Monetary Policy and a Stock Market Boom-Bust Cycle

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Asset markets have been volatile

Should monetary policy react to the volatility?
Is monetary policy somehow responsible for the volatility?

Suppose (following Beaudry-Portier) asset price booms triggered by expectation of improved future productivity, which are not realized.

A standard monetary DSGE model implies:

\[ \text{inflation targeting as implemented in practice} + \text{sticky wages} = \text{suboptimal volatility} \]

hard to understand boom-busts without monetary policy
Our finding contradicts conventional wisdom:

inflation stabilization also stabilizes asset markets and real economy (Bernanke-Gertler)

Conventional wisdom assumes inflation rising in stock market booms
Inflation and Stock Price

Inflation and Stock Price (real terms) in Interwar Period

Inflation and Stock Price (real terms) in 1950s to 1970s

Inflation and Stock Price (real terms) in 1990s to 2005

Note: Inflation is computed as the year-on-year change in GNP Deflator. Stock Price is Dow Jones divided by GNP Deflator.

Note: Inflation is computed as the year-on-year change in GDP Deflator. Stock Price is Dow Jones divided by GDP Deflator.

Inflation appears to be falling during the start-up of boom-bust episodes

Stock Price (right-hand scale)

Inflation (percentage points, left-hand scale)
‘Stock Market Boom-Bust Cycle’

Episode in which:

• Stock prices, consumption, investment, output, employment rise sharply and then fall

• Inflation
  – low during boom
  – tends to rise near end (Adalid-Detken, Bordo-Wheelock)
Argument

• We argue that it is difficult to account for boom-bust with a non-monetary model.

  – Even with ‘bells and whistles’, non-monetary model has a hard time accounting for duration and magnitude.

  – Non-monetary model has a hard time accounting for procyclical stock prices.

• Easy to account for in a monetized model.
Signal about future technology

• Time series representation:

\[ a_t = \rho a_{t-1} + \varepsilon_t + \xi_{t-p} \quad (a_t = \log, \text{technology}) \]

• If \( \varepsilon_{t+p} = -\xi_t \), then signal turns out to be false

• If \( \varepsilon_{t+p} = 0 \), then signal turns out to be correct.
RBC Model with Bells and Whistles

- **Household preferences:**
  \[ E_0 \sum_{t=0}^{\infty} \beta^t [\log(C_t - bC_{t-1}) + \psi \log(1 - h_t)]. \]

- **Production function:**
  \[ Y_t = K_t^\alpha (\exp(a_t)h_t)^{1-\alpha} \]

- **Capital accumulation:**
  \[ K_{t+1} = (1 - \delta)K_t + (1 - S\left(\frac{I_t}{I_{t-1}}\right))I_t. \]

- **Resource constraint**
  \[ C_t + I_t \leq Y_t \]
Simple RBC model

• No adjustment costs in investment:
  \[ S = 0 \]

• No habit persistence:
  \[ b = 0 \]

• Other parameters:
  \[ \alpha = 0.36, \beta = 1.03^{-0.25}, \delta = 0.02, \psi = 2.3. \]

• Signal of future improvement in technology leads to:
  – Fall in employment, investment
  – Rise in consumption
  – Price of capital is constant

• Terrible model of boom-bust cycle!
IRFs: Anticipated shock to technology is not realized (Logs)

Standard RBC Model: no investment adjustment costs and standard utility of consumption
Adding bells and whistles

• Investment adjustment costs

\[ S = S' = 0 \text{ in Steady State} \]
\[ S'' = 5 \text{ in Steady State} \]

• Habit persistence

\[ b = 0.75 \]

• Now we have a better theory of the boom-bust cycle
IRFs: Anticipated shock to technology is not realized (Logs)

RBC Model with adjustment costs in flow of investment and habit persistence
Diagnosing the results

• Role of habit persistence: major
  – Ensures that consumption rises in the boom

• Role of investment adjustment costs: major
  – Ensures that investment rises in the boom
  – Adjustment costs in level of investment does not work

\[ K_{t+1} = (1 - \delta)K_t + S\left(\frac{I_t}{K_t}\right)K_t, \quad S' > 0, \quad S'' < 0 \]

• Puzzle: why does the theory imply a fall in the stock market?
Some Capital Theory

• In a production economy, price of capital (‘stock market’) satisfies two relations
  – Usual present discounted value relation (‘demand side’)
  – Tobin’s q relation (‘supply side’)
  – Tobin’s q relation especially useful for intuition

• First, we derive the present discounted value relation

• Then, Tobin’s q
• Lagrangian

\[ \sum \beta_t \left\{ \frac{[(C_t - bC_{t-1})(1 - h_t)]^\psi}{1 - \gamma} \right\}^{1-\gamma} + \lambda_t \left[ (K_t)^\alpha (z_th_t)^{1-\alpha} - C_t - I_t \right] + \mu_t \left[ (1 - \delta)K_t + (1 - S\left(\frac{I_t}{I_{t-1}}\right))I_t - K_{t+1} \right] \}

• Consumption first order condition

\[ \lambda_t = (C_t - bC_{t-1})^{-\gamma} (1 - h_t)^{\psi(1-\gamma)} - \beta b(C_{t+1} - bC_t)^{-\gamma} (1 - h_{t+1})^{\psi(1-\gamma)} . \]

• First order condition with respect to \( K_{t+1} \)

\[ \mu_t = \beta \left[ \lambda_{t+1} \alpha(K_{t+1})^{\alpha-1} (z_{t+1}h_{t+1})^{1-\alpha} + \mu_{t+1}(1 - \delta) \right] . \]
• Divide both sides of $K_{t+1}$ FONC by $\lambda_t$:

\[
\frac{\mu_t}{\lambda_t} = \beta \frac{\lambda_{t+1}}{\lambda_t} \left[ \alpha (K_{t+1})^{\alpha-1} (z_{t+1} h_{t+1})^{1-\alpha} + \frac{\mu_{t+1}}{\lambda_{t+1}} (1 - \delta) \right].
\]

• ‘Time $t$ Price of Capital, $K_{t+1}$’ (Tobin’s $q$):

\[
\frac{\mu_t}{\lambda_t} = \frac{dU_t}{dK_{t+1}} = \frac{dC_t}{dK_{t+1}} \equiv P_{k',t}.
\]

• Rewrite FONC for $K_{t+1}$:

\[
P_{k',t} = \beta \frac{\lambda_{t+1}}{\lambda_t} \left[ \alpha (K_{t+1})^{\alpha-1} (z_{t+1} h_{t+1})^{1-\alpha} + P_{k',t+1} (1 - \delta) \right].
\]
• Repeating FONC for $K_{t+1}$

$$P_{k',t} = \beta \frac{\lambda_{t+1}}{\lambda_t} \left[ \alpha(K_{t+1})^{a-1} (z_{t+1} h_{t+1})^{1-a} + P_{k',t+1}(1 - \delta) \right].$$

• Suppose households earn $r_{t+1}$ on bonds
  – Household FONC:

$$\beta \frac{\lambda_{t+1}}{\lambda_t} = \frac{1}{1 + r_{t+1}}.$$

• So,

$$P_{k',t} = \frac{1}{1 + r_{t+1}} \left[ \alpha(K_{t+1})^{a-1} (z_{t+1} h_{t+1})^{1-a} + P_{k',t+1}(1 - \delta) \right],$$
• Repeating:

\[ P_{k',t} = \frac{1}{1 + r_{t+1}} \left[ \alpha(K_{t+1})^{\alpha - 1}(z_{t+1}h_{t+1})^{1-\alpha} + P_{k',t+1}(1 - \delta) \right], \]

• Rental rate on capital under competition:

\[ r_{t+1}^k = \alpha(K_{t+1})^{\alpha - 1}(z_{t+1}h_{t+1})^{1-\alpha} \]

• So,

\[ P_{k',t} = \frac{1}{1 + r_{t+1}} \left[ R_{t+1}^k + P_{k',t+1}(1 - \delta) \right]. \]
• Repeating,
\[
P_{k',t} = \frac{1}{1 + r_{t+1}} \left[ r_{t+1}^k + P_{k',t+1}(1 - \delta) \right].
\]

• Recursive substitution yields usual present value relation:

\[
P_{k',t} = \frac{1}{1 + r_{t+1}} r_{t+1}^k + \frac{(1 - \delta)}{1 + r_{t+1}} P_{k',t+1}
\]

\[
= \frac{1}{1 + r_{t+1}} r_{t+1}^k + \frac{(1 - \delta)}{1 + r_{t+1}} \left[ \frac{1}{1 + r_{t+2}} r_{t+2}^k + \frac{(1 - \delta)}{1 + r_{t+2}} P_{k',t+2} \right]
\]

\[
= \frac{1}{1 + r_{t+1}} r_{t+1}^k + \frac{(1 - \delta)}{(1 + r_{t+1})(1 + r_{t+2})} r_{t+2}^k + \frac{(1 - \delta)}{1 + r_{t+1}} \frac{(1 - \delta)}{1 + r_{t+2}} P_{k',t+2}
\]

\[
= \ldots
\]

\[
= \sum_{i=1}^{\infty} \left( \prod_{j=1}^{i} \frac{1}{1 + r_{t+j}} \right) (1 - \delta)^{i-1} r_{t+i}^k.
\]
Tobin’s $q$ (price of capital from supply side)

- Lagrangian FONC w.r.t $I$:
  
  $$- \lambda_t + \mu_t(1 - S\left(\frac{I_t}{I_{t-1}}\right)) - \mu_t S'(\frac{I_t}{I_{t-1}}) \frac{I_t}{I_{t-1}}$$
  
  $$+ \beta \mu_{t+1} S'(\frac{I_{t+1}}{I_t})\left(\frac{I_{t+1}}{I_t}\right)^2 = 0.$$  

- Taking into account the definition of the price of capital,

  $$P_{K',t} = \frac{1}{1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'(\frac{I_t}{I_{t-1}}) \frac{I_t}{I_{t-1}}} \left\{1 - \left(\frac{1}{1 + r_{t+1}}\right)P_{K',t+1} S'(\frac{I_{t+1}}{I_t})\left(\frac{I_{t+1}}{I_t}\right)^2\right\}.$$
• Repeating,

\[ P_{K',t} = \frac{1}{1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}}} \left\{ 1 - \left(\frac{1}{1 + r_{t+1}}\right) P_{K',t+1} S'\left(\frac{I_{t+1}}{I_t}\right) \left(\frac{I_{t+1}}{I_t}\right)^2 \right\} \]

\[ I_{t+1}/I_t > 0 \rightarrow \text{this term is big} \]

= Static Marginal Cost + Dynamic Part

• This clarifies why \( P_{K',t} \) falls during boom

  – Anticipated High Future Investment Implies there is an Extra Payoff to Current Investment.

  – Under Competition, This Extra Payoff Would Lead Sellers of Capital to Sell at a Lower Price.
A monetized model

• When we monetize the RBC model, get a more promising model of the response to an anticipated technology shock

• Intuition is simple, and can be explained in the CGG model.

• An anticipated future technology shock in principle drives up the real rate. Under standard monetary policy, the monetary authority prevents the rise and thereby exacerbates the boom-bust in real variables, and causes the stock market to boom too.
The standard New-Keynesian Model

\[ a_t = \rho a_{t-1} + \varepsilon_t + \xi_{t-p} \quad (a_t = \log, \text{technology}) \]

\[ rr^*_t = rr - (1 - \rho)a_t + \xi_{t+1-p} \quad (\text{natural (Ramsey) rate}) \]
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\[ \pi_t = \beta E_t \pi_{t+1} + \kappa x_t - \pi_t \ (\text{Calvo pricing equation}) \]

\[ x_t = -[r_t - E_t \pi_{t+1} - rr^*_t] + E_t x_{t+1} \ (\text{intertemporal equation}) \]

\[ r_t = \phi_\pi E_t \pi_{t+1} + \phi_x x_t \ (\text{policy rule}) \]
• Can we get a boom-bust out of this?
  – Rise in output and employment, and weak inflation in boom

Response to (false) signal in period 0 that technology will jump 1% in period 1

<table>
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<tr>
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\[ \rho = 0.95, \phi_{\pi} = 1.5, \phi_x = 0.5, \theta = 0.82 \]
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$\rho = 0.95, \phi_\pi = 1.5, \phi_x = 0.5, \theta = 0.82$

• What happens in an empirically-constructed model?
Empirically-based model

• Features:
  – Habit persistence in preferences
  – Investment adjustment costs in change of investment
  – Calvo sticky wages and prices
    • Non-optimizers: \( P_{it} = P_{i,t-1}, \quad W_{j,t} = \mu_z W_{j,t-1} \)
  – Robustness to version of Gertler-Trigari model of labor market.

• Estimation by standard Bayesian methods
Shocks and observables

• Six observables:
  – output growth,
  – inflation,
  – hours worked,
  – investment growth,
  – consumption growth,
  – T-bill rate.
• Shocks:

\[ E_t^j \sum_{l=0}^{\infty} \beta^l \mathcal{A}_{c,t+l} \left\{ \log(C_{t+l} - bC_{t+l-1}) - \psi L \frac{l^2_{t+l,j}}{2} \right\} \]

\[ K_{t+1} = (1 - 0.02)K_t + (1 - S) (I_t \frac{I_t}{I_{t-1}}) )I_t \]

\[ Y_t = \left[ \int_0^1 Y_{jt} \frac{1}{\lambda_{f,t}} dj \right] \]

\[ \alpha_t = \rho \alpha_{t-1} + \epsilon_t + \xi^4_{t-4} + \xi^8_{t-8} \]
Some parameters

wage-stickiness parameter
\[ \hat{\theta}_w = 0.83, \]
price stickiness parameter
\[ \hat{\theta}_f = 0.77, \]
curvature on adjustment costs
\[ \hat{S}'' = 8.8 \]

\[
\log R^*_t = \log \left[ \frac{\mu_z \pi^{\text{target}}}{\beta} - 1 \right] + 1.50E_t \left[ \pi_{t+1} - \hat{\pi}^{\text{target}} \right] + 0.12 \log(Y_t/Y^s)
\]

\[
\log R_t = 0.79 \log R_{t-1} + (1 - 0.79) \log R^*_t + u^m_{t+1}
\]
### Variance decompositions

Percent Variance in Row Variable due to Indicated Column Shock

<table>
<thead>
<tr>
<th>Technology shocks</th>
<th>variable</th>
<th>innovation</th>
<th>4 quarter advance</th>
<th>8 quarter advance</th>
<th>$\xi_{c,t}$</th>
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**Technology shocks**

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*big*, *bigger!*
First and second moments of posterior distribution, \textit{iid} shock standard deviations (\times 100)

<table>
<thead>
<tr>
<th>Shock</th>
<th>Mode</th>
<th>Std. Dev., Posterior Distribution</th>
<th>Mode</th>
<th>Std Dev</th>
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<tbody>
<tr>
<td>Innovation to technology</td>
<td>0.59</td>
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<td></td>
<td>8.8</td>
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<td>0.23</td>
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<td>6.7</td>
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<tr>
<td>Innovation to marginal efficiency of investment, $\xi_{i,t}$</td>
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<td>0.39</td>
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<td>Innovation to markup, $\lambda_{f,t}$</td>
<td>1.09</td>
<td>0.26</td>
<td></td>
<td>4.1</td>
</tr>
<tr>
<td>Innovation to monetary policy, $u_{t\text{mp}}$</td>
<td>7.3</td>
<td>0.59</td>
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</tr>
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</table>
• Estimated technology shock process:

\[ a_t = \rho a_{t-1} + \xi^1_{t-1} + \xi^2_{t-2} + \xi^3_{t-3} + \xi^4_{t-4} + \xi^5_{t-5} + \xi^6_{t-6} + \xi^7_{t-7} + \xi^8_{t-8} + \varepsilon_t. \]
Centered 5-quarter moving average of shocks

- NBER trough
- Signals 5-8 quarters in past
- NBER peak
- Current shock plus most recent four quarters’ signals
Benchmark: *Ramsey* Response to Signal Shock

- Drop Monetary Policy Rule.

- Now, economic system under-determined. Many equilibria.

- We select the best equilibrium, the Ramsey equilibrium: optimal monetary policy.
Response of Simple Monetary Model to Positive Signal About Technology in Period 8 that is not Realized

![Graphs showing response of output, investment, consumption, and hours worked to a positive signal about technology.]

- Output
- Investment
- Consumption
- Hours worked

...monetary policy converts what should be a small fluctuation into a big, inefficient boom...

- Ramsey Simple Monetary Model
- Equilibrium Simple Monetary Model
1. In the equilibrium, inflation is below steady state.

2. In Ramsey, inflation has a zero steady state.
Problem: monetary policy does not raise the interest rate
Price of capital (marginal cost of equity) rises in equilibrium
Sticky wages exacerbate the problem
Why is the Boom-Bust So Big?

• Most of boom-bust reflects suboptimality of monetary policy.

• What’s the problem?

  – Monetary policy ought to respond to the natural (Ramsey) rate of interest.

  – Relatively sticky wages and inflation targeting exacerbate the problem.
Policy solution

• Modify the Taylor rule to include:
  – Natural rate of interest
  – Credit growth
  – Stock market
  – Wage inflation instead of price inflation.

• Explored consequences of adding credit growth and/or stock market by adding Bernanke-Gertler-Gilchrist financial frictions.
Welfare effects of perturbations to policy

<table>
<thead>
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<th>Welfare Costs of Business Cycles, In Percent of Consumption</th>
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<tbody>
<tr>
<td><strong>Shock</strong></td>
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<td>------------------------------------------------------------</td>
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<td>$R_t^* = \alpha \pi [E_t(\pi_{t+1}) - \bar{\pi}] + \alpha_y \log\left(\frac{y_t}{y^*}\right) + X_t$</td>
</tr>
<tr>
<td>$X_t = \alpha_c \text{Credit Growth}_t + \alpha_s \text{Net Worth Growth}_t$</td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Boom-bust ($\varepsilon_t$)</td>
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</table>

Looking at credit growth helps
Welfare effects of perturbations to policy

<table>
<thead>
<tr>
<th>Shock</th>
<th>Ramsey</th>
<th>Equilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$R_t^* = \alpha \pi [E_t(\pi_{t+1}) - \bar{\pi}] + \alpha_y \log \left( \frac{Y_t}{Y_t} \right) + X_t$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$X_t = \alpha_c $\text{Credit Growth}_t + \alpha_s $\text{Net Worth Growth}_t$</td>
</tr>
<tr>
<td>Baseline</td>
<td>$\alpha_c = 1$</td>
<td>$\alpha_s = 1$</td>
</tr>
<tr>
<td>Boom-bust ($\epsilon_t$)</td>
<td>0.0520</td>
<td>0.3760 0.2257 0.3452 0.1289</td>
</tr>
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Replacing price inflation by wage inflation is best!
Welfare effects of perturbations to policy

### Welfare Costs of Business Cycles, In Percent of Consumption

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<td>$R_t^* = \alpha_\pi[E_t(\pi_{t+1}) - \bar{\pi}] + \alpha_\gamma \log\left(\frac{Y_t}{Y_{t-1}}\right) + X_t$</td>
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<td>0.0520</td>
<td>0.3760</td>
</tr>
<tr>
<td>Boom-bust signal 4)</td>
<td>0.0275</td>
<td>0.3627</td>
</tr>
<tr>
<td>Boom-bust signal 8)</td>
<td>0.0243</td>
<td>0.3996</td>
</tr>
<tr>
<td>Cost push ($\lambda_{f,t}$)</td>
<td>0.00265</td>
<td>0.0033</td>
</tr>
<tr>
<td>Discount rate shocks ($\zeta_{c,t}$)</td>
<td>0.0698</td>
<td>0.1601</td>
</tr>
<tr>
<td>Marginal efficiency of investment ($\zeta_{i,t}$)</td>
<td>0.0587</td>
<td>0.0965</td>
</tr>
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Replacing price inflation by wage inflation is the best in all but two cases.
What do real wages do in boom-bust episodes?

• We looked at three 20\textsuperscript{th} century US episodes.
  
  • Great Depression (real wage low)
  
  • 1950-1969 (real wage not low)
  
  • 1982-2000 (real wage low)
mean percent annual real wage growth over whole post war sample = 1.8764
mean percent annual real wage growth over whole post war sample = 1.8764
mean percent annual real wage growth over 1950s and 1960s boom = 2.5874
Conclusion

• Difficult to account for boom-busts in a real version of standard DSGE models.

• A boom-bust explanation emerges when nominal frictions are introduced and monetary authority does not (or, cannot) respond to the natural rate
  
  – Problem is most severe when wages are sticky relative to prices.

• Robust to:
  
  – Various treatments of indexation
  
  – Alternative models of labor market (Gertler-Trigari) that do not fall prey to Barro critique.

• Explored some modifications to policy that might help ameliorate the problem