Empirical DSGE Models:
Sources of Fluctuations, Transmission Mechanisms, and Optimal Policy

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Based on 3 papers with Justiniano and Tambalotti

1. “Is there a trade-off between inflation and output stabilization?”

2. “Investment shocks and business cycles”

3. “Investment shocks and the relative price of investment”
HP-detrended GDP in the US
Imperfect competition and inefficient fluctuations

- Modern business cycle models feature imperfect competition

- Market power in goods & labor markets implies
  - Price markups over MC
  - Wage markups over the MRS
Imperfect competition and inefficient fluctuations

- Markups vary over time for 2 reasons:
  1. Direct shocks to markups ➔ exogenous markup variation
  2. Sticky prices and wages ➔ endogenous markup variation
Imperfect competition and inefficient fluctuations

- Markups vary over time for 2 reasons:
  1. Direct shocks to markups → exogenous markup variation
  2. Sticky prices and wages → endogenous markup variation

- Markups variation contributes to fluctuations
  - Inefficient fluctuations
  - Would not be observed in a competitive economy
The questions

1. How important are inefficient fluctuations in US postwar business cycles?
The questions

① How important are inefficient fluctuations in US postwar business cycles?

➔ Inefficient fluctuations are large
The questions

1. How important are inefficient fluctuations in US postwar business cycles?

   \[\text{Inefficient fluctuations are large}\]

2. Should a monetary authority counteract these inefficient fluctuations?
The questions

① How important are inefficient fluctuations in US postwar business cycles?

→ Inefficient fluctuations are large

② Should a monetary authority counteract these inefficient fluctuations?

→ Yes, because policy faces a minor trade-off between output gap and inflation stabilization at business cycle frequencies
3. Which shocks drive business cycles?
The questions

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Investment shocks: disturbances to the transformation of investment into productive capital
The questions

③ Which shocks drive business cycles?

Investment shocks: disturbances to the transformation of investment into productive capital

④ How to interpret these shocks?
The questions

③ Which shocks drive business cycles?

➡️ Investment shocks: disturbances to the transformation of investment into productive capital

④ How to interpret these shocks?

➡️ They seem to proxy for omitted financial factors
Outline

- Sketch of the model
  - Why a medium/large-scale model

- Bayesian approach to inference

- Results
  1. How important are inefficient fluctuations?
  2. Should monetary policy counteract them?
  3. What are the drivers of business cycles?
  4. What is the interpretation of these shocks?

- Where do we go from here?
The model: summary

- Medium-scale DSGE model of the US business cycle
  - Christiano, Eichenbaum and Evans (2005, JPE)
  - Smets and Wouters (2007, AER)

- Stochastic growth model + Shocks + “Frictions”
The model

- Production technology of final-good producers

\[ Y_t = \left[ \int_0^1 Y_t(i) \frac{1}{1 + \lambda_{p,t}} \, di \right]^{1 + \lambda_{p,t}} \]

price markup shock
The model

- Production technology of intermediate goods producers

\[ Y_t(i) = A_t^{1-\alpha} K_t(i)^{\alpha} L_t(i)^{1-\alpha} \]

- Monopolistically competitive markets

- Optimizing firms set prices by maximizing PDV of profits

- Calvo type stickiness: a fraction \( \xi_p \) of firms cannot re-optimize
  - index prices to ss and past inflation
The model

- **Households maximization problem**

\[ E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[ \log(C_t - hC_{t-1}) - \varphi_t \frac{L_t(j)^{1+\nu}}{1 + \nu} \right] \]

subject to

\[ P_t C_t + P_t I_t + T_t + B_t \leq R_{t-1}B_{t-1} + Q_t(j) + \Pi_t + W_t(j)L_t(j) + r_t^k K_t \]

\[ K_{t+1} = (1 - \delta)K_t + \left(1 - S \left( \frac{I_t}{I_{t-1}} \right) \right) \mu_t I_t \]
The model

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**Labor supply shock**

**Investment shock**
The model

- Households maximization problem

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- Monopolistically competitive suppliers of specialized labor

- Calvo-type stickiness: a fraction \( \xi_w \) of HH cannot re-optimize
  - index wages to ss and past inflation-productivity
The model

- Employment agencies aggregate differentiated labor into homogeneous labor

\[ L_t = \left[ \int_0^1 L_t(j) \frac{1}{1+\lambda_{w,t}} \, di \right]^{1+\lambda_{w,t}} \]

wage markup shock
The model

- Monetary policy sets the short-term nominal interest rate following a Taylor-type rule

\[
\frac{R_t}{R} = \left( \frac{R_{t-1}}{R} \right)^{\rho_R} \left[ \left( \frac{\pi_{t-3,t}^*}{\pi_t} \right)^{\phi_\pi} \left( \frac{X_t / X_{t-4}}{\epsilon^{\gamma}} \right)^{\phi_X} \right]^{1-\rho_R} \varepsilon_{R,t}
\]
The model: summary

“Frictions”

1. Preferences
   - Habit in consumption

2. Technology
   - Adjustment costs in investment
   - Variable capital utilization

3. Market structure: Imperfect competition
   - Monopolistic competition in products and labor markets
   - Price and wage stickiness (endogenous markups)
Exogenous disturbances

- **Tastes & technology**
  - Neutral technology ➔ growth rate is AR(1)
  - Investment specific ➔ AR(1)
  - Inter-temporal preference shock ➔ AR(1)
  - Labor supply ➔ AR(1)

- **Shocks to markets competitiveness**
  - Markup shock in wages ➔ $i.i.d.$
  - Markup shock in prices ➔ AR(1)

- **Policy**
  - Government spending ➔ AR(1)
  - MP shocks ➔ $i.i.d.$
  - Inflation target shock ➔ persistent AR(1)
Exogenous disturbances

- **Tastes & technology**
  - Neutral technology → growth rate is AR(1)
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- **Shocks to markets competitiveness**
  - Markup shock in wages → $i.i.d.$
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- **Policy**
  - Government spending → AR(1)
  - MP shocks → $i.i.d.$
  - Inflation target shock → persistent AR(1)
Data and estimation

- Observable variables
  1. GDP
  2. Consumption
  3. Investment
  4. Hours
  5. Inflation
  6. Federal funds rate
  7. Wages

- Bayesian inference
Bayesian approach to inference

- Solution of the log-linearized DSGE model:

\[ x_t = G(\theta) x_{t-1} + M(\theta) \varepsilon_t \]

\[ y_t = H(\theta) x_t \]

- Model’s unknown coefficients: \( \theta \)
Bayesian approach to inference

- Solution of the log-linearized DSGE model:
  \[ x_t = G(\theta) x_{t-1} + M(\theta) \varepsilon_t \]
  \[ y_t = H(\theta) x_t \]

- Model’s unknown coefficients: \( \theta \)

- Posterior distribution: \( p(\theta | Y) \propto p(Y | \theta) \cdot p(\theta) \)

Likelihood function \quad Prior information
Why Bayesian

- “Philosophical” reasons
  - Pull ML estimates towards plausible regions of the parameter space
  - Smooth out narrow peaks of the likelihood function
  - Probability models
  - Want to use these models for policy
Why Bayesian

- "Philosophical" reasons
  - Pull ML estimates towards plausible regions of the parameter space
  - Smooth out narrow peaks of the likelihood function
  - Probability models
  - Want to use these models for policy

- "Practical" reasons
  - Multiple peaks in the likelihood function
  - Likelihood can be flat along some directions
Appeal of Bayesian medium-scale DSGE models

- Encompasses most existing views

- Probability models

- Fit comparable to VARs
Outline

- Sketch of the model
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- Results
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- Where do we go from here?
What is the share of inefficient fluctuations?

- Compare actual output to potential output

- Potential output
  - Level of output that would prevail under constant markups
  - Almost identical log-linear dynamics of efficient output (i.e. output under perfect competition)
Model economy

- Shocks to preferences and technology
- Shocks to the degree of market competitiveness
- Sticky prices and wages
  - Estimated policy rule
  - Habit formation, etc...
- Observed Output
  - Y
Model economy

Shocks to preferences and technology

Sticky prices and wages
Estimated policy rule
Habit formation, etc…

Observed Output

Shocks to the degree of market competitiveness
Model economy under **constant markups**

- **Potential Output**
  - **Scheduled Output**
  - **Y**

Potential output = level of output that would have been observed in the absence of inefficient markup variation.
Actual and DSGE-potential output

(a): GDP and Potential GDP

(b): Output Gap
Actual and DSGE-potential output

(a): GDP and Potential GDP

(b): Output Gap
Actual and DSGE-potential output
Summary of results about inefficient fluctuations

- Potential output is quite volatile, as in RBC
- The output gap is cyclical and also quite volatile

Inefficient fluctuations are large
Summary of results about inefficient fluctuations

- Potential output is quite volatile, as in RBC
- The output gap is cyclical and also quite volatile

Inefficient fluctuations are large

Next question ➔ What should policy do about it?
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The policy tradeoff

- Efficient allocation
  
  \[ MRS_t = MPL_t = \frac{W_t}{P_t} \]
  
  \[ Y_{it} = Y_t \quad \forall i \]
  
  \[ L_{jt} = L_t \quad \forall j \]
The policy tradeoff

- Efficient allocation
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- Our economy with sticky prices and wages
  - \( P_t = \mu_t^p MC_t \)
  - \( \frac{W_t}{P_t} = \mu_t^w MRS_t \)
The policy tradeoff

- **Efficient allocation**
  - \( MRS_t = MPL_t = \frac{W_t}{P_t} \)
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- **Our economy with sticky prices and wages**
  - \( P_t = \mu_t^p MC_t \)
  - \( \frac{W_t}{P_t} = \mu_t^w MRS_t \)
  - \( MRS_t \cdot \mu_t^w \cdot \mu_t^p = MPL_t \)
The policy tradeoff

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  \[ MRS_t = MPL_t = \frac{W_t}{P_t} \]
  
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  \[ \begin{aligned}
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The policy tradeoff

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  - \( P_t = \mu^p_t MC_t \)
  - \( \frac{W_t}{P_t} = \mu^w_t MRS_t \)
  - \( Y_{it} \neq Y_t \)
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\[ MRS_t \cdot \mu^w_t \cdot \mu^p_t = MPL_t \]
The policy tradeoff

- The efficient allocation is not achievable by monetary policy in our economy
  - Many independent distortions and one instrument

- Tradeoff between
  - Real stabilization, i.e. eliminating the variation of average markups
  - Nominal stabilization, i.e. eliminating price and wage dispersion
The policy tradeoff

- The efficient allocation is not achievable by monetary policy in our economy
  - Many independent distortions and one instrument

- Tradeoff between
  - Real stabilization, i.e. eliminating the variation of average markups
  - Nominal stabilization, i.e. eliminating price and wage dispersion

- Sources of trade-off
  - Sticky prices and wages
  - Markup shocks
The optimal allocation

- Maximize the utility of the average HH
  - Subject to the (nonlinear) constraints represented by the equilibrium behavior of private agents

- Compute a first order approximation to the dynamics under optimal policy

- Plot the path of variables in a counterfactual economy hit by the same shocks, but with Ramsey policy since the beginning of time
The optimal allocation

(a): Actual and Optimal GDP in deviation from potential

(b): Price Inflation

(c): Wage Inflation
The optimal allocation

(a): Actual and Optimal GDP in deviation from potential

(b): Price Inflation

(c): Wage Inflation
Summary of results about the optimal allocation

- Optimal $\approx$ potential output
- Optimal inflations are quite stable
Summary of results about the optimal allocation

- Optimal \( \approx \) potential output
- Optimal inflations are quite stable

1. Little trade-off between output and inflation stabilization (at business cycle frequencies)
Summary of results about the optimal allocation

- Optimal $\approx$ potential output

- Optimal inflations are quite stable

1. Little trade-off between output and inflation stabilization (at business cycle frequencies)

2. A large fraction of fluctuations should have been avoided
Outline

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- Results
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- Where do we go from here?
Sources of business cycles

- Use the DSGE’s spectrum to analyze fluctuations at business cycle frequencies
  
- 6 to 32 quarters (Stock and Watson)
## Variance decomposition (BC frequencies)

<table>
<thead>
<tr>
<th>Series</th>
<th>Monetary</th>
<th>Neutral</th>
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<th>Price mark-up</th>
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<tr>
<td>Output</td>
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<td>0.04</td>
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Why investment shocks become so important?
Why investment shocks become so important?

- Standard neoclassical models

  - Investment shocks unlikely drivers of business cycles

\[
\text{MRS (C, H) = MPL (H)}
\]

\[
+ + -
\]
Frictions

Deviations from Neoclassical model

1. Preferences → MRS
   - Habit in consumption
Frictions

- Deviations from Neoclassical model
  
  1. Preferences $\rightarrow$ MRS
     - Habit in consumption
  
  2. Technology $\rightarrow$ MRT
     - Adjustment costs in investment
     - Variable capital utilization
Frictions

- Deviations from Neoclassical model

1. Preferences  ➔  MRS
   - Habit in consumption

2. Technology  ➔  MRT
   - Adjustment costs in investment
   - Variable capital utilization

3. Market structure: Imperfect competition  ➔  Wedge
   - Monopolistic competition in products and labor markets
   - Price and wage stickiness (endogenous mark-ups)
Why investment shocks become so important?

\[ \mu_p(H) \cdot \mu_w(H) \cdot \text{MRS}(C, H) = \text{MPL}(H) \]

Price markup \quad Wage markup
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What is the interpretation of investment shocks?

\[ K_{t+1} = (1 - \delta)K_t + \mu_t \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \]

- Disturbance to the transformation of investment into productive capital
What is the interpretation of investment shocks?

\[ K_{t+1} = (1 - \delta)K_t + \mu_t \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \]

- Disturbance to the transformation of investment into productive capital
- Prime suspect: access to credit
- Proxy for financial frictions?
What is the interpretation of investment shocks?

\[ K_{t+1} = (1 - \delta)K_t + \mu_t \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)I_t \]

- Disturbance to the transformation of investment into productive capital
- Prime suspect: access to credit
- Proxy for financial frictions?
  - One model in which this is literally true
  - Empirical evidence
    - they are correlated to spreads
    - responsible for the recession
Investment shocks and the financial accelerator

- Calstrom and Fuerst’s (1997) financial accelerator
  - Entrepreneurs borrow but cannot be monitored
  - Resulting agency costs ($\Phi_t$) impede capital formation

$$K_{t+1} = (1 - \delta)K_t + (1 - \Phi_t)I_t$$

- “Isomorphic to model with capital adjustment costs”
Investment shocks and the financial accelerator

Calstrom and Fuerst’s (1997) financial accelerator

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$$K_{t+1} = (1 - \delta)K_t + (1 - \Phi_t)I_t$$

- “Isomorphic to model with capital adjustment costs”

Compare to

$$K_{t+1} = (1 - \delta)K_t + \mu_t (1 - S_t) I_t$$

Key difference: $\Phi_t$ is endogenous
Some suggestive evidence: shocks and spreads

- Baa - Aaa investment grade securities
- MEI shock
A reality check: the 2008 recession

Figure 4: Recent fluctuations in output and hours explained by MEI shocks only

Annual output growth

-5 0 5

2002 2003 2004 2005 2006 2007 2008

Actual
MEI shocks

Hours

-8 -6 -4 -2 0 2 4

2002 2003 2004 2005 2006 2007 2008

Actual
MEI shocks
Where do we go from here?

- Investment shocks are key & may proxy for financial factors
Where do we go from here?

- Investment shocks are key & may proxy for financial factors
- Recent evidence that financial markets are not just a veil
Where do we go from here?

- Investment shocks are key & may proxy for financial factors
- Recent evidence that financial markets are not just a veil
- Next step is to incorporate financial frictions in DSGE

**How?**
- Carlstrom and Fuerst
- Bernanke and Gertler
- Kiyotaki and Moore

**Where?**
- Households
- Firms
- Banks
Where do we go from here?

- Re-evaluate of conclusions on inefficiency of business cycles and optimal policy
Conclusions

Results
- Inefficient fluctuations are large
- Monetary policy should reduce them
- Business cycles originate from investment shocks
- Investment shocks may proxy for financial factors

Need to incorporate financial factors