shock

Generally, results are noisy, as one would expect.

Interest rate, money growth, velocity responses not pinned down.

Interestingly, inflation response is immediate and precisely estimated.

Shock?

Interpretation of the response of inflation to a monetary policy shock done through the lens of identification.
Type of technology shock that affects all industries. This has very large impact on broad trends in the data, and 2000 boom-bust recession.

Monetary policy shocks have a big impact on 1980 Volcker recession. All three shocks together account for large part of business cycle.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1980</th>
<th>2000</th>
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</thead>
<tbody>
<tr>
<td>Output</td>
<td></td>
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<tr>
<td>Real Wage</td>
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<tr>
<td>Avg Hours</td>
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<tr>
<td>Capacity Util.</td>
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<tr>
<td>Avg Hours Growth</td>
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<td>Capacity Util.</td>
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<tr>
<td>Money Growth</td>
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<td>Inflation</td>
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<tr>
<td>Fed Funds</td>
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<td></td>
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<tr>
<td>Capacity Util.</td>
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<td></td>
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<tr>
<td>Price of investment goods</td>
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</table>
Now, to the construction of a monetary equilibrium model, based on the previous impulse response functions.

Objectives

- Constructing a standard (consensus) DSGE model
- Estimation of model using impulse responses from SVARs
- Determine if there is a conflict regarding price behaviour between micro and macro data.
- Macro Evidence:
  - Inflation appears sluggish
  - Inflation responds slowly to monetary shock
- Micro Evidence:
  - Inflation responds slowly to monetary shock
  - Inflation appears sluggish

- Model features:
  - Base

Bd – Christiano–Eichenbaum–Linde

\[ \text{Bd} \]
Description of Model

Assumptions

- Firms
- Households
- Monetary Authority
- Goods Market Clearing and Equilibrium

Technological shocks realized.

Production Employment Purchases Occur and

Monetary Policy Shock Realized.

Household Money Demand Decision Made.

Investment, Capital Utilization Decisions.

Agents Make Price/Wage Setting, Consumption,

Technological shocks realized.

Firms

Households

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Technical shocks realized.
Is Calvo a Good Reduced Form Model?

Evidence of probability of price change

- Evidence on relative frequency of large and small price changes suggests "yes."
- Evidence on relative frequency of large and small price changes suggests "yes."

Evidence from Midrigan, 'Menu Costs, Multi-Product Firms, and Aggregate Fluctuations'

Lot's of small changes

\[
\frac{P_t}{P_{t-1}} \quad \text{for two sets pooled across all goods/stores/months in sample.}
\]

- Standard Approach in Literature:
  \[
  \frac{1}{d} = \alpha, \quad \frac{1}{d} = \alpha
  \]

- With probability 2:
  \[
  \text{Calvo Price Setting}
  \]

\[
\rho d + 1 - \rho d = 1 - \rho d \quad \text{or} \quad \log \rho - \log \rho = \log 1
\]

\[
\frac{d \lambda}{d} = \left( \frac{d}{d} \right)^\lambda \lambda
\]

\[
\text{Technology:} \quad \text{Each } \lambda \text{ produced by a Monopolistic With Demand Curve.}
\]

Immediate Good Fits...
Households:

\[
\frac{\partial Q}{\partial P} = \lambda
\]

Wage shock realized.

Monetary policy shock realized.

Variable rate set.

Insurance markets open.

Utilization:

Decisions: Consumption, Capital accumulation, Capital utilization.

Technology shock realized.

Households: Sequence of Events.
Dynamic Response of Monetary Policy Shock

Monetary Policy Shock

Dynamic Response of Investment to Monetary Policy Shock

In Estimated Impulse Responses:

- Investment Rises in Hump-Shape Pattern:

  \[ \text{Econometric Estimation Strategy Given the Option, } b > 0 \]

- Hump-Shape Consumption Response Not a Puzzle

- Marginal Utility Function of Slope of Consumption

\[ U(c) = \log(c - q) - c^{-1} \]

- Habit Persistence in Consumption

\[ c_{t+1} = \beta c_t + \eta_t \]

- Falling Slope of Consumption

- Rising Consumption (Problem)

Concave Consumption Response Displays:

One Resolution to Consumption Puzzle

Habit Persistence in Consumption

Marginal Utility Function of Slope of Consumption

In Estimated Impulse Responses:

- Consumption Rises in Hump-Shape Pattern:

  \[ R_{t+1} = R_t + \frac{1 + f_c^o}{1 + f_c^o} \cdot \frac{1 + f_c^o}{1 + f_c^o} \cdot \frac{1 + f_c^o}{1 + f_c^o} \cdot \frac{1 + f_c^o}{1 + f_c^o} \]

  \[ \text{Standard Preferences} \]

- Intertemporal First Order Condition

  \[ \text{Consumption Puzzle, 'Puzzle'} \]

- Real Interest Rate Falls

  \[ R_{t+1} = R_t + \frac{1 + f_c^o}{1 + f_c^o} \cdot \frac{1 + f_c^o}{1 + f_c^o} \cdot \frac{1 + f_c^o}{1 + f_c^o} \cdot \frac{1 + f_c^o}{1 + f_c^o} \]

  \[ \text{Intertemporal First Order Condition} \]

- Dynamic Response of Consumption to Monetary Policy Shock

- Habit Persistence in Consumption

- Habit Persistence in Consumption
One Solution to Investment Puzzle...

Cost of Change Adjustment Costs:

\[ \text{Cost} \]

This does produce a Hump-Shape Investment

\[ I \left( \frac{1 - I}{I} \right)^{\alpha} + \beta \left( G - I \right) = I \]

One Solution to Investment Puzzle...
Choose parameters of economic model so that the dynamic response to shocks resembles as closely as possible the impulse responses estimated from SVARs.

- Make sure that identifying assumptions used in the SVARs are satisfied in the model.

Econometric Methodology

Estimating Parameters in the Model

We adopt a standard sequence-of-parameters identification concept:

\[ \Lambda > \left[ \Lambda (m) + \eta \right] A + \varepsilon \]

The aggregate response function is

\[ \Delta^e - \Delta^s x = H^e A \]

Loan market clearing:

\[ 1 - r - 1 - i^e x = i^e x \]

Financial intermediaries receive \( i^e x + i^e x \), which use the funds to lend all of their intermediate good loans, which use the funds to

\[ 1 - r - 1 - i^e x = i^e x \]

Loan Market and Final Good Market Clearing


Monetary and Fiscal Policy

Government has access to lump sum taxes. Pursues a Keynesian fiscal policy:

- Response of monetary policy to an innovation in capital goods:\n
\[ 0.9 - 1 - 0.9 x + 1 - 0.9 x = 1 - 0.9 x \]

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Policy on consumption, investment, output, etc. can account for the observed effects of monetary stickiness; monetary policy shock without a lot of price — can account for stickiness of aggregate response to key findings:

Monetary Policy Shock

Neutral technology shock, is highly persistent. Other parameters, reasonable; estimation results real.

Parameters of exogenous shocks:

<table>
<thead>
<tr>
<th>Benchmark Model</th>
<th>Parameter Estimates</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>p</td>
</tr>
<tr>
<td>0.17</td>
<td>1.35</td>
</tr>
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</table>

At point estimates: $d = 0.58$, $z = 0.38$ quarters. Other parameter estimates imply prices relatively flexible at micro level. Parameters are surprisingly consistent with estimates reported in MFE (2005) based on studying only monetary policy shocks.

Parameters: 

- War sticky wages!
- Parameters of exogenous shocks:

**TABLE 2: ESTIMATED PARAMETER VALUES**

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FURTHER WORK WITH THIS MODEL

• Can construct micro panel data sets implied by model:
  - Gain power to test model by developing its micro implications:

POLICY QUESTIONS:

- Role of monetary policy in asset price volatility
- Role of monetary policy in transmission of technology shocks

What are cross-sectional implications of model for:

- Prices and quantities at the firm level?
Implications for Panel Data

Demand shocks for intermediate good firms:

\[ Y_t = \gamma X_t + \eta_t \]

Supply shocks for intermediate good firms:

\[ Y_t = \gamma X_t + \eta_t \]

Conclusion of Consensus Model

Construction and Estimation

Identified features of a model (wants and capital)

Identified SVAR impulse responses

Consistent with recent data (hours and wages)

Full information methods have been used to estimate

Implications

The estimation strategy focused on a subset of model

Implications of macro models for panel data sets.

A future phase of empirical work will draw out the

Raw data (wages and hours)

Response to increase in interest rate spreads?

A future phase of empirical work will draw out the

Identified SVAR impulse responses

Cannot ask, what should monetary authority do in

Propagating financial markets are not a source of shocks or

Financial markets

Sticky wages

Sticky wages in model subject to Barro critique of

Recent results in search-matching literature:

Standard sticky wage model implausible

Setting to be strongly affected by details of the timing of wage-

Most worker-time relationships are long-term, and unlikely

Barro critique

Additional model development

Labor market

Sticky wages

Financial market

Response to increase in interest rate spreads?

Consensus Model

Labour market

Does not apply to idea that wage friction matter for extensive

Intensive margins:

Barro critique applies to idea that wage friction matter in the

(employment) margin:

Must distinguish between intensive (hours) and extensive

Recent results in search-matching literature:

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Recent results in search-matching literature:

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Recent results in search-matching literature:

Sticky wages

Sticky wages in model subject to Barro critique of

Recent results in search-matching literature:
Stock of employees in each agency reduced by exogenous separations increased by new arrivals.

Vacancies posted increased by new arrivals.

Bargaining internalizes nature of the job.

Wages set: If it's a time to bargain, choose wage to maximize

Marginal value of worker to agency = marginal cost of labor for worker.

Otherwise, do simple updating.

Extension to Incorporate Financial Frictions

Financial friction models: Features of the relationship between borrowers and lenders.

- Financial friction models suppose borrowers and lenders are different people, with conflicting interests.
- Financial friction models internalize borrowing and lending.

- Standard model assumes borrowers and lenders are the same people, no conflict of interest.

- Standard model assumes borrowers and lenders are the same people, no conflict of interest.

- Financial friction models internalize borrowing and lending.

- Financial friction models suppose borrowers and lenders are different people, with conflicting interests.

- General idea:

- Functional friction models internalize borrowing and lending.

- Financial friction models internalize borrowing and lending.

- Financial friction models suppose borrowers and lenders are different people, with conflicting interests.

- General idea:
Frictions in Financings of Physical Capital

Entrepreneurs

Labor

Producers

Capital

Demand

Supply

Commodity

Households

Money

Savers

Investors

Entrepreneurs (BEC)

Entrepreneurs

Have Ideas, but no Money

Have Money, but no Ideas

Savers

Money

Entrepreneurs

Have Ideas, but no Money

Have Money, but no Ideas

Savers

Money

Frictions in Financings of Physical Capital
Financial frictions.

Risks, shocks, and news:
- Add shocks and earnings effects cancel each other.
- Fisher and earnings effects cancel each other.
- Shocks that drive output and price in opposite directions are affected by financial frictions.
- Shocks that drive output and price in opposite directions are affected by financial frictions.

Prediction of financial friction model:
Risk Shocks are Important

Summary of Empirical Results with BVAR and Simpler Models.

Our out-of-sample R{\textsuperscript{2}}s and MSEs of the model perform well compared with standard Bayesian methods. We remove sample means from data and set steady state of X to zero in estimation.

<table>
<thead>
<tr>
<th>Risk Shocks</th>
<th>Financial Frictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of oil</td>
<td>Modest contribution to forecast ability</td>
</tr>
<tr>
<td>Relatively unimportant as a source of shocks</td>
<td></td>
</tr>
<tr>
<td>Money demand and mechanism of producing inside money</td>
<td></td>
</tr>
<tr>
<td>Propagation</td>
<td></td>
</tr>
<tr>
<td>First order deflation channel has a substantial impact on</td>
<td></td>
</tr>
<tr>
<td>News on the risk shock important</td>
<td></td>
</tr>
<tr>
<td>— Important source of fluctuations</td>
<td></td>
</tr>
</tbody>
</table>

Table: Variance Decomposition, HP filtered data, EA

Shocks:
- Risk
- Shocks are Important
- Risk and signals
- Temporary tech
- Monetary policy
- Government Permanent tech
- Gamma shock
- Capital tech
- Money demand
- Long rate error
- Measurement error
- Inflation target

Note:
- (1) as suggested by the picture, risk shocks are relatively important at lower frequencies
- (2) We find that they are the single most important source of low frequency fluctuation in the EA, and a close second (after permanent tech shocks) in the US.
Table: Variance Decomposition, HP filtered data, EA

<table>
<thead>
<tr>
<th>Term</th>
<th>Money demand</th>
<th>Markup</th>
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<tbody>
<tr>
<td>0.59</td>
<td>1.29</td>
<td>0.02</td>
<td>0.44</td>
<td>0.52</td>
<td>1.44</td>
<td>0.24</td>
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<td>xb</td>
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<tr>
<td>gamma shock</td>
<td>0.00</td>
<td>0.14</td>
<td>0.00</td>
<td>0.10</td>
<td>5.04</td>
<td>42.39</td>
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<tr>
<td>signal</td>
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</table>

Money demand is not a source of shocks.

Banking and money demand are unimportant as a source of fluctuations in inflation.

Markup shock unimportant as a source of fluctuations in inflation.

Gamma shocks are not very important as a source of shocks.
External finance premium is a negative leading finance premium and GDP. Important, look at dynamics of external premium, primarily risk shocks.

Why is Risk Shock so Important?

Importance of Risk Signals

External finance premium is a negative leading

Finance premium and GDP. Important, look at dynamics of external

Premium, primarily risk shock.

According to the model, external finance

indicator

\[ \log(\text{likelihood ratio}) = \log(\text{baseline}) \]

Risk component

Risk, components

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Risk, component
Why is Risk Shock so Important?

Our data set includes the stock market. Output, stock market investment, and procyclical output together in late 1990s. This is predicted by risk shock.

Explaining the Slope of the Term Structure

Difference between the yield on the lowest rated corporate bonds (Baa) and the highest rated corporate bonds (Aaa)

Euro Area US

Data under the assumption that only the monetary policy shock was operative.

Actual data

Corporate bonds (Baa)

Euro Area

Output stock market investment all procyclical– surge together in late 1990s

Response to shock in Cross-entrepreneurial distribution
the risk premium.

The model does well on everything, except
the additional complications of the model.

There is not a loss of forecasting power with
Out of Sample RMSEs

Impact of Financial Frictions on
Property

In opposite directions.
by BGG financial frictions because \( P \) and \( Y \) go
Effects of technology shocks on \( \delta g \) amplified

In same direction.
by BGG financial frictions because \( P \) and \( Y \) go
Effects of monetary shocks on \( \delta g \) amplified

Baseline model with no Fisher Effect

Baseline model with no financial frictions

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There is not a loss of forecasting power with
the additional complications of the model.

Impact of Financial Frictions on
Property

In opposite directions.
by BGG financial frictions because \( P \) and \( Y \) go
Effects of technology shocks on \( \delta g \) amplified

In same direction.
by BGG financial frictions because \( P \) and \( Y \) go
Effects of monetary shocks on \( \delta g \) amplified

Baseline model with no Fisher Effect

Baseline model with no financial frictions

Out of Sample RMSEs

There is not a loss of forecasting power with
the additional complications of the model.

There is not a loss of forecasting power with
the additional complications of the model.
Conclusion

Financial Frictions

Empirical Analysis

Incorporating financial frictions changes inference about the sources of shocks and of propagation of risk shocks.

- Fisher debt deflation
- Risk shock

Models with financial frictions can be used to ask interesting policy questions:

- When there is an increase in risk spreads, how should monetary policy respond?
- How should monetary policy react to credit variables?
- How should monetary policy respond to credit variables? When there is an increase in risk spreads, how should monetary policy respond?

Figure 6a: RMI; Confidence bands indicates 2 std and is centered around VAR

Figure 6b: RMI; Confidence bands indicates 2 std and is centered around VAR