Financial Factors in Economic Fluctuations

Lawrence Christiano
Roberto Motto
Massimo Rostagno
What we do

• Integrate financial frictions into standard equilibrium model and estimate the model using Euro Area and US data.
  – Asymmetric information and costly state verification (Townsend (1978), Bernanke-Gertler-Gilchrist (1999))
  – Endogenous determination of financial liabilities, like M1 and M3 (Chari-Christiano-Eichenbaum (1995))

• Decompose 14 aggregate data series into shocks and propagation mechanisms:
  – A new shock, a ‘risk’ shock
  – A new source of propagation: non-state contingent nominal rates of interest.
Outline

• Describe the basic ingredients of the model.

• Results
**Standard Model**

**Firms**

\[ Y_t = \left[ \int_0^1 Y_{jt} \frac{1}{\lambda_{jt}} d\lambda_{jt} \right]^\lambda_{jt}, \ 1 \leq \lambda_{jt} < \infty, \]

\[ Y_{jt} = \epsilon_i K_{jt}^\alpha (z_t l_{jt})^{1-\alpha} \]

**Households**

Backyard capital accumulation:

\[ \bar{K}_{t+1} = (1 - \delta) \bar{K}_t + G(\zeta_{i,t}, I_t, I_{t-1}) \]

\[ u_{c,t} = E_i \beta \zeta_{c,t} u_{c,t+1} \frac{r_{t+1}^k}{\pi_{t+1}} \]

Rent capital

Supply labor

Investment goods

Consumption
Standard Model

- Firms
  - Labor market
  - Household
  - Market for Physical Capital

Arrows indicate the flow of resources or factors of production:
- $L$ from Labor market to Firms
- $C$ from Household to Firms
- $I$ from Household to Firms
- $K$ from Market for Physical Capital to Firms
Financing

• In the standard model, already have borrowing by firms for working capital.
  – will now have banks intermediate this borrowing between households and firms.

• In standard model, ‘putting capital to work’ is completely straightforward and is done by households. They just rent capital into a homogeneous capital market.

• Now: ‘putting capital to work’ involves a special kind of creativity that only some households – entrepreneurs – have.
  – Entrepreneurs finance the acquisition of capital in part by themselves, and in part by borrowing from regular ‘households’.
  – Conflict of interest, because there is asymmetric information about the payoff from capital.
  – Standard sharing contract between entrepreneur and household not feasible.
Financial Frictions with Physical $K$

Firms

Labor market

Capital Producers

Entrepreneurs

Entrepreneurs sell their $K$ to capital producers

household
Financial Frictions with Physical $K$

- Firms
- Labor market
- Capital Producers
- Entrepreneurs
- Household
- Banks

$K'$

Loans
Extension to Incorporate Financial Frictions

• General idea:

  – Asset Side of Bank Balance Sheets:
    • Short term financing of working capital
    • Financing of physical capital (subject to CSV)

  – Liability Side of Bank Balance Sheets:
    • Assets that provide various degrees of transactions services.
    • ‘Time deposits’ to help finance capital.
### Assets and Liabilities, Financial System

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reserves</td>
<td></td>
</tr>
<tr>
<td>Working capital loans to firms</td>
<td>Household demand deposits</td>
</tr>
<tr>
<td>Loans to entrepreneurs to purchase capital</td>
<td>Savings deposits</td>
</tr>
<tr>
<td></td>
<td>Time deposits</td>
</tr>
</tbody>
</table>

- Technology for producing transactions services:
  - (Chari-Christiano-Eichenbaum (1995)):

\[
\frac{D_t^h + D_t^f + \xi D_t^m}{P_t} = a_t \left( (K_t^b)^a (z_t l_t^b)^{1-a} \right)^{\xi_t} \left( \frac{E_t^r}{P_t} \right)^{1-\xi_t}
\]
Households

- Preferences:

\[ E_t^i \sum_{l=0}^{\infty} \beta^l \zeta_{c,t+l} \{ u(C_{t+l} - bC_{t+l-1}) - \psi_L \frac{h_{j,t+l}^{1+\sigma_L}}{1 + \sigma_L} \} \]

\[ - v \left[ \left( \frac{(1+\tau^c)P_{t+l}C_{t+l}}{M_{t+l}} \right)^{(1-\chi_{t+l})\theta} \left( \frac{(1+\tau^c)P_{t+l}C_{t+l}}{D^h_{t+l}} \right)^{(1-\chi_{t+l})(1-\theta)} \left( \frac{(1+\tau^c)P_{t+l}C_{t+l}}{D^m_{t+l}b} \right) \chi_{t+l} \right]^{1-\sigma_q} \]

- Features:
  - Habit formation in consumption, differentiated Labor
  - Monopolistic supplier of specialized labor input (EHL)
  - Enjoy deposits services of two bank assets
  - Hold time deposits
Banks, Households, Entrepreneurs

Accounts for about 30% of GDP

\[ \omega \sim F(\omega, \sigma_t), \quad E\omega = 1 \]

Standard debt contract
• Net worth of an entrepreneur who goes to the bank to receive a loan in period $t$:

$$
\begin{align*}
n_t &= P_{k',t}(1 - \delta)\omega K_t + r^k_t \omega K_t - B_{t-1} \frac{Z_{t-1}}{\pi_t} \\
&= \frac{\text{value of capital after production}}{\text{earnings from capital after utilization costs}}
\end{align*}
$$

An entrepreneur who bought capital in $t-1$ experienced an idiosyncratic shock, $\omega$.

This log-normal shock has mean unity across all entrepreneurs, $\omega \sim F(\omega, \sigma_t)$.

An entrepreneur’s shock can only be observed by lender by paying a monitoring cost.

Under standard debt contract, entrepreneur either pays the interest rate on the debt, or (if $\omega$ is too low) declares bankruptcy, in which case he/she is monitored and loses everything to the bank.
Accelerator and Debt Deflation Effects

- Net worth, averaged across entrepreneurs:

\[ N_t = \underbrace{P_{k',t} (1 - \delta) \bar{K}_t + r^k_t \bar{K}_t} - \underbrace{B_{t-1} \frac{Z_{t-1}}{\pi_t}} \]

Source of standard ‘accelerator effects’  
source of ‘Fisher deflation effects’

- Shocks that raise output tend to be amplified if the shock also raises capital values and entrepreneurial income (‘accelerator effects’)

- Shocks that reduce the price level hurt entrepreneurial net worth and depress output (‘Fisher deflation effect’)

- Finding based on estimated model of US and EA (CMR):
  - Financial frictions magnify output effect of shocks that raise \( Y \) and \( P \).
  - Financial frictions have little impact on shocks that move \( Y \) and \( P \) in opposite directions.
Five Adjustments to Standard DSGE Model for CSV Financial Frictions

• Drop: household intertemporal equation for capital.

• Add: characterization of the loan contracts that can be offered in equilibrium (zero profit condition for banks).

• Add: efficiency condition associated with entrepreneurial choice of contract.

• Add: Law of motion for entrepreneurial net worth (source of accelerator and Fisher debt-deflation effects).

• Introduce: bankruptcy costs in the resource constraint.
Risk Shock and News

• Assume

\[ \hat{\sigma}_t = \rho_1 \hat{\sigma}_{t-1} + u_t \]

i.d.d., univariate innovation to \( \hat{\sigma}_t \)

• Agents have advance information about pieces of \( u_t \)

\[ u_t = \xi^0_t + \xi^1_{t-1} + \ldots + \xi^8_{t-8} \]

\[ \xi^i_{t-i} \sim \text{iid, } E(\xi^i_{t-i})^2 = \sigma^2_i \]

\[ \xi^i_{t-i} \sim \text{piece of } u_t \text{ observed at time } t - i \]
Economic Impact of Risk Shock

lognormal distribution:
20 percent jump in standard deviation

Larger number of entrepreneurs in left tail problem for bank
Banks must raise interest rate on entrepreneur
Entrepreneur borrows less
Entrepreneur buys less capital, investment drops, economy tanks
Monetary Policy

- Monetary policy rule:

\[
\hat{R}_i^e = \rho_i \hat{R}_{t-1}^e + (1 - \rho_i) \alpha_\pi \frac{\pi}{R_e} \left[ E_t(\hat{\pi}_{t+1}) - \hat{\pi}_t^{\text{target}} \right] \\
+ (1 - \rho_i) \frac{\alpha_y}{4R_e} \log \left( \frac{GDP_t}{\mu^*_GDP_{t-1}} \right) + (1 - \rho_i) \alpha_{d\pi} \frac{\pi}{R_e} (\hat{\pi}_{t} - \hat{\pi}_{t-1}) \\
+ (1 - \rho_i) \frac{\alpha_b}{4R_e} \log \left( \frac{B_{t+1}}{\mu^*_B B_t} \right) \frac{1}{400R_e} \varepsilon_t,
\]

- Monetary policy shock:

\[ \varepsilon_t \sim \text{white noise} \]

- Inflation target:

\[
\hat{\pi}_t^{\text{target}} = \rho_\pi \hat{\pi}_{t-1}^{\text{target}} + \varepsilon_t^{\text{target}}, \quad E(\varepsilon_t^{\text{target}})^2 = \sigma_\pi, \\
\]

\[ \rho_\pi = 0.965, \quad \sigma_\pi = 0.00035 \]
Monetary Policy

• Nominal rate of interest function of:
  – Anticipated level of inflation and change.
  – Slowly moving inflation target.
  – Deviation of output growth from ss path.
  – Growth of credit in case of EA.
  – Monetary policy shock.
Estimation

- EA and US data covering 1985Q1-2008Q2

\[ X_t = \begin{pmatrix} 
\Delta \log \left( \frac{\text{per capita stock market index}}{P_t} \right) \\
\text{GDP deflator inflation} \\
\log(\text{per capita hours}_t) \\
\Delta \log \left( \frac{\text{per capita credit}}{P_t} \right) \\
\Delta \log(\text{per capita GDP}_t) \\
\Delta \log \left( \frac{\text{Hourly compensation}}{P_t} \right) \\
\Delta \log(\text{per capita investment}_t) \\
\Delta \log \left( \frac{\text{per capita M1}}{P_t} \right) \\
\Delta \log \left( \frac{\text{per capita M3}}{P_t} \right) \\
\Delta \log(\text{per capita consumption}_t) \\
\text{Risk Spread}_t \\
R^{long}_t - R^e_t \\
R^e_t \\
\Delta \log(P_H) \\
\Delta \log(\text{real oil price}_t) \\
\Delta \log \left( \frac{\text{per capita Bank Reserves}}{P_t} \right) 
\end{pmatrix} \]

- Standard Bayesian methods
Key Result

• Risk shocks:
  
  – important source of fluctuations.

• Out-of-Sample evidence suggests the model deserves to be taken seriously.
Risk Shocks

• Important

• Why are they important?

• What shock do they displace, and why?
Figure: Year-over-year GDP Growth Rate - Data (black) versus what data would have been with only the risk shock

Risk shock important
Variance Decomposition, US Data

<table>
<thead>
<tr>
<th>Percent Variance Due to Risk Shock, $\sigma_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Cycle Frequencies (8-32 quarters)</td>
</tr>
<tr>
<td>Low Frequencies (cycles longer than 8 years)</td>
</tr>
<tr>
<td>Output</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>47</td>
</tr>
<tr>
<td>Investment</td>
</tr>
<tr>
<td>57</td>
</tr>
<tr>
<td>64</td>
</tr>
<tr>
<td>Consumption</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>27</td>
</tr>
<tr>
<td>Risk Spread</td>
</tr>
<tr>
<td>96</td>
</tr>
<tr>
<td>95</td>
</tr>
<tr>
<td>Real Value of Stock Market</td>
</tr>
<tr>
<td>83</td>
</tr>
<tr>
<td>74</td>
</tr>
</tbody>
</table>

• Not surprisingly in view of earlier chart, more important in the lower frequencies, for output, consumption, investment
• Very important for financial variables
Why Risk Shock is so Important

- A. Our econometric estimator ‘thinks’ risk spread ~ risk shock.

- B. In the data: the risk spread is strongly negatively correlated with output.

- C. In the model: bad risk shock generates a response that resembles a recession.

- A+B+C suggests risk shock important.
Correlation (risk spread(t), output(t-j)), HP filtered data, 95% Confidence Interval

The risk spread is significantly negatively correlated with output and leads a little.

Notes: Risk spread is measured by the difference between the yield on the lowest rated corporate bond (Baa) and the highest rated corporate bond (Aaa). Bond data were obtained from the St. Louis Fed website. GDP data were obtained from Balke and Gordon (1986). Filtered output data were scaled so that their standard deviation coincide with that of the spread data.
Another Reason the Risk Shock is so Important

- Positive shock to risk triggers what looks like a recession
Dynamic response to contemporaneous and 8 period lagged news about risk, $\sigma_t$
Dynamic response to contemporaneous and 8 period lagged news about risk, $\sigma_t$

Response to signal about risk 8 quarters in future
What Shock Does the Risk Shock Displace, and why?

• The risk shock crowds out some of the role of the marginal efficiency of investment shock.
### Business Cycle Frequencies

<table>
<thead>
<tr>
<th>Model</th>
<th>Risk shock, $\sigma_t$</th>
<th>marginal efficiency of investment shock, $\zeta_{i,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>30</td>
<td>14</td>
</tr>
<tr>
<td>CEE-SW</td>
<td>na</td>
<td>44</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>57</td>
<td>34</td>
</tr>
<tr>
<td>CEE-SW</td>
<td>na</td>
<td>87</td>
</tr>
</tbody>
</table>

Risk shock appears to crowd out the marginal efficiency of investment shock.
Why does Risk Crowd out Marginal Efficiency of Investment?

Price of capital

Demand shifters: risk shock, $\sigma_t$; wealth shock, $\omega_t$.

Quantity of capital
Why does Risk Crowd out Marginal Efficiency of Investment?

Price of capital

Demand shifters:
- risk shock, $\sigma_t$

Supply shifter:
marginal efficiency of investment, $\zeta_{i,t}$

Quantity of capital
• Marginal efficiency of investment shock can account well for the surge in investment and output in the 1990s, as long as the stock market is not included in the analysis.

• When the stock market is included, then explanatory power shifts to financial market shocks.
‘Out of Sample Evidence’

- Out of sample forecasting performance good.

- Predictions for aggregate bankruptcy rate good.

- Correlates well with Bloom evidence on cross-sectional uncertainty.
Figure 4. RMSE, Confidence band represents 2 std and is centred around BVAR (in percent)
Other support for the model

- Model predicted default rates positively correlated with measures of default in the data.
Our Measure of Idiosyncratic Risk, versus Bloom, et al.
A Policy Experiment....
How Should Policy Respond to the Risk Spread?

• Taylor’s recommendation:

\[ R_t = \alpha \pi_t^e + \beta y_t - \gamma (\text{Risky rate}_t - \text{Risk free rate}_t) \]

\[ \gamma = 1 \]

• Evaluate this proposal by comparing performance of economy with \( \gamma = 1 \) and \( \gamma = 0 \) against Ramsey-optimal benchmark.
Get a recession, just like in earlier graph.
Taylor suggestion creates a boom
Is it too much?
Taylor’s suggestion overstimulates.
Conclusion

• Incorporating financial frictions changes inference about the sources of shocks:
  – 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 be structured to avoid excess asset market volatility?
  – What are the pro’s and con’s of ‘unconventional monetary policy’?