# DSGE Models: A User Guide for Policymakers

Lawrence J. Christiano

# Outline

- Why models?
- Why did New Keynesian DSGE models become so popular in past decade?
- DSGE models after 2008.

# Why Models?

- Policy questions:
  - Should monetary policy respond to credit growth or stock prices and, if so, by how much?
  - How should monetary policy respond to changes in interest rate spreads?
  - What is the optimal inflation rate?
  - How many, if any, private assets should the central bank purchase?
  - How should leverage restrictions on financial firms move over the cycle?

- All these questions:
  - have a quantitative answer.
  - require contemplating the interaction of financial, labor, goods markets, etc.
  - difficult to work out in one's head.

# Why Models?

- Models can be used to grind out the quantitative answers that are required.

- They can ensure that the rationale for whatever decision is taken in the end is coherent.

- They are a discipline device: if the answer they give contradicts your intuition, you can fight it out with the model.
  - Either you discover your intuition was wrong.
  - Or, you realize you are right and that the model is not to be taken seriously because it has an implausible feature.
    - In this case, you've gained a deeper understanding of your own initial intuition.
  - Either way, the policymaker gains.

# Why did DSGE models become so popular in the past decade?

- Two key findings:
  - They resolved a age-old puzzle.
  - They are useful for forecasting.
- They played an important role in the analysis of policy questions.

# Hume essay, *Of Money*

- …money… must first quicken the diligence of every individual, before it encrease the price of labour.

- The farmer and gardener, finding, that all their commodities are taken off, apply themselves with alacrity to the raising more…

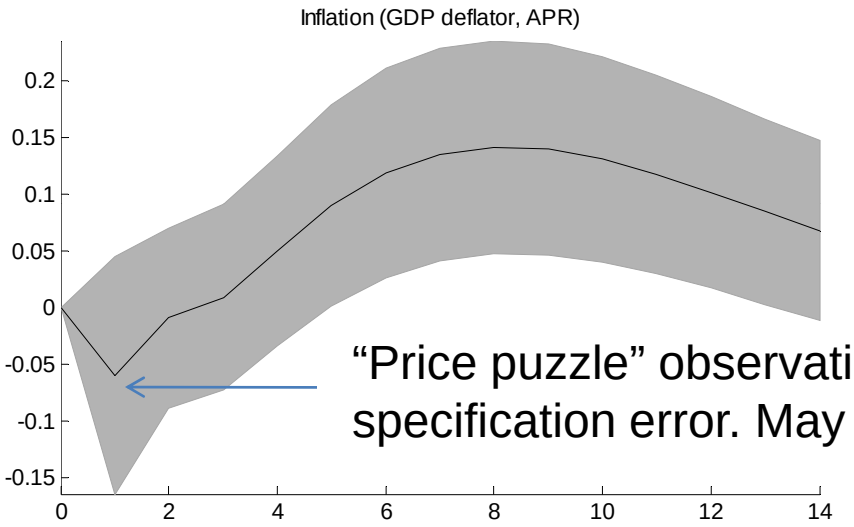
# Early Monetary DSGE Models

- Generally inconsistent with Hume observation (also, Friedman's AEA Presidential address).

- In those models, monetary expansion produced an immediate rise in *P* and little rise in output.
  - Not surprisingly, early academic models little use to practical people.

– Can use VARs to quantify Hume observations…

# The Hume Problem

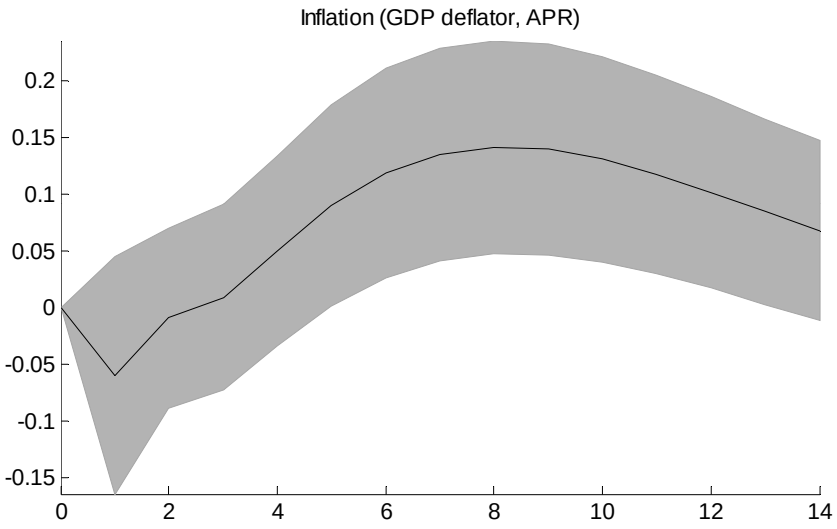


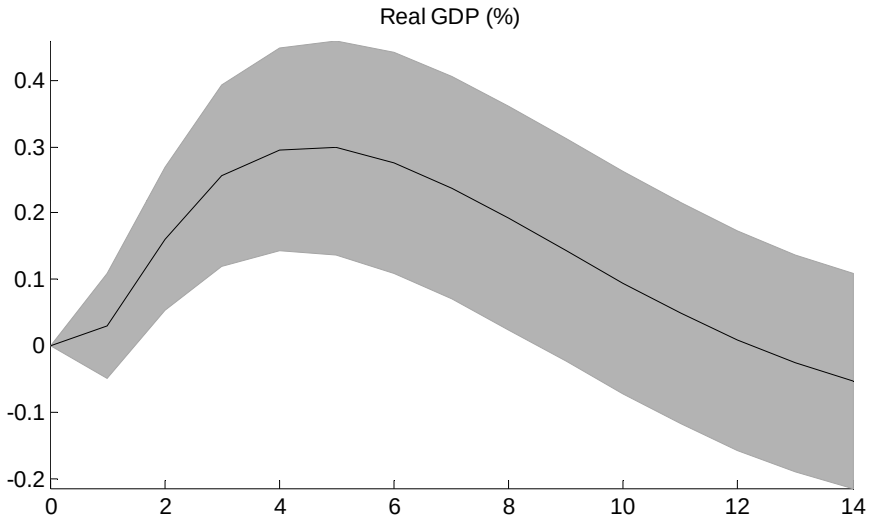

"Price puzzle" observation: initially thought to reflect econometric specification error. May actually reflect a real feature of the data.

Responses to a one-standard deviation shock to monetary policy

source: Christiano, Traband and Walentin, 2010, DSGE Models for Monetary Policy Analysis, in Friedman and Woodford, editors, Handbook of Monetary Economics

# The Hume Problem

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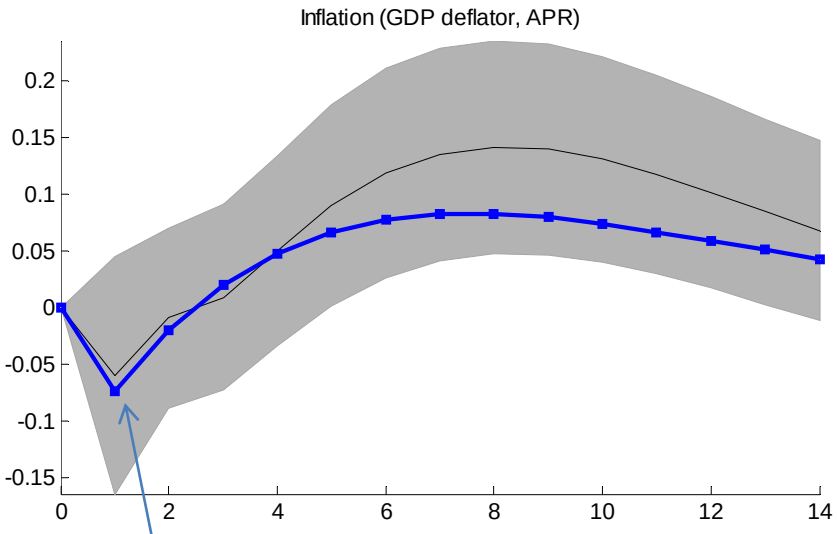
# Position in late 1990s

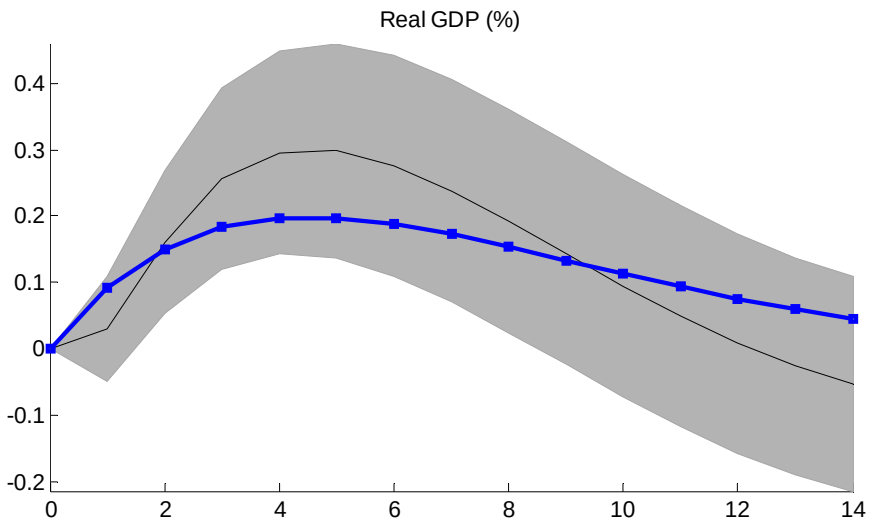
- Mankiw (2000,NBER WP 7884) argued that no plausibly parameterized model would soon come to terms with the Hume observation.
  - A quantitative account would require assuming prices stuck for two years…inconsistent with micro evidence.

- The discovery was then made that New Keynesian models give a plausible account for the Hume observation.

- New Keynesian DSGE models elevated from 'toy model' status.

# The Hume Problem and DSGE Models




Responses to a one-standard deviation shock to monetary policy

source: Christiano, Traband and Walentin, 2010, DSGE Models for Monetary Policy Analysis, in Friedman and Woodford, editors, Handbook of Monetary Economics

Assumption that firms must borrow to finance variable inputs (the "working capital channel") implies that an expansionary monetary policy shock (which drives down the interest rate) reduces inflation for a while.

# Significance of First Observation

- Earlier models, which were not compatible with Hume observation seemed to miss key aspects of the monetary transmission mechanism.
  - Lacked the credibility needed to be useful in the analysis of monetary policy.

# A Second Key Finding

- Smets and Wouters' demonstration that New Keynesian DSGE models forecast about as well as sophisticated atheoretical models.

- This elevated DSGE models from status of 'toys' to serious tools.

# Contribution of New Keynesian DSGE Models to Analysis of Monetary Policy

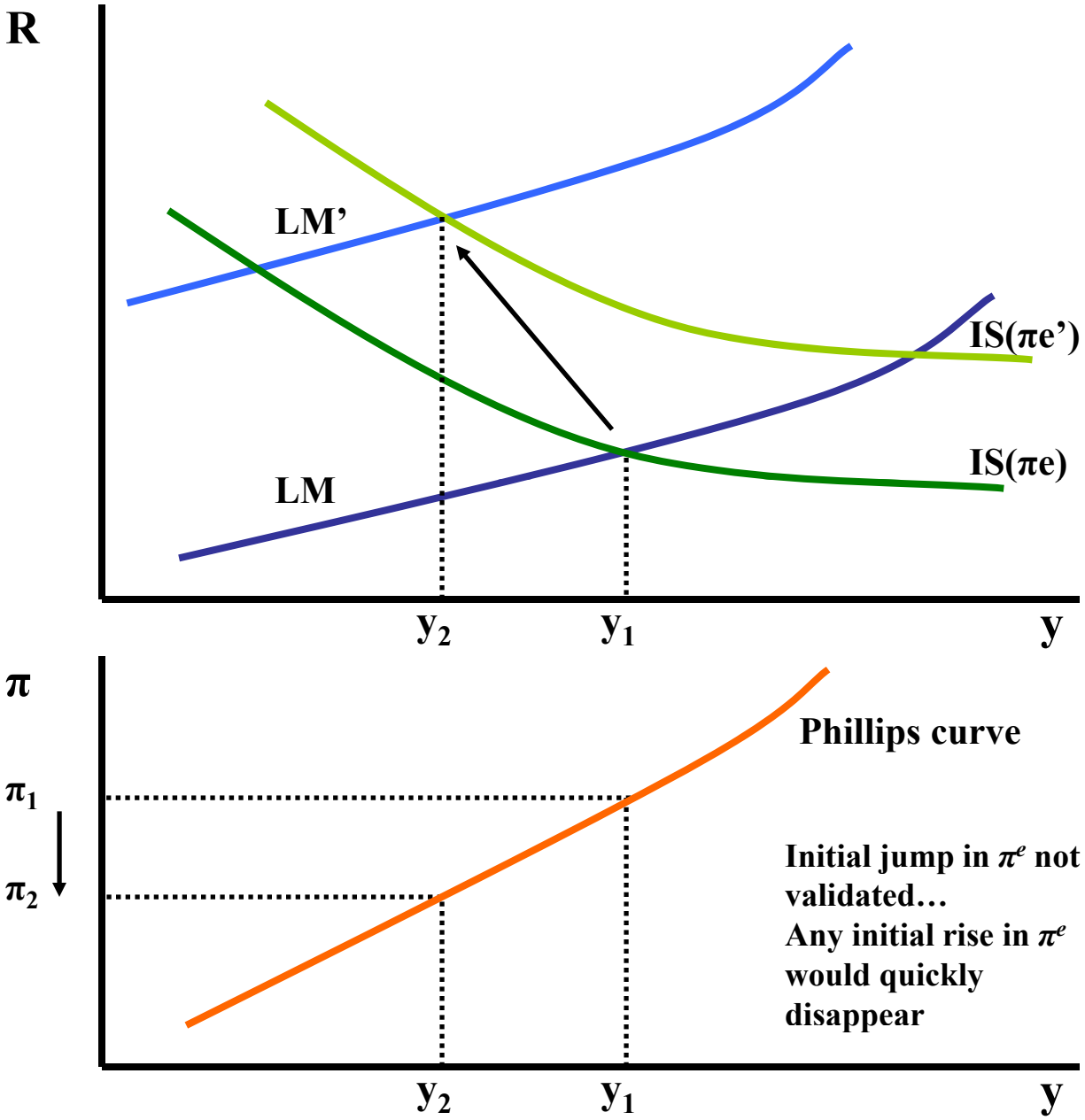
- Much discussion of inflation targeting and the Taylor Principle:
  - If inflation rises 1%, raise nominal interest rate by more than 1%.
- DSGE models helped quantify the wisdom in the Taylor Principle.
- They also articulate some possible pitfalls
  - If working capital channel is strong enough, Taylor Principle may destabilize.
  - Taylor Principle may inadvertently trigger a 'rational asset price bubble'.

# The Rationale for the Taylor Principle

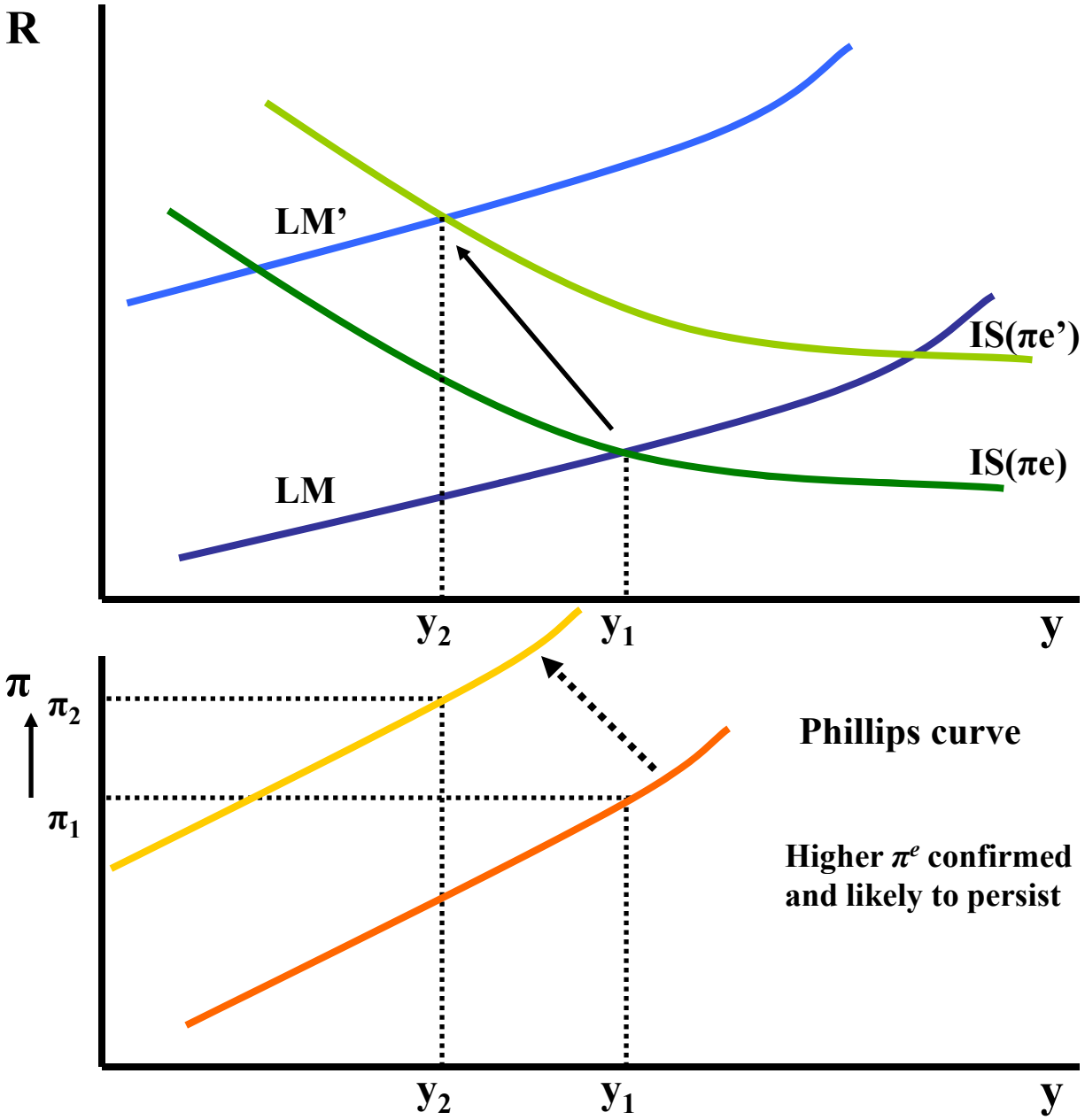
- The case for the Taylor principle is
  - On average the inflation target will be met.
  - Minimizes economic and inflation instability.

- The instability that it eliminates:
  - Spontaneous volatility in which expectations drive inflation and economic activity.
  - Is thought by some (Clarida-Gali-Gertler, others) to have characterized the 1970s inflation in the US.

- Illustration of How Taylor Principle Reduces Instability…..


R
LM'
IS(πe')
IS(πe)
LM
y2
y1
y
π
π1
π2
Phillips curve
Initial jump in πe not validated…
Any initial rise in πe would quickly disappear
y2
y1
y

- Introduce a significant working capital channel.
  - Higher *R* shifts supply curve left (like a negative technology shock)
- If the working capital channel is strong enough, Taylor Principle may *destabilize*.


R
LM'
IS(πe')
IS(πe)
LM
y2
y1
y
π
π2
π1
Phillips curve
Higher πe confirmed
and likely to persist
y2
y1
y

# Evidence Suggests that Previous Pitfall Should be Taken Seriously

- Recent financial crisis highlighted the importance of short term borrowing for firms.

- Other empirical evidence also draws attention to the potential importance of short term borrowing:
  - Barth-Ramey, Christiano-Eichenbaum-Evans, Ravenna-Walsh.
  - 'Price puzzle' in VAR analysis.
- Practical people often assert that high interest rates place upward pressure on inflation by raising costs.
  - Wright Patman in early 1970s.

# Another Possible Pitfall With Taylor Principle

- Described with a combination of data and DSGE model simulations.
- Background….
  - There is a consensus ('Jackson Hole View') that Central Banks ought not to actively identify and then 'prick' stock market bubbles.
  - Best to let bubbles die on their own.
  - Moreover, vigorous application of Taylor principle will deflate them anyway

Stock market bubble is about future expected developments, not present things.

$$R_t = \alpha_\pi \pi^e_{t+1}$$

Boom is demand-led and, hence inflationary.

Inflation targeting central bank then raises rates, cooling bubble.

# Problems with Jackson Hole View

- Facts: all stock market booms in US history are associated with ***lower*** than usual inflation.

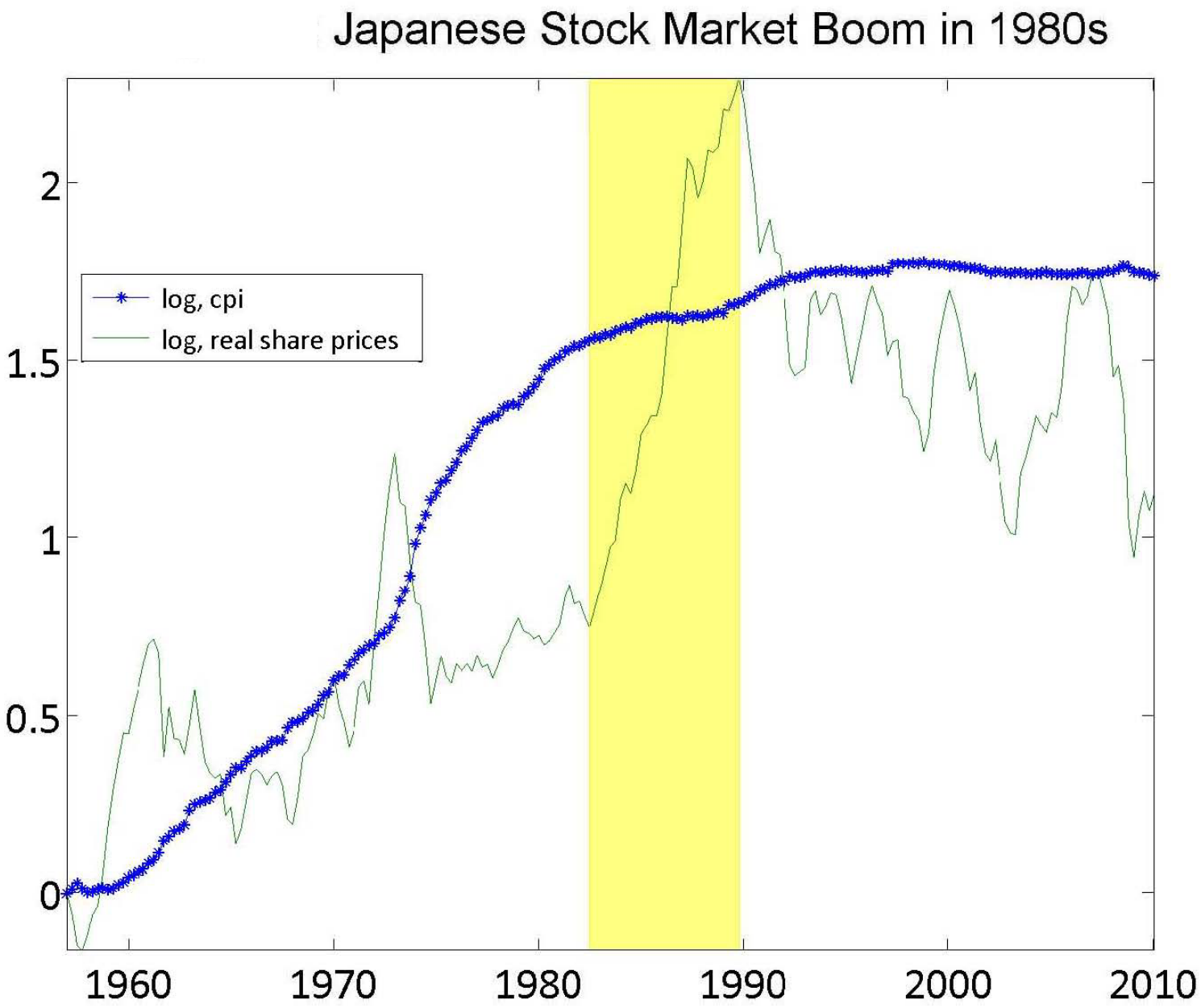
- Thus among those which were bubbles, vigorous application of Taylor principle would have been *destabilizing*.

# US Results

| 1803-1914 | | | | |
|---|---|---|---|---|
| Periods | CPI | Credit | GDP | Stock Price |
| Boom | -2.5 | 9.5 | 4.6 | 10.2 |
| Other (non-Boom, non-war) | 0.7 | 4.0 | 3.1 | -6.3 |

| 1919Q1-2010Q1 | | | | |
|---|---|---|---|---|
| Boom | 1.8 | 5.3 | 4.6 | 13.8 |
| Other (non-Boom, non-war) | 4.0 | 2.3 | 2.7 | 2.7 |

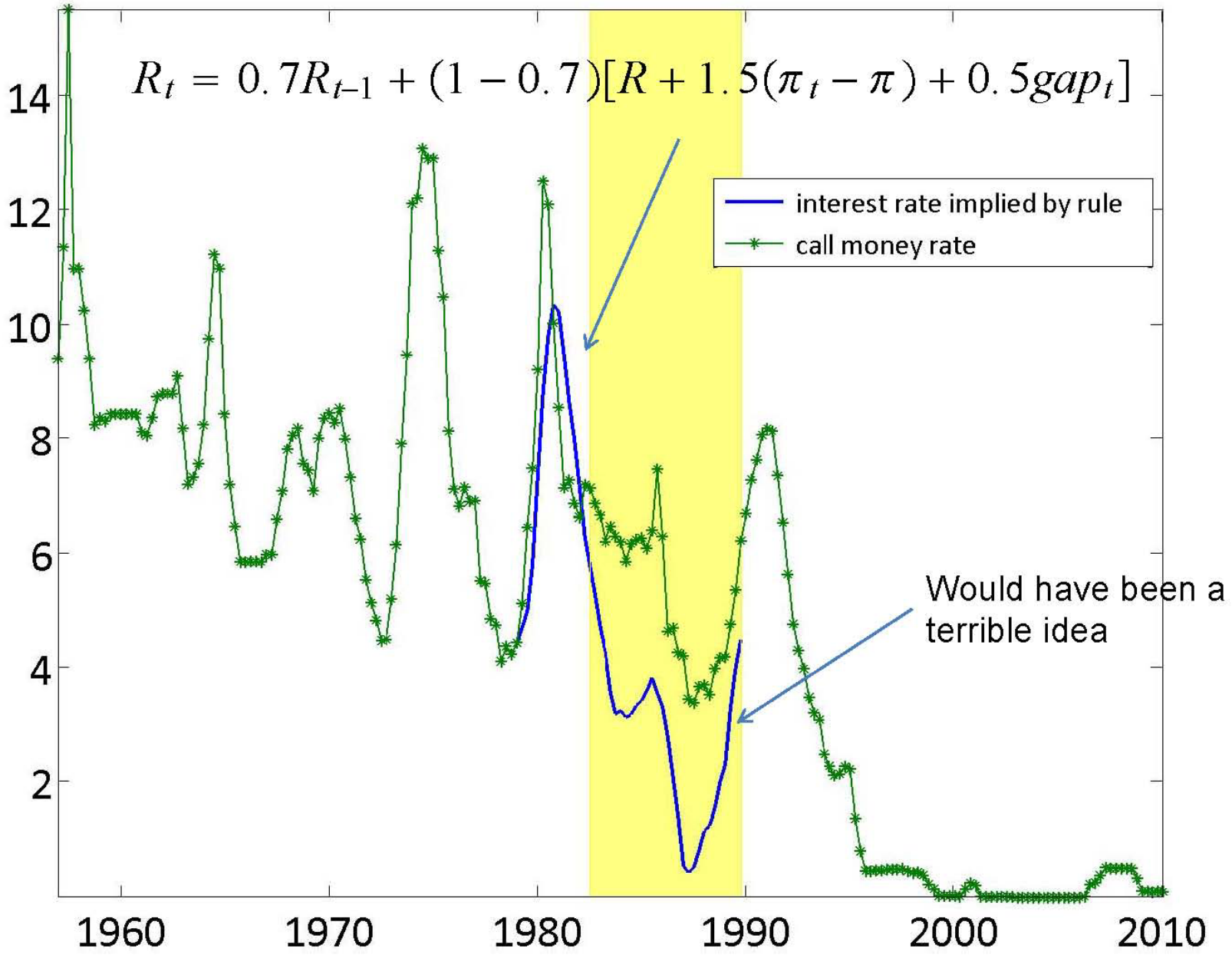
- Japan’s boom in the 1980s is particularly striking….


Japanese Stock Market Boom in 1980s
log, cpi
log, real share prices
2
1.5
1
0.5
0
1960
1970
1980
1990
2000
2010

- What would a standard inflation-targeting interest rate rule have done to the interest rate during the Japanese stock market boom?

- Plug in actual Japanese data on right-side of Taylor rule and compute implied interest rate.

Figure 4: Japan, Actual Rate and Rate Implied by Simple Interest Rate Rule



- Evidence suggests a conjecture:
  - Vigorous application of Taylor rule may *fuel* stock market boom, not smooth it out.
- At first glance, this idea may seem illogical.
  - How could it possibly be that a stock market bubble triggers inflation?
  - Need for this to all make sense before we take it seriously.
- New Keynesian DSGE model provides a framework for making sense of the facts and for suggesting a way out.

# Simple New Keynesian Model with a News Shock

$$\pi_t = \beta E\pi_{t+1} + \kappa x_t \text{ (Phillips curve)}$$

$$x_t = -[r_t - E_t\pi_{t+1} - R_t^{natural}] + E_t x_{t+1} \text{ (IS curve)}$$

$$r_t = \phi_\pi \pi_t + \phi_x x_t \text{ (Taylor rule)}$$

$$R_t^{natural} = E_t a_{t+1} - a_t \text{ (natural rate of interest)}$$

This is technology. In the natural ('best') equilibrium, consumption is Proportional to the level of technology.
So, the natural rate of interest corresponds to expected consumption Growth in the equilibrium with the best possible monetary policy.

# Simple New Keynesian Model with a News Shock

$$\pi_t = \beta E\pi_{t+1} + \kappa x_t \text{ (Phillips curve)}$$

$$x_t = -[r_t - E_t\pi_{t+1} - R_t^{natural}] + E_t x_{t+1} \text{ (IS curve)}$$

$$r_t = \phi_\pi \pi_t + \phi_x x_t \text{ (Taylor rule)}$$

$$R_t^{natural} = E_t a_{t+1} - a_t \text{ (natural rate of interest)}$$

News about future technology

$$a_t = \rho a_{t-1} + \xi_{t-1} + \varepsilon_t \text{ (law of motion of technology, } a_t\text{)}$$

# News Shocks

- Here, $\xi_t$ is a shock that signals a future movement in technology:

$$a_{t+1} = \rho a_t + \xi_t + \varepsilon_{t+1}$$

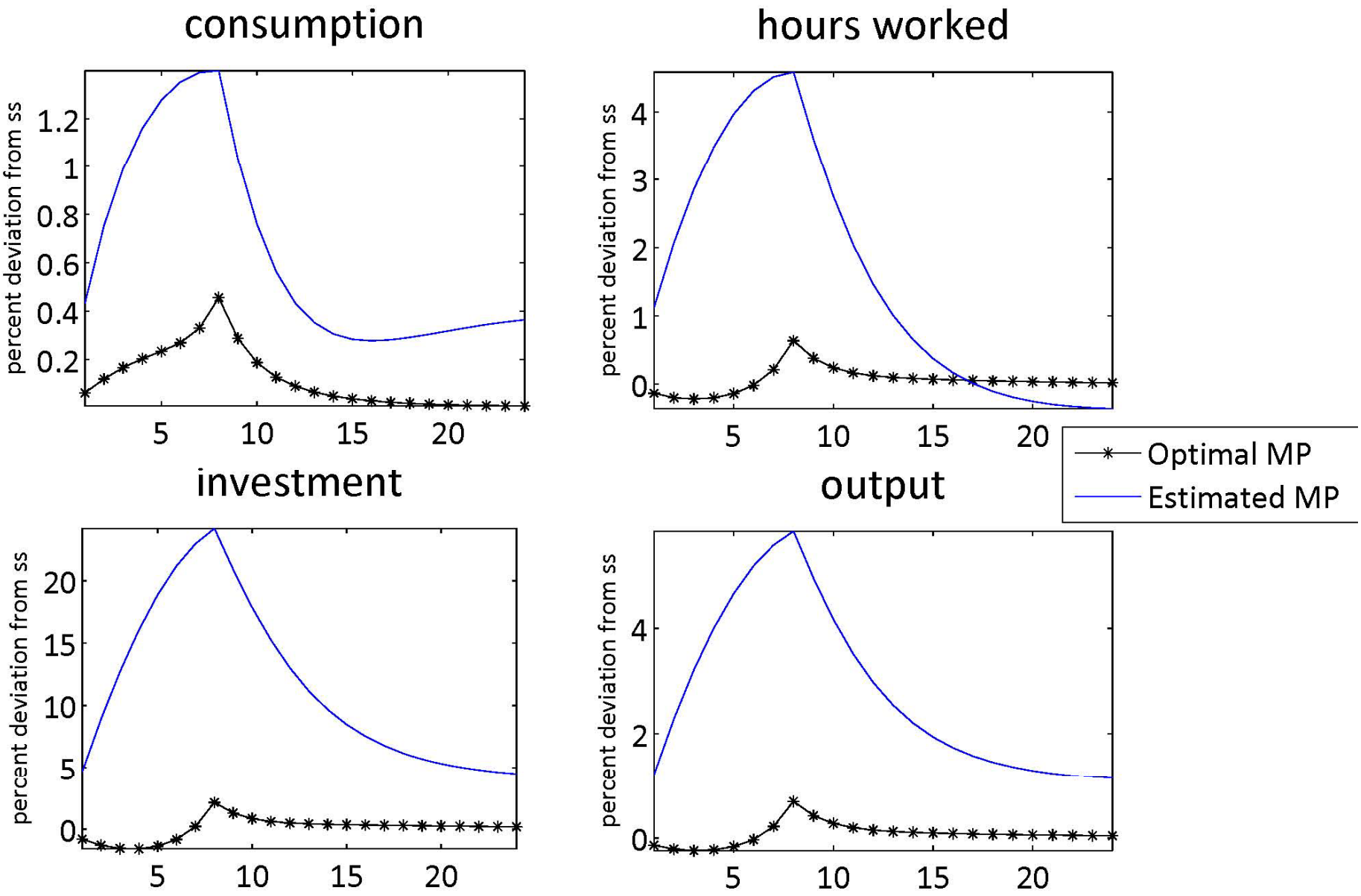
- The variable, $\xi_t$ , can formalize the notion that people are excited about something in the future.
- Increasingly, economists are recognizing that economic agents receive advance news about shocks:
  - Technology shocks (Michelle Alexopoulos)
  - Government spending shocks (Valerie Ramey)

# Model Analysis

- We* construct a simulation exercise in which the boom is triggered by rosy expectations about the future, expectations which in the end turn out to be false.
  - This is a classic demand driven boom
  - Yet, inflation is low (it's low because of the impact on current prices of the expected future reduction in costs).
  - The boom mostly reflects the destabilizing effects of the interest rate rule.
  - Helps to add credit growth and/or stock market to the rule.

*Note: see Christiano, Ilut, Rostagno and Motto, 2010, paper presented at Jackson Hole.

Figure 5: Response of Model to Signal Shock (Signal not realized), Optimal Monetary Policy (MP) and Estimated Interest Rate Rule



# Problem with Monetary Policy in the Example

- Interest rate targeting rule that supports optimal monetary policy:

$$R_t = R_t^{\text{natural}} + a_\pi(\pi^e_{t+1} - \pi) + a_y gap_t$$

- The Taylor rule leaves out $R_t^{natural}$ and under the Taylor Principle focuses principally on inflation.

- Problem is, with news shocks $R_t^{natural}$ and inflation may move in opposite directions.

- In simulation, inflation goes down as forward looking price setters anticipate a future drop in costs.
  - But, natural rate jumps sharply in response to the news shock.

# Problem in the example, cnt'd

- Reasons why economists don't think we need to worry about including natural rate in policy rule based on DSGE model simulations:

  - The natural rate is hard to measure.
  - The natural rate does not move much anyway, given DSGE model estimates that shocks are highly persistent.
    - Random walk shock:

$$a_{t+1} = a_t + \varepsilon_{t+1}$$

$$R_t^{natural} = E_t a_{t+1} - a_t = 0, \text{ constant}$$

    - News shock:

$$a_{t+1} = a_t + \xi_t + \varepsilon_{t+1}$$

$$R_t^{natural} = E_t a_{t+1} - a_t = \xi_t$$

Natural rate moves one-for-one with news shock

# Implications of Data and Model Simulations:

- Making inflation too much the centerpiece of an interest rate policy rule could increase both economic and asset market volatility.

- Need to introduce a measure of the natural rate of interest.
  - Intuition and model simulations suggest that a good measure might be credit growth or a measure of the stock market.

# Crisis of 2008

- Not predicted by DSGE models.
  - Models are tools that can help check and clarify your thinking, but won't tell you what to think about.
  - People were thinking about the 'Great Moderation', not about the possibility that a shock would emerge from the financial system and rock the economy.

- Why were financial factors not generally included in models?
  - There was a general consensus in macroeconomics (sort of encouraged by observations) that financial markets are not a source of instability.
    - These possibilities were left out of the consensus DSGE models.

- However, the profession was not at a *complete* loss. When the crisis hit, policymakers had models available to help conceptualize what was happening and what should be done
  - Diamond-Dybvig model of bank runs.
  - Models of liquidity shortage (Kiyotaki-Moore).
  - Models of banking (Bernanke and Gertler and others).

- Good news: when the crisis hit, key policymaker (Bernanke) had a lot of experience with the existing models.

# Moving Forward

- New policy questions are on the table.
  - Are the financial markets a source of shocks?
  - Are the financial markets a source of propagation of shocks?
  - How should central banks respond to widening credit spreads?
  - What dangers are we exposed to because of the zero lower bound on the interest rate, and how can we avoid them?

- Macro-prudential policy
  - What should leverage restrictions on banks be?
  - How should these restrictions move with the business cycle?

# Zero Lower Bound

- Equilibrium nominal interest rates cannot dip (much) below zero.

- According to New Keynesian DSGE models, when the economy hits the zero lower bound, a *very* severe economic contraction is possible.
  - literature is technical (actually, poses some formidable computational problems).
  - Fortunately, basic ideas are very intuitive.

# The Whole Analysis (Over) Simplified

- Identity:

$$\text{expenditures} = \text{GDP}$$

- If one group reduces spending, then GDP must fall unless another group increases.

- Another group increases if real rate drops:

$$\frac{R}{\pi^e}$$

- If *R* is at lower bound and $\pi^e$ cannot rise, have a problem
  - Problem could be made vastly worse by a deflation spiral.

# The Whole Analysis, cnt'd

- Reason $\pi^e$ may be slow to rise:
  - Monetary authority spent years persuading people it would not use inflation to stabilize economy. Fears consequences of loss of credibility in case it raises $\pi^e$ now for stabilization purposes.
- If credibility were not an issue, zero lower bound would not be a big problem.

# The Whole Analysis, cnt'd

- Options for solving zlb problem:
  - Direct: increase government spending
  - Tax credits
    - Investment tax credit
    - 'cash for clunkers'
  - Increase (effective) anticipated inflation
    - Convert to a VAT tax in the future (Feldstein, Correia-Fahri-Nicolini-Teles).
  - Don't: cut labor tax rate or subsidize employment! (Eggertsson)
    - Eggertsson-Krugman call economics in the zero lower bound 'topsy-turvy economics'

# Financial Frictions

- Introduced to investigate:
  - is financial sector is a source of shocks?
  - is it a source of propagation?

- In traditional (RBC, initial New Keynesian DSGE) models, financial sector contributed nothing at all.

- Models with financial frictions can also be used to address the new policy questions.

# Bernanke-Gertler- Gichrist Model

- Bernanke-Gertler-Gilchrist model has been very successful in empirical applications
  - Used to study great depression, post-war business cycles in the US and the EA.*

- In the standard model with no financial frictions:
  - Households build physical capital and 'rent' it to firms without complications.
  - Capital is homogeneous schmoo.

*See Christiano, Motto and Rostagno, JMCB, 2003 on US Great Depression and 2010 on US and EA economies.

# Bernanke-Gertler- Gichrist Model

- In BGG, capital is produced by 'capital producers'.

- It is purchased and owned by entrepreneurs, who put capital to work by renting it to firms.
  - Process of putting capital to work involves some 'magic'
    - Some entrepreneurs take capital and turn it into gold (e.g., Steve Jobs with the Iphone, Ipad, etc. )
    - Some take capital and it goes nowhere (a 'cool' concept for a restaurant that fizzles).

Finding: accounts for about 30 percent of business fluctuations in US and EA.

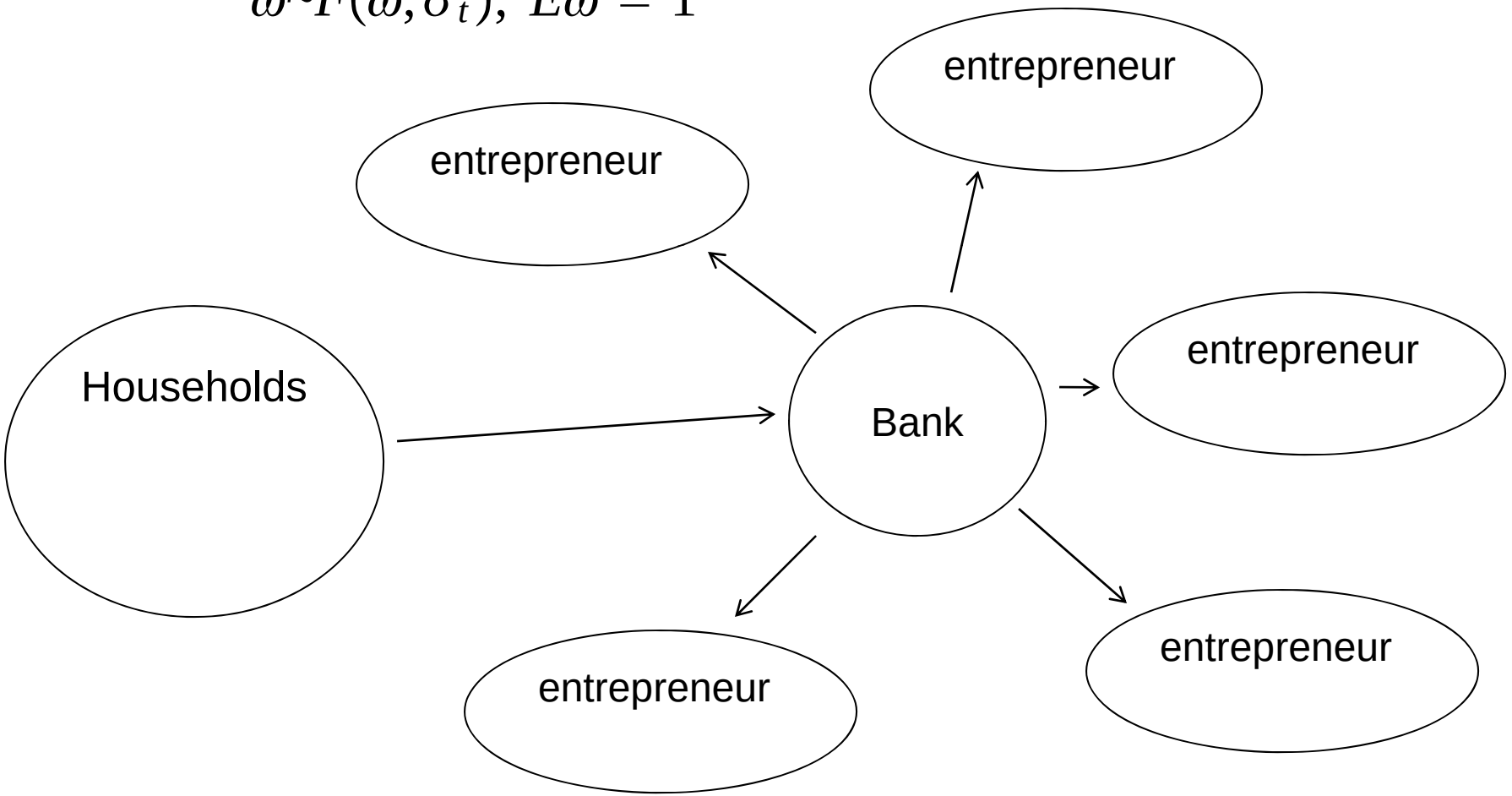
- In the BGG model:

capital bought by entrepreneur $\overbrace{k}$ $\rightarrow$ capital shrinks or expands $\overbrace{k\omega}$ , $\overbrace{\int \omega dF(\omega, \sigma_t) = 1}^{\omega \text{ drawn from cdf, } F}$

Accounts for about 30% of GDP

# Banks, Households, Entrepreneurs

$$\omega \sim F(\omega, \sigma_t),\ E\omega = 1$$




Standard debt contract

# Situation of Bank

- Notation:

  $B$ ~ loan given to individual entrepreneur

  $Z$ ~ interest rate paid by entrepreneur on loan, if it is able

  $P$ ~ fraction of entrepreneurs that cannot repay debt contract

  $R$ ~ interest rate received by households for their deposits in banks

  $Q$ ~ average receipts from bankrupt entrepreneurs, net of recovery costs for the bank

- There is no risk for the banks and they are competitive, so they must make zero profits per loan:

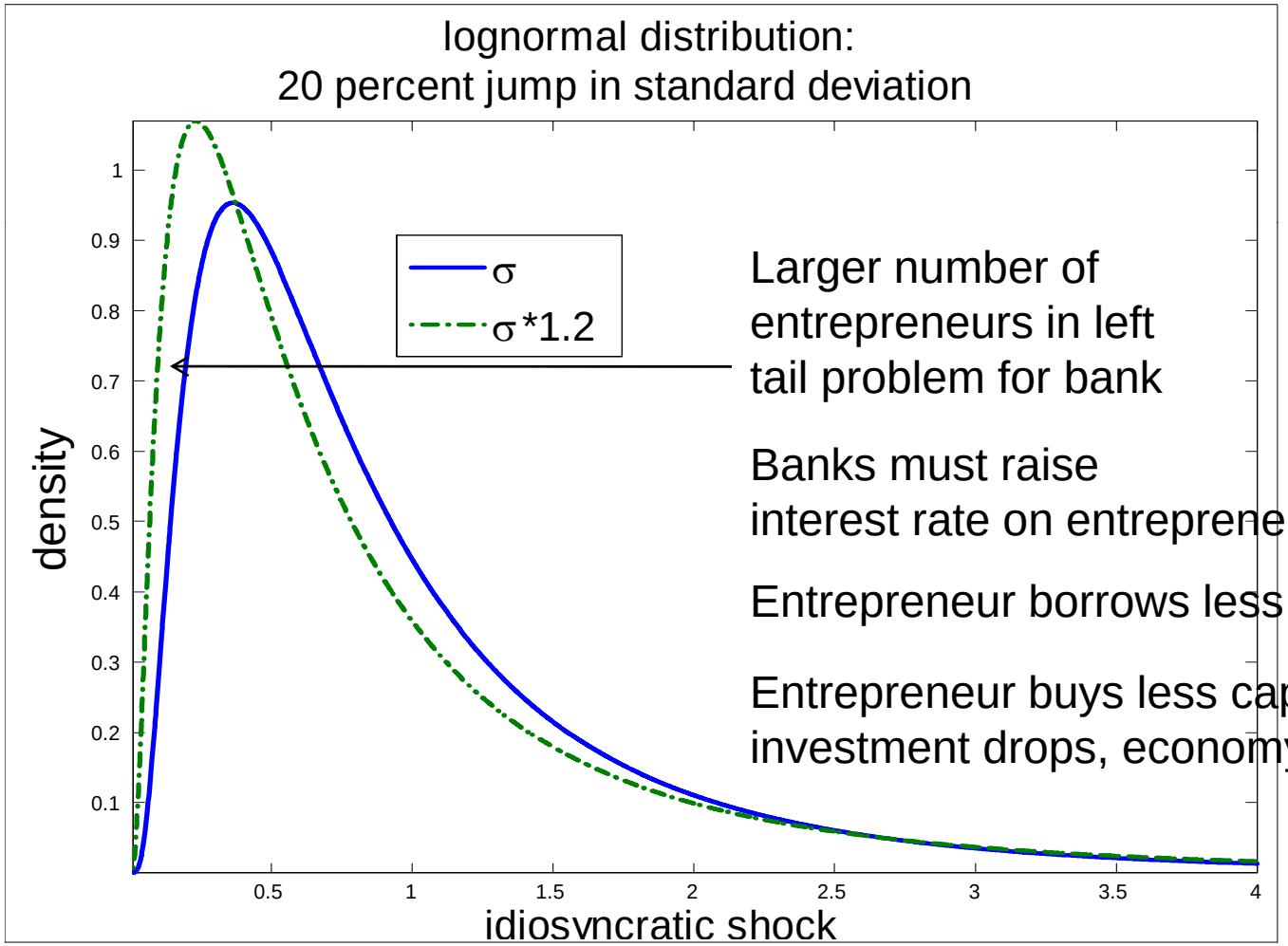
$$[1-P]ZB + PQ = RB$$ ← Payments to household

- Note: interest rate that household looks at, corresponds to the *average* return on entrepreneurial projects

$$R = \frac{[1-P]ZB + PQ}{B}$$

Interest rate spread, *Z/R,* exclusively reflects bankruptcy costs.

# Economic Impact of Risk Shock




Larger number of entrepreneurs in left tail problem for bank

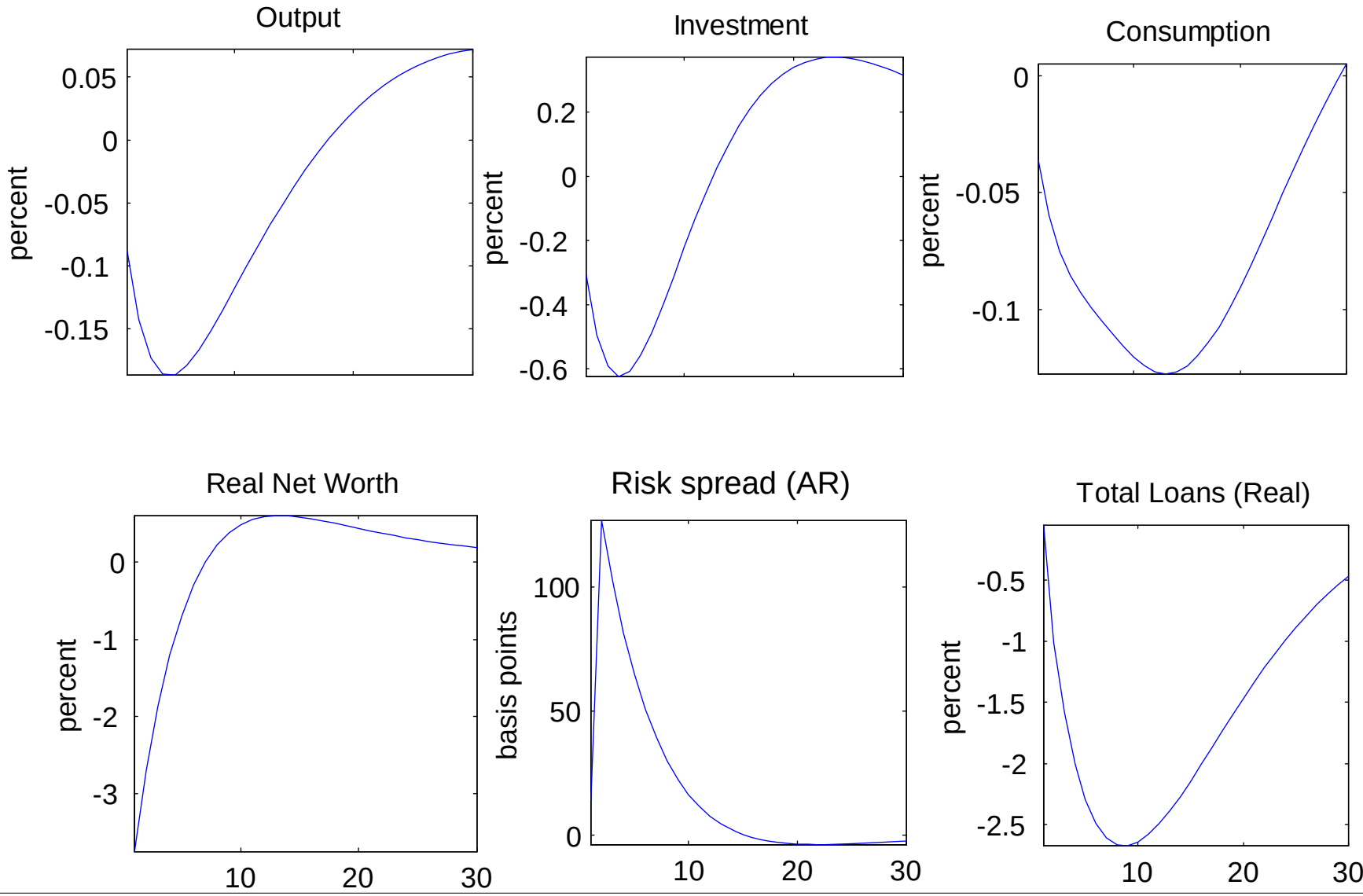
Banks must raise interest rate on entrepreneur

Entrepreneur borrows less

Entrepreneur buys less capital, investment drops, economy tanks

# US, Impulse Response to Riskiness Shock (contemporaneous)

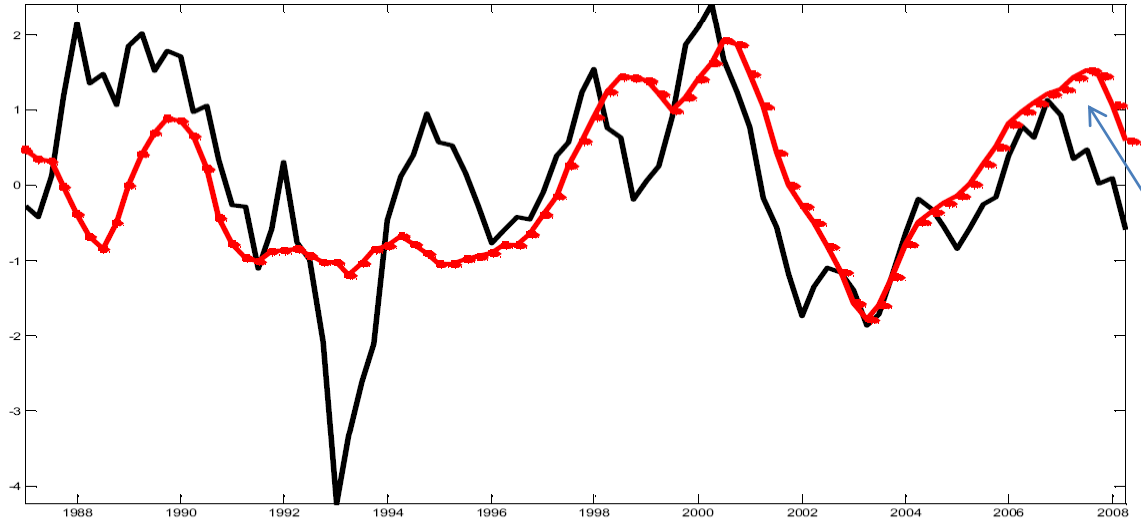
## Credit procyclical, risk spread countercyclical



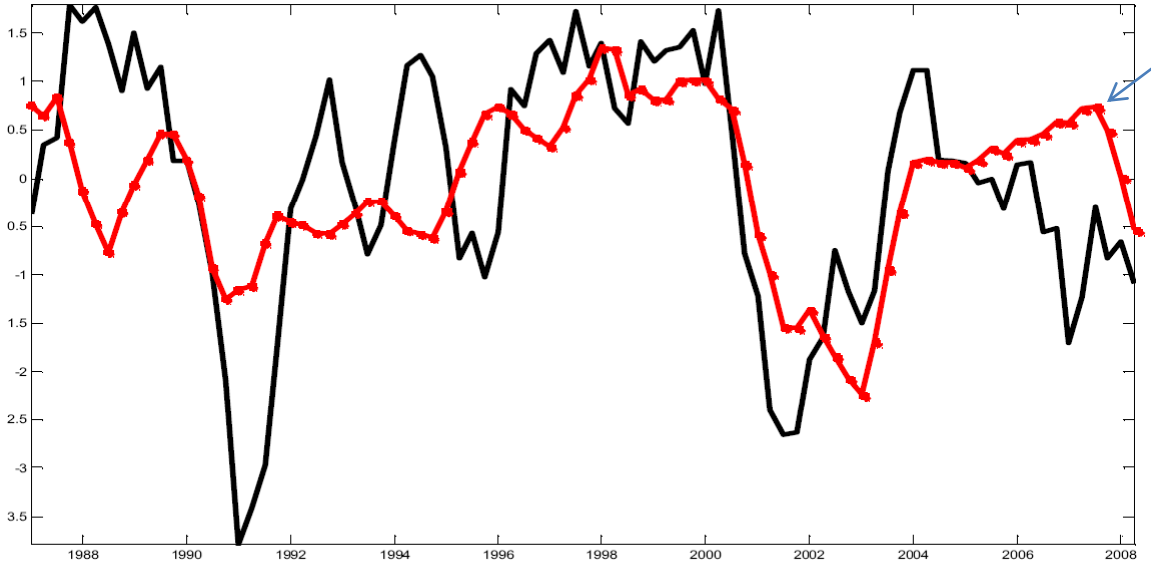
- Our (standard Bayesian) estimator concludes that the risk shock is important….

Figure: Year-over-year GDP Growth Rate - Data (black) versus what data would have been with only the risk shock

US




EA




Spreads did not open up until late 2008, after recession had started.

# Variance Decomposition, US Data

| Percent Variance Due to Risk Shock, $\sigma_t$ | |
|---|---|
| Business Cycle Frequencies (8-32 quarters) | Low Frequencies (cycles longer than 8 years) |
| Output | |
| 30 | 47 |
| Investment | |
| 57 | 64 |
| Consumption | |
| 4 | 27 |
| Risk Spread | |
| 96 | 95 |
| Real Value of Stock Market | |
| 83 | 74 |

- 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'

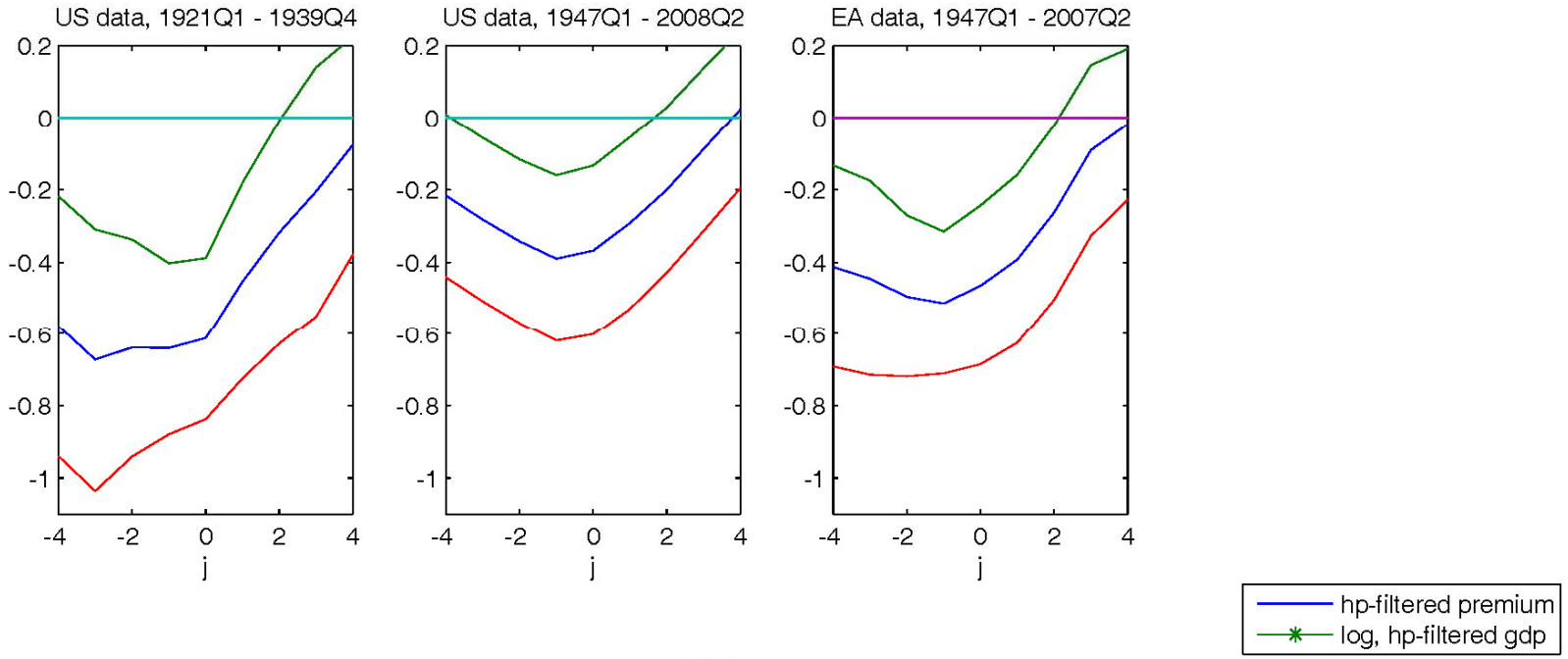
  risk spread ~ risk shock.

- 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.

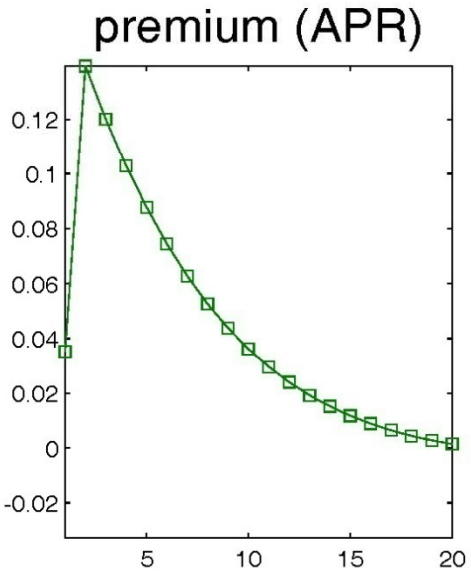
# How Should Policy Respond to the Risk Spread?

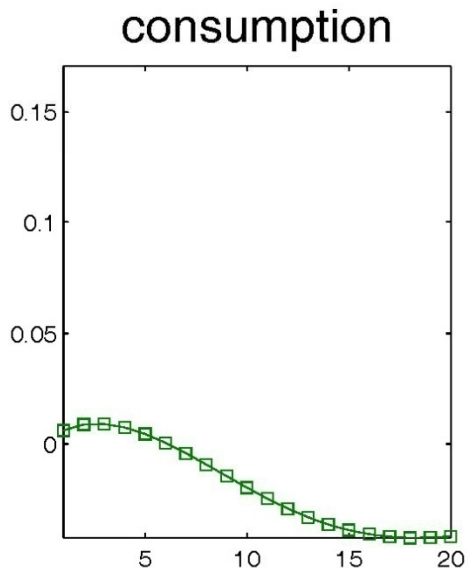
- Taylor's recommendation:

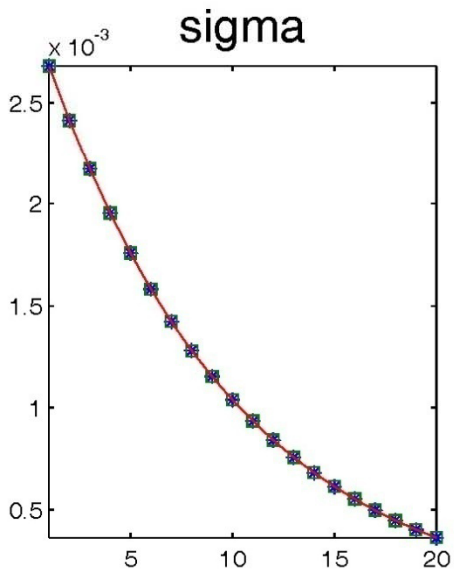
$$R_t = \alpha\pi_t^e + \beta y_t - \gamma(\text{Risky rate}_t - \text{Risk free rate}_t)$$

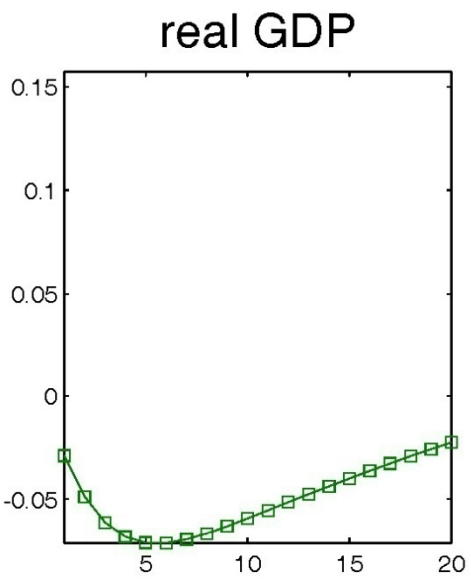
$$\gamma = 1$$

- Evaluate this proposal by comparing performance of economy with $\gamma = 1$ and $\gamma = 0$ against Ramsey-optimal benchmark.



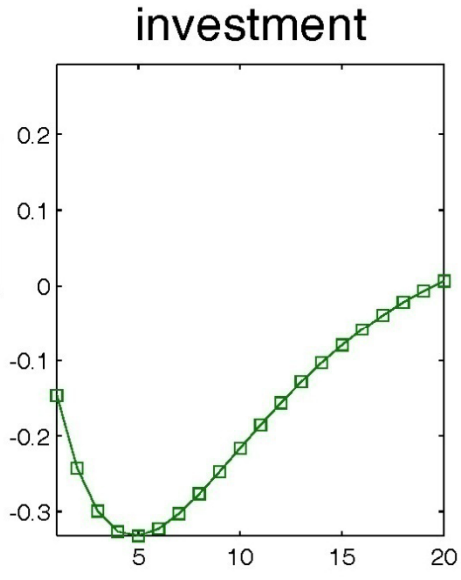



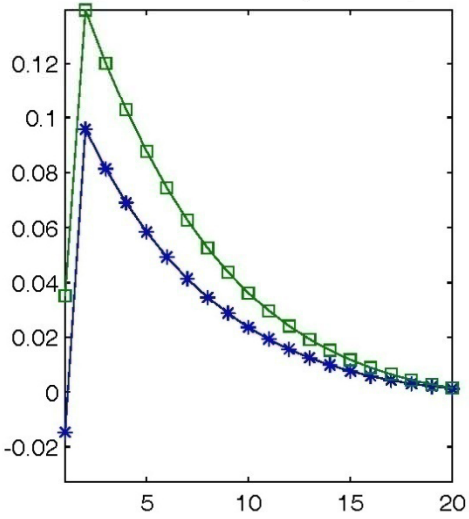




Taylor proposal
Taylor rule without spread
Ramsey Util

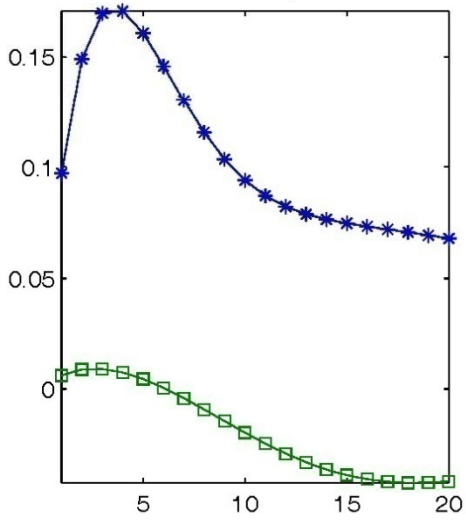
Get a recession, just like in earlier graph



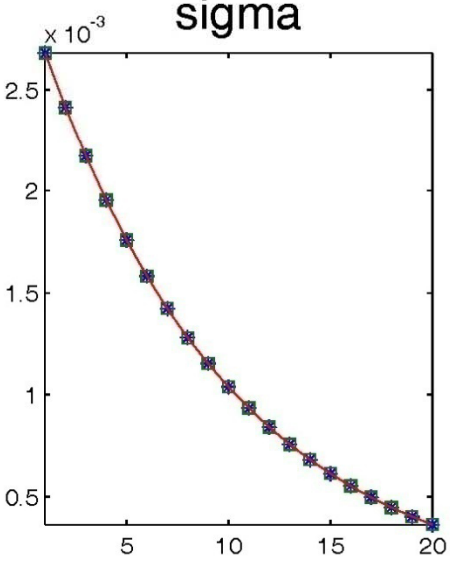
premium (APR)



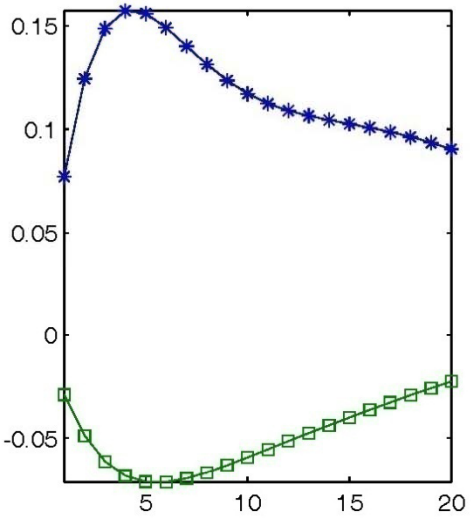

consumption




sigma



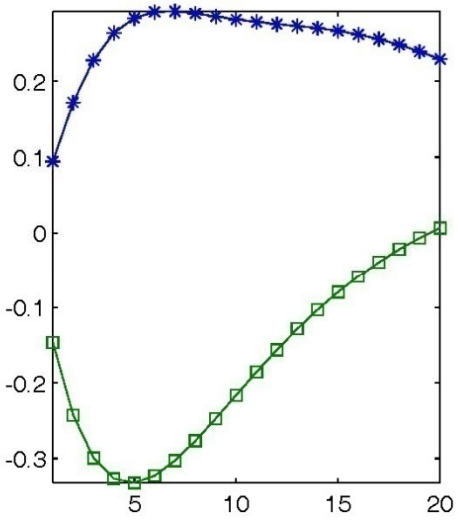

real GDP

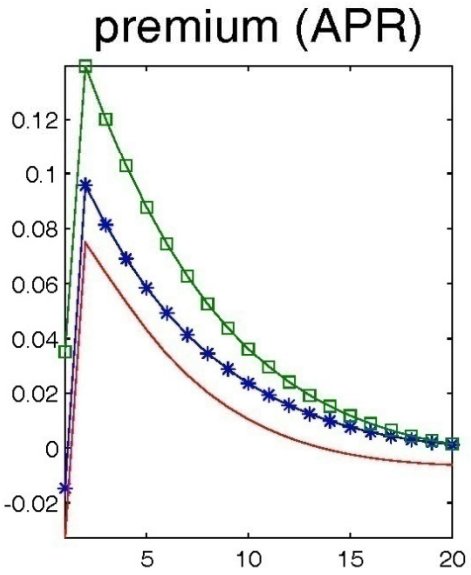


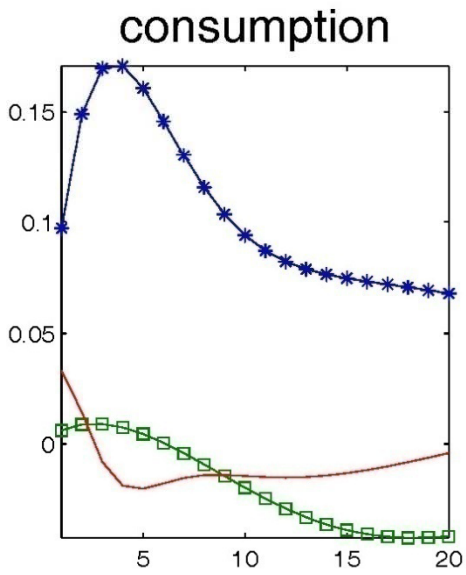

Taylor proposal
Taylor rule without spread
Ramsey

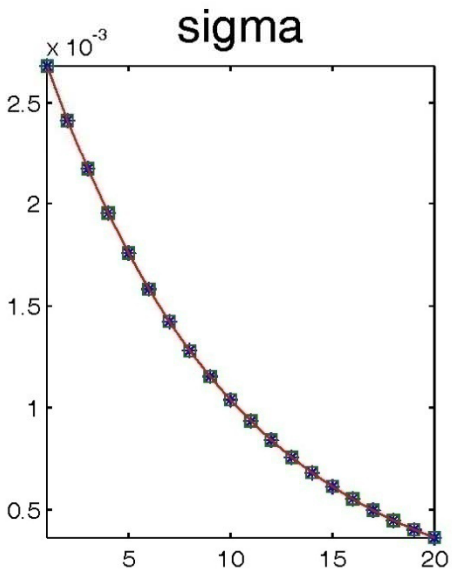
Taylor suggestion creates a boom
Is it too much?

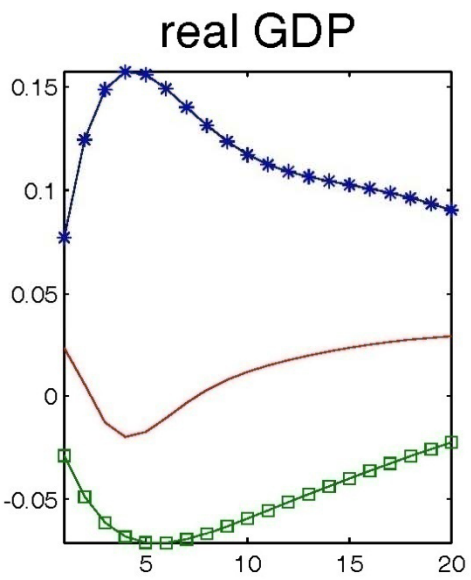
investment



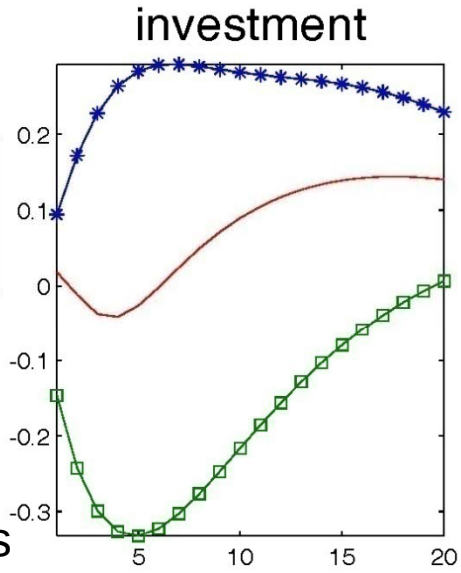



Taylor proposal
Taylor rule without spread
Ramsey Util




Taylor's suggestion overstimulates

# Additional Challenges

- Other important policy questions:
  - What are the mechanisms by which unconventional monetary policy actions (government purchases of private assets and/or long term treasury debt) affect interest rate premia and economic activity?
  - What are the welfare benefits produced by unconventional monetary policy?
- How should leverage restrictions on banks vary over the cycle?

# Leverage Restrictions

- Model for the analysis of leverage restrictions on banks should:
  - Have the property that an unregulated banking system would produce a socially excessive amount of leverage.

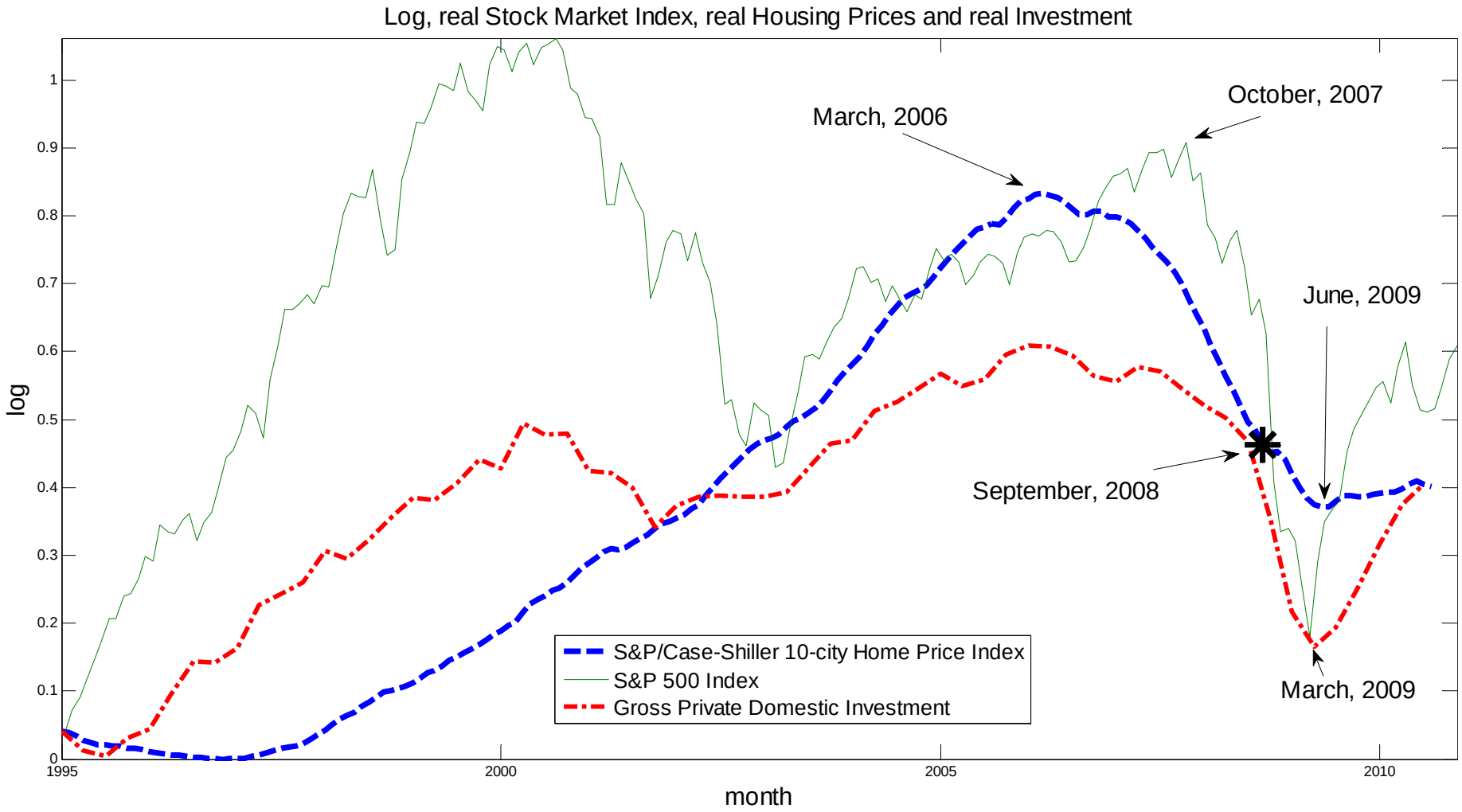
- For example, models with frictions like BGG tend to produce *insufficient* leverage.
  - In those models, households look at the *average return* on entrepreneurial activity, while a social planner would prefer that they look at the *marginal* return.
  - In those models, the marginal return tends to be higher than the average return, so households save too little and there is too little leverage.
  - Studying proposals to restrict leverage in a model like this is like studying proposals to build umbrellas in a model where there is no rain!

- One model for studying leverage has the following properties:
  - Banks are vulnerable to Diamond-Dybvig bank runs.
  - Government responds sensibly by providing guarantees.
  - Creates excessive leverage for moral hazard reasons.
  - Simple ways of capturing these ideas in a dynamic setting are needed.

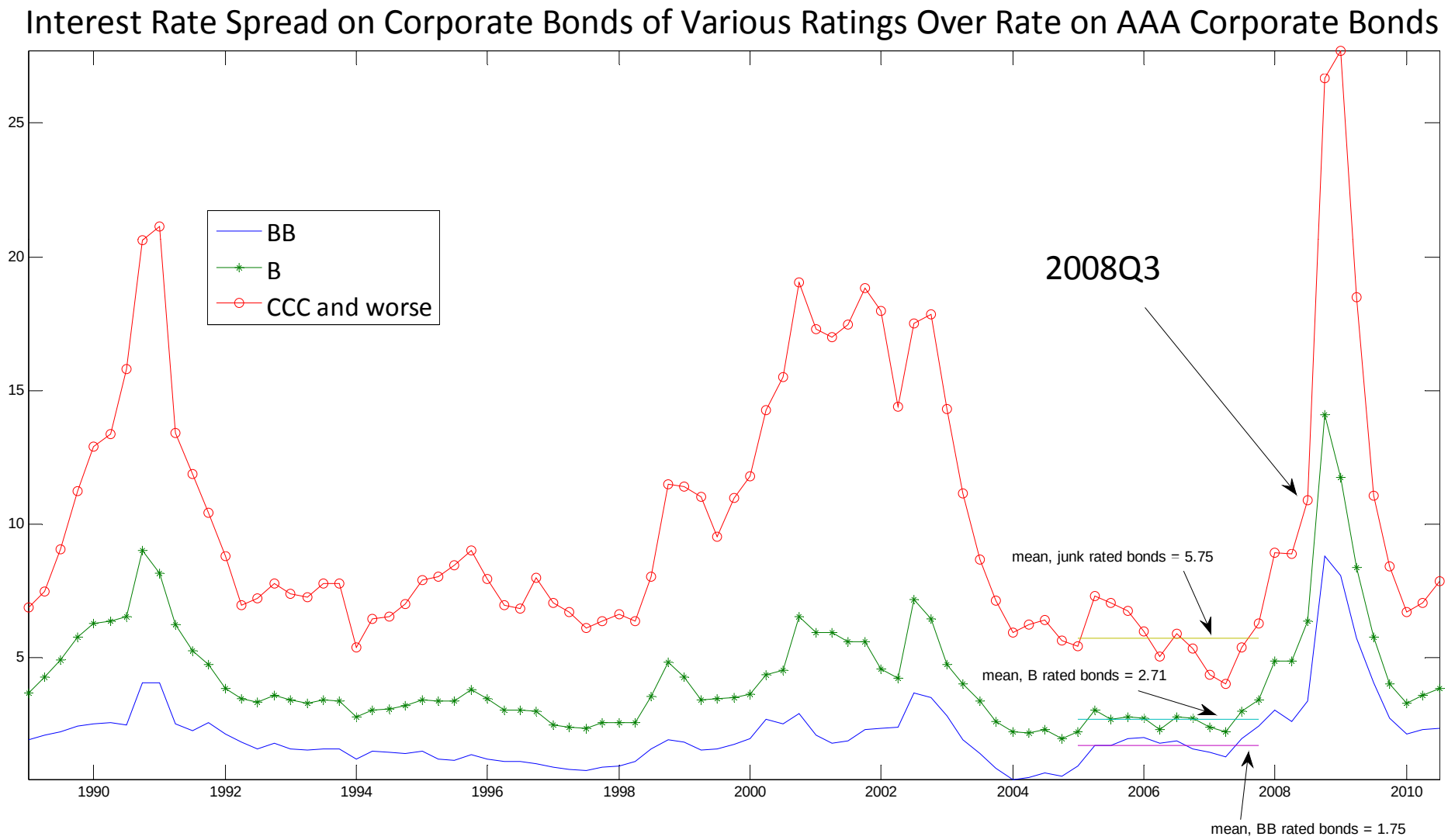
# Unconventional Monetary Policy: Motivation

- Beginning in 2007 and then accelerating in 2008:
  - Asset values collapsed.
  - Intermediation slowed and investment/output fell.
  - Interest rates spreads over what the US Treasury and highly safe private firms had to pay, jumped.
  - US central bank initiated unconventional measures (loans to financial and non-financial firms, very low interest rates for banks, etc.)
- In 2009 – the worst parts of 2007-2008 began to turn around.

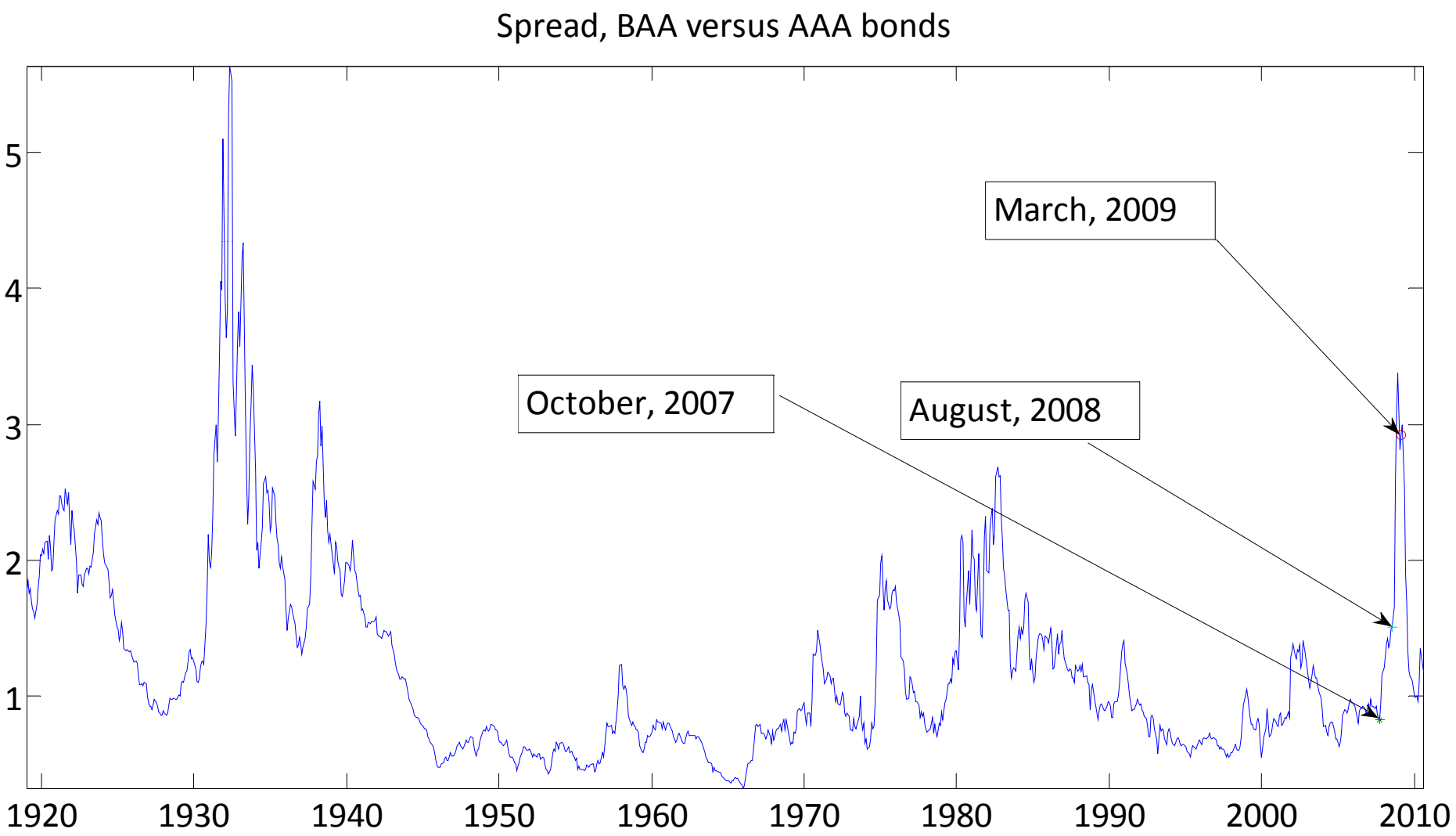
# Collapse in Asset Values and Investment



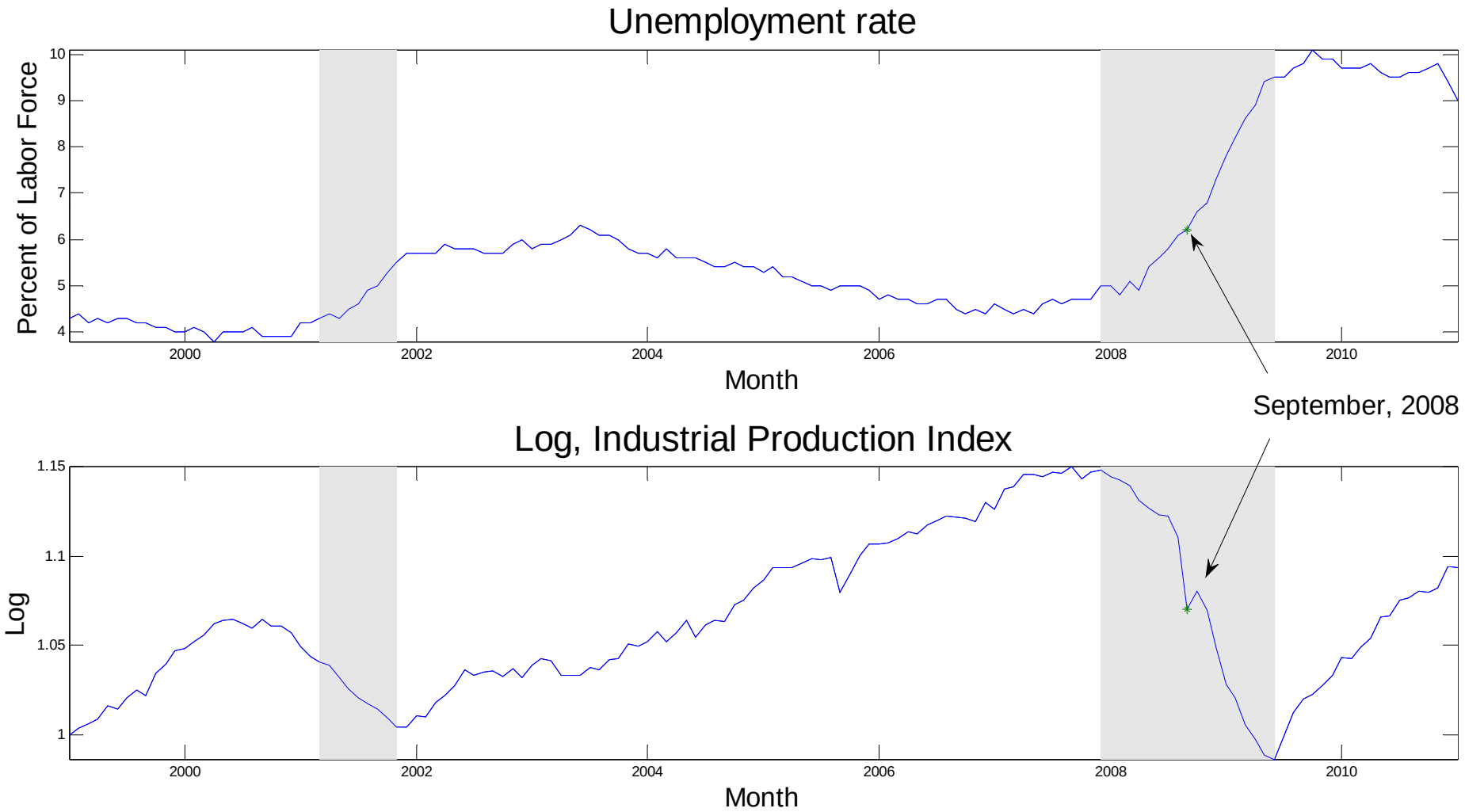
# Spreads for ‘Risky’ Firms Shot Up in Late 2008



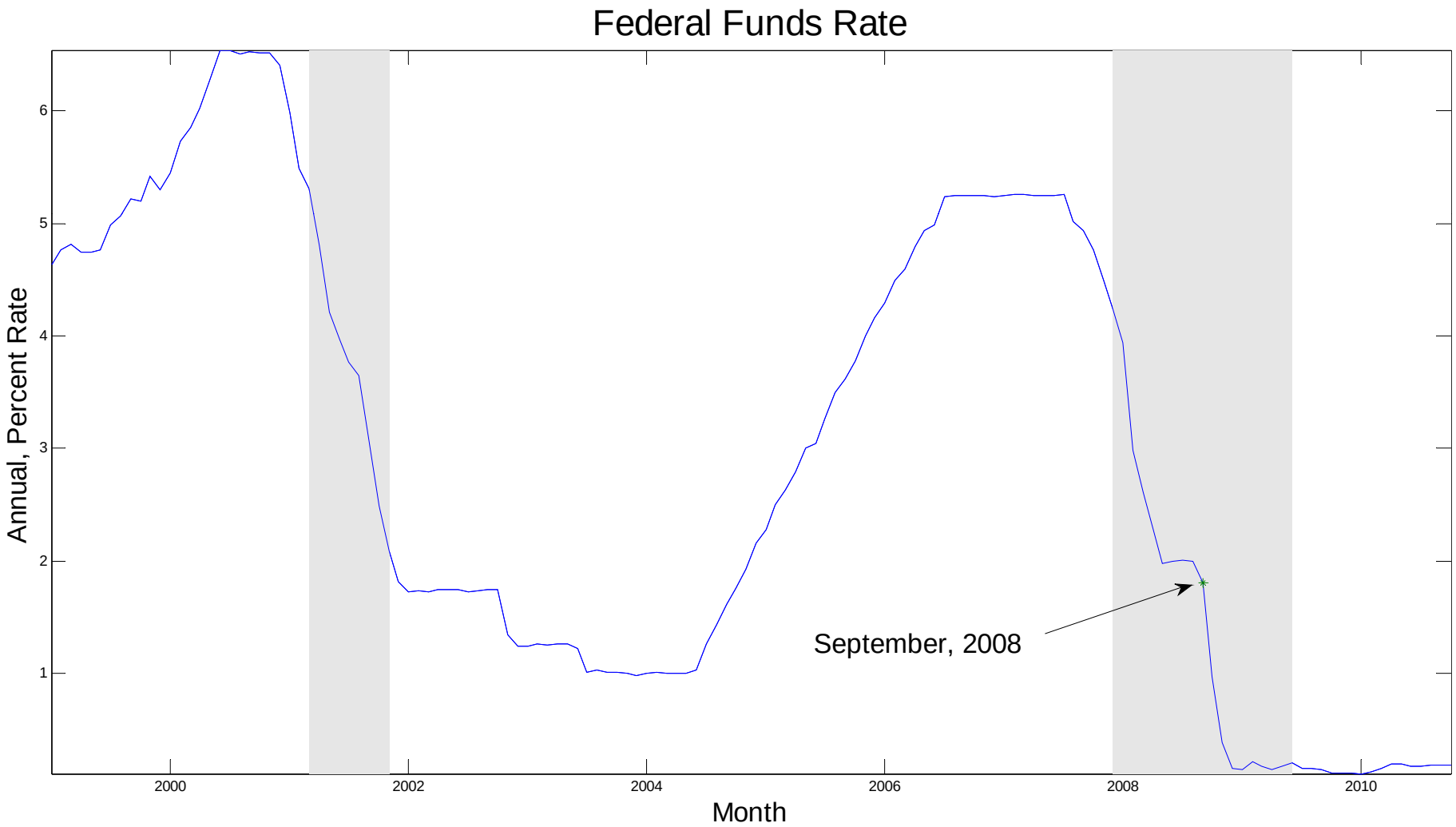
# Must Go Back to Great Depression to See Spreads as Large as the Recent Ones



# Economic Activity Shows (tentative) Signs of Recovery June, 2009



# Banks' Cost of Funds Low



# A Characterization of the Crisis

- Asset Values Fell.
- Banking System Became 'Dysfunctional'
  - Interest rate spreads rose.
  - Intermediation and economy slowed.
- Monetary authority:
  - Transferred funds on various terms to private companies and to banks.
  - Sharply reduced cost of funds to banks.
- Economy in (tentative) recovery.
- Seek to construct models that links these observations together.

# Challenge for Understanding Unconventional Monetary Policy

- Construct models that capture in a rough way, the characterization of the crisis.

- This has been done by Gertler-Kiyotaki/Gertler-Karadi (GK), Christiano-Daisuke (CD)

- Message: the details matter a lot. Both GK and CD obtain models that characterize the crisis in ways that seem very similar, yet
  - GK implies that government asset purchases help.
  - CD implies they don't help.
  - Message: details matter a lot for unconventional monetary policy.

# Conclusion

- Dynamic, Stochastic, General Equilibrium Models are likely to remain a central policy tool for a long time.
- The current generation of models will undergo major developments in response to the crisis.
- However, we will most likely never have models that are so complete that we will anticipate every possible crisis.
  - Models, to be useful, must educate one's intuition. This means they must be simple and abstract from things.
  - Occasionally, one of those things will 'get' you.
  - What you can hope for is that when that happens, you'll be prepared.
    - Current climate in academic economics of 'letting a thousand flowers bloom' is essential for this.