

Lectures in Behavioral Macroeconomics

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Introduction

- The financial crisis came about as a result of
 - inefficiencies in the financial markets (bubbles and crashes)
 - and a poor understanding of economic agents of the nature of risks.
- Yet mainstream Dynamic Stochastic General Equilibrium models (DSGE-models) are populated by agents who are maximizing their utilities in an inter-temporal framework using all available information including the structure of the model

- In other words, agents in these models have incredible cognitive abilities.
 - They are able to understand the complexities of the world
 - and they can figure out the probability distributions of all the shocks that can hit the economy.

- Extraordinary assumptions that leave the outside world perplexed about what macroeconomists have been doing during the last decades.
- Need to develop different kind of macroeconomic models
- that do not make these implausible assumptions about the cognitive capacities of individual agents

- It is useful to make distinction between top-down and bottom-up systems
- top-down system: one or more agents fully understand the system.
 - agents are capable of representing whole system in a **blueprint** that they can store in their mind.
 - depending on their position in the system they can use this blueprint to take over the command, or they can use it to optimize their own private welfare.
 - there is a **one to one mapping** of the information embedded in the system and the information contained in the brain of one (or more) individuals.
 - Example: a building that can be represented by a blueprint and is fully understood by the architect.

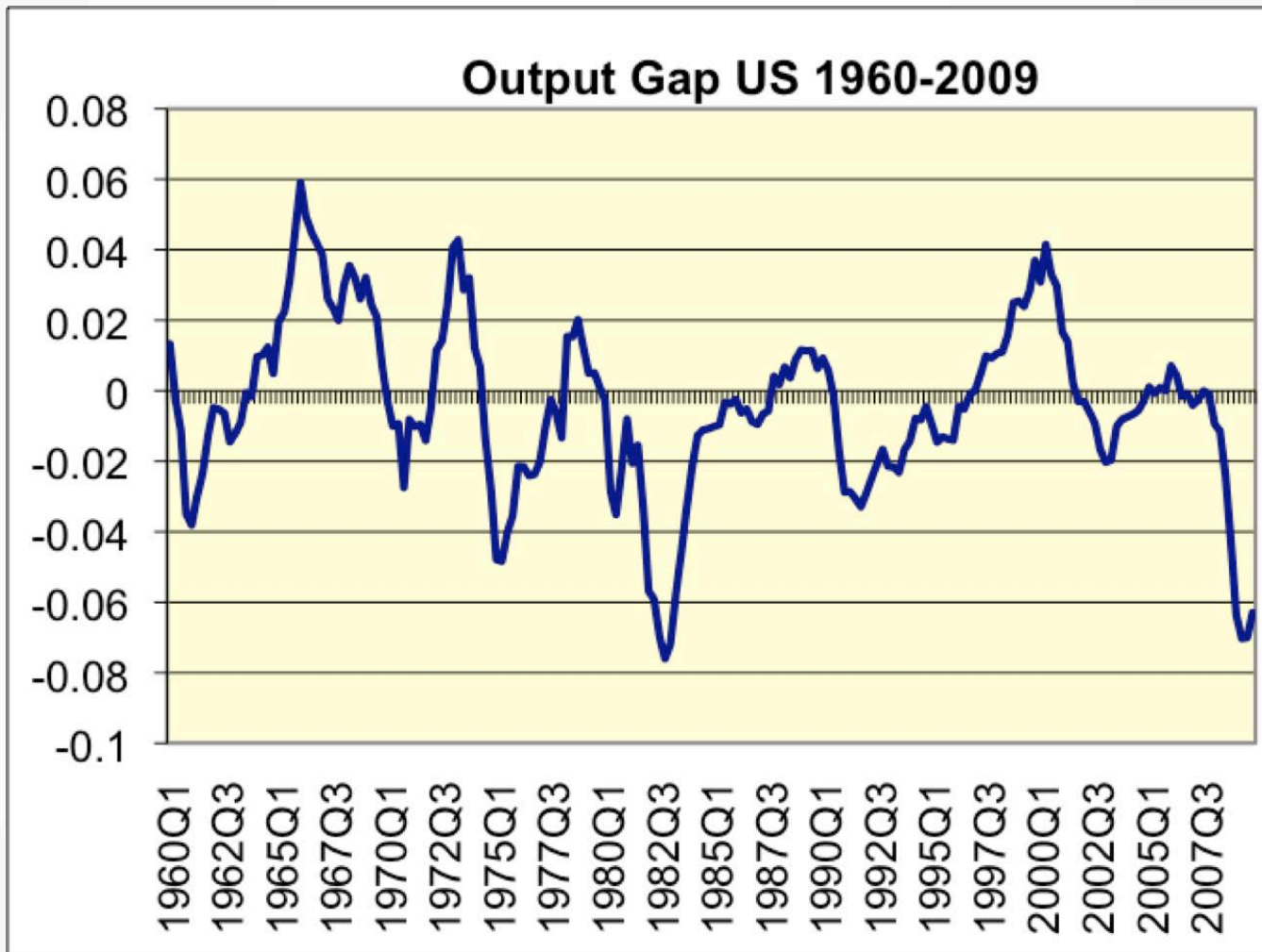
- Bottom-up systems: no individual understands the whole picture.
 - Each individual understands only a very **small part** of the whole.
 - These systems function and grow as a result of the application of **simple rules** by the individuals populating the system.
 - Most living systems follow this bottom-up logic (e.g. the embryo)
 - The market system is also a bottom-up system.

Objective of my lectures

- To develop a bottom-up macroeconomic model.
- This will be a model in which agents have **cognitive limitations** and do not understand the whole picture (the underlying model).
 - Instead they only understand small bits and pieces of the whole model
 - and use simple rules to guide their behavior.
- Rationality will be introduced through a **selection mechanism** in which agents evaluate the performance of the rule they are following
- and decide to **switch** or to stick to the rule depending on how well the rule performs relative to other rules.

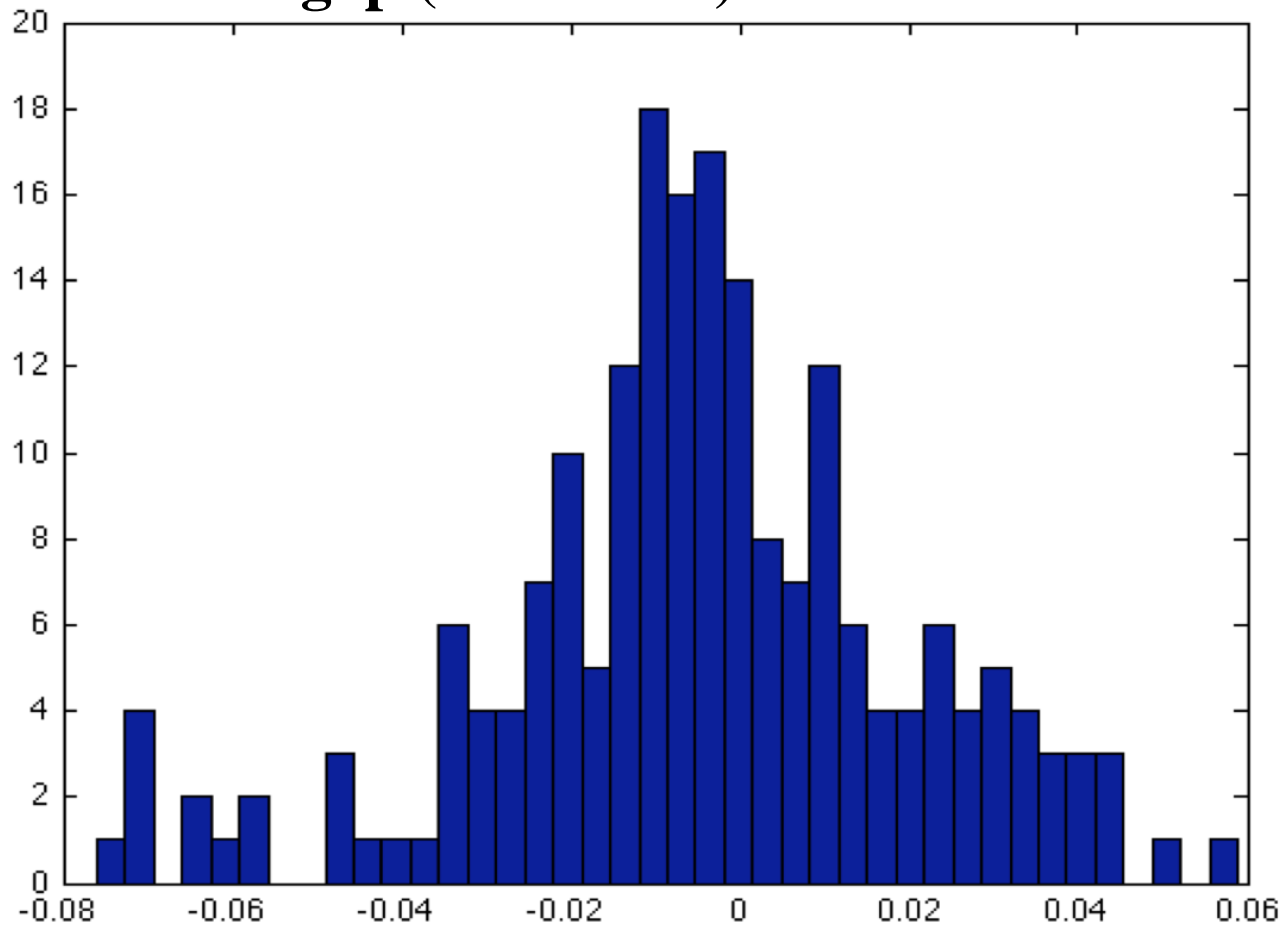
First some stylized facts

- Let us first look at the facts
- US output gap movements during last 50 years



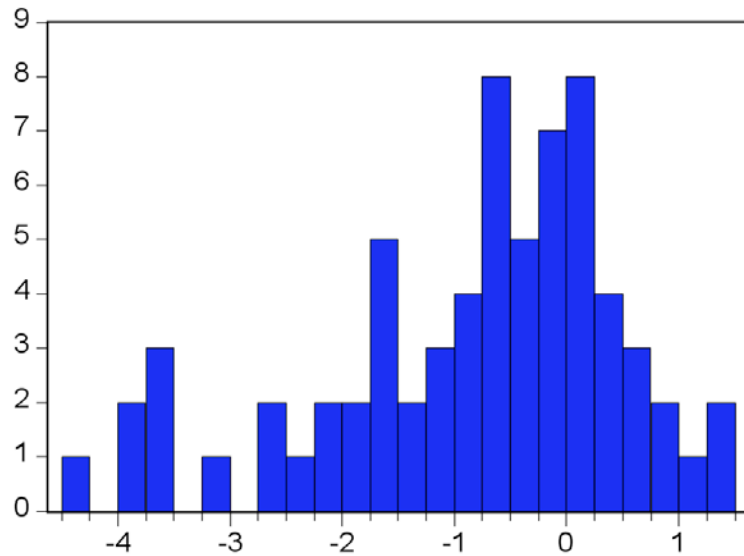
Source: US Department of Commerce and Congressional Budget Office

Frequency distribution of US Output gap (1960-2009)



kurtosis: 3.61; Jarque-Bera: 7.17 with p-value=0.027

Figure 9.3: Frequency distribution of UK output gap

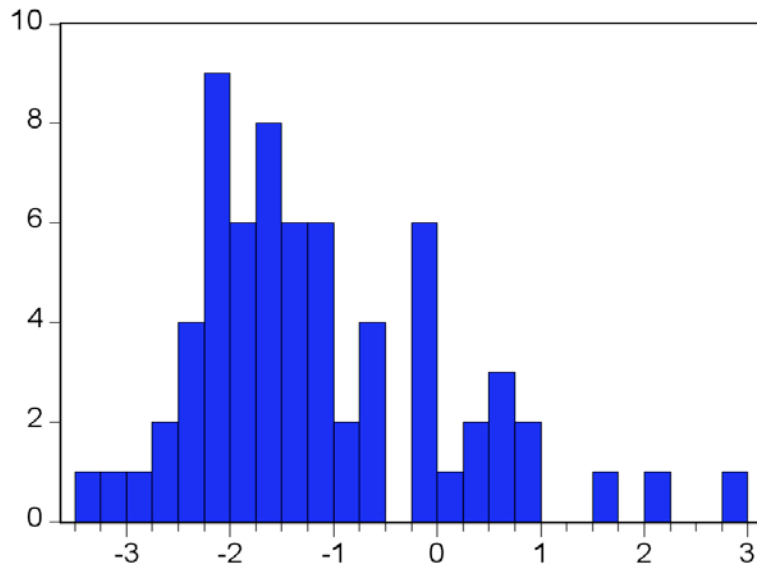


Series: UK
 Sample 1991:1 2007:4
 Observations 68

Mean -0.836548
 Median -0.519114
 Maximum 1.375667
 Minimum -4.347250
 Std. Dev. 1.368099
 Skewness -0.848991
 Kurtosis 3.128224

Jarque-Bera 8.215495
 Probability 0.016445

Figure 9.4: Frequency distribution of German output gap



Series: DE
 Sample 1991:2 2007:4
 Observations 67

Mean -1.140230
 Median -1.365473
 Maximum 2.893201
 Minimum -3.279188
 Std. Dev. 1.242444
 Skewness 0.960223
 Kurtosis 3.823937

Jarque-Bera 12.19116
 Probability 0.002253

Two stylized facts

- Cyclical movements: autocorrelation coefficient = 0.94
- Output gap is not normally distributed
 - There is excess kurtosis
 - Fat tails

- The same regularity for the output gap has been analysed by Fagiolo, et al. (2008) and (2009).
- These authors also confirm that output **growth rates** in most OECD-countries are non-normally distributed, with tails that are much fatter than those in a Gaussian distribution.

Interpretation

- Capitalism is characterized by booms and busts
- Tranquil periods alternate with periods of turbulence when large shocks occur (tail risk)
- Mainstream macroeconomic models explain this phenomenon by invoking exogenous shocks that are non-normally distributed.
- This is not a very satisfactory explanation as it shifts our ignorance one step further.
- Let's try to do better.

The basic behavioral model

Model structure is the same in behavioral model and in DSGE model

- **Aggregate demand**

$$\tilde{y}_t = a_1 \hat{E}_t \tilde{y}_{t+1} + (1 - a_1) \tilde{y}_{t-1} + a_2 (r_t - \hat{E}_t \pi_{t+1}) + \varepsilon_t$$

- Forward and backward looking term (habit formation)
- \hat{E} above E means: non rational expectation

- **Aggregate supply:** New Keynesian Phillips curve

$$\pi_t = b_1 \hat{E}_t \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 \tilde{y}_t + \eta_t$$

- **Taylor rule** describes behavior of central bank

$$r_t = c_1 (\pi_t - \pi^*) + c_2 \tilde{y}_t + c_3 r_{t-1} + u_t$$

when $c_2 = 0$ there is strict inflation target

Introducing heuristics: output forecasting

- I assume two possible forecasting rules
 - A fundamentalist rule
 - An extrapolative rule
- Fundamentalist rule: agents estimate equilibrium output gap and forecast output gap to return to steady state
- Extrapolative rule: agents extrapolate past output gap
- Note: more complicated rules can be introduced. Surprisingly they do not affect the dynamics much
- Aim: how far can we get with such simple rules?

output forecasting

- Fundamentalist rule

$$\tilde{E}_t^f y_{t+1} = 0$$

- Extrapolative rule

$$\tilde{E}_t^e y_{t+1} = y_{t-1}$$

- Clearly the rules are ad-hoc but not more so than assuming that agents understand the whole picture.
- It a parsimonious representation of a world where agents do not know the “Truth” (i.e. the underlying model).
- The use of simple rules does not mean that the agents are dumb and that they do not want to learn from their errors.
- I will specify a learning mechanism in which these agents continuously try to correct for their errors by switching from one rule to the other.

- Market forecasts are weighted average of fundamentalist and extrapolative forecasts

$$\tilde{E}_t y_{t+1} = \alpha_{f,t} \tilde{E}_t^f y_{t+1} + \alpha_{e,t} \tilde{E}_t^e y_{t+1}$$

$\alpha_{f,t}$ = probability agents choose fundamentalist rule

$\alpha_{e,t}$ = probability agents choose extrapolative rule

$$\alpha_{f,t} + \alpha_{e,t} = 1$$

Inflation forecasts

- I also allow inflation forecasters to be heterogeneous.
- I follow Brazier et al. (2006) in allowing for two inflation forecasting rules.
 - One rule is based on the announced inflation target which provides anchor
 - the other rule extrapolates inflation from the past into the future.
 - Here also agents select the rule that forecasts best
 - They switch from the bad to the good forecasting rule

Inflation “targeters”:

$$\hat{E}_t^{tar} \pi_{t+1} = \pi^*$$

Inflation extrapolators:

$$\hat{E}_t^{ext} \pi_{t+1} = \pi_{t-1}$$

Market forecasts are weighted average of these two forecasting rules

$$\hat{E}_t \pi_{t+1} = \beta_{tar,t} \hat{E}_t^{tar} \pi_{t+1} + \beta_{ext,t} \hat{E}_t^{ext} \pi_{t+1}$$

Introducing discipline

- The beauty of rational expectations theory is that it is a disciplining device
- Expectations must be model consistent
- This determines on how we can specify the expectations formation of agents
- The problem of this disciplining device is that it assumes extraordinary cognitive abilities on human beings
- that only Godlike creatures can have

- I propose a different way to introduce discipline
- So as to avoid that everything becomes possible
- This is a discipline provided by a selection mechanism based on fitness of the rules agents use

How to do this?

- We apply notions of **discrete choice theory** (see Brock & Hommes(1997)) in specifying the procedure agents follow in this evaluation process
- Discrete choice theory takes the view that agents are boundedly rational: utility has a deterministic component and a random component

Applying discrete choice theory

$$\alpha_{f,t} = \frac{\exp(\gamma U_{f,t})}{\exp(\gamma U_{f,t}) + \exp(\gamma U_{e,t})}$$

$$\alpha_{e,t} = \frac{\exp(\gamma U_{e,t})}{\exp(\gamma U_{f,t}) + \exp(\gamma U_{e,t})} = 1 - \alpha_{f,t}$$

- when forecast performance of the extrapolators (utility) improves relative to that of the fundamentalists agents are more likely to choose the extrapolating rule about the output gap for their future forecasts.
- γ intensity of choice parameter; it parametrizes the extent to which the deterministic component of utility determines actual choice

Utility of rule: Forecast performance

Agents compute mean squared forecast errors obtained from using the two forecasts

This determines the utility of using a particular rule:

$$U_{f,t} = -\sum_{k=0}^{\infty} \omega_k \left[y_{t-k-1} - \tilde{E}_{f,t-k-2} y_{t-k} \right]^2$$

$$U_{e,t} = -\sum_{k=0}^{\infty} \omega_k \left[y_{t-k-1} - \tilde{E}_{e,t-k-2} y_{t-k} \right]^2$$

- This switching mechanism is the disciplining device introduced in this model on the kind of rules of behaviour that are acceptable.
- Only those rules that pass the fitness test remain in place.
- The others are weeded out.

Note on learning

- this is a model of learning based on “trial and error”
- Contrast with the rational expectations forecasting rule.
 - rational expectations implies that agents understand the complex structure of the underlying model.
 - Since there is only one underlying model (there is only one “Truth”), agents understand the same “Truth”.
 - They all make exactly the same forecast.

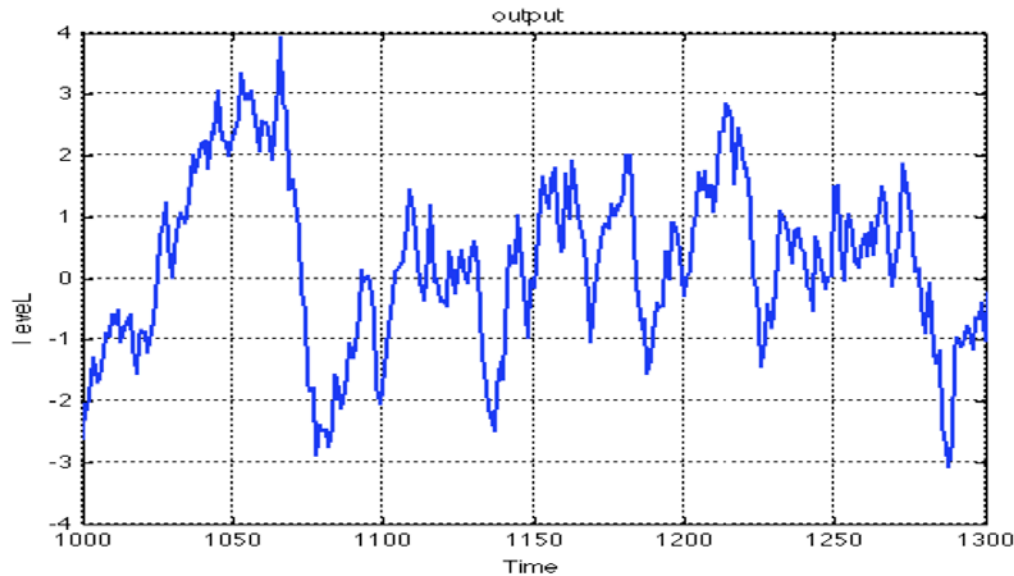
- In rational expectations models focus on just one “representative agent” .
- In the adaptive learning mechanism that is used here, agents can use different forecasting rules.
- Thus there will be **heterogeneity** among agents.
- Heterogeneity creates interactions between agents.
- leading to a dynamics that is absent from rational expectations models.

Calibrating the model

- The model has non-linear features making it difficult to arrive at analytical solutions.
- That is why I use numerical methods to analyze its dynamics.
- In order to do so, I have to calibrate the model, i.e. to select numerical values for the parameters of the model.

- I calibrate the model by giving numerical values to the parameters that are often found in the literature
- And simulate it assuming i.i.d. shocks with std deviations of 0.5%
- I will also perform sensitivity analysis

Output gap



- strong cyclical movements in the output gap.

- the source of these cyclical movements is the fraction of those who forecast positive output gaps (optimists)

- The model generates endogenous waves of optimism and pessimism

- Keynes' "animal spirits"

- Timing is unpredictable

- Optimism and pessimism self-fulfilling

- Correlation output gap and fraction optimists = 0.86

Correlation animal spirits and output gap

- I find a correlation coefficient between fraction of optimists and output gap in a range of 0.8-0.9
- This correlation depends on a number of parameters

Conditions for animal spirits to arise

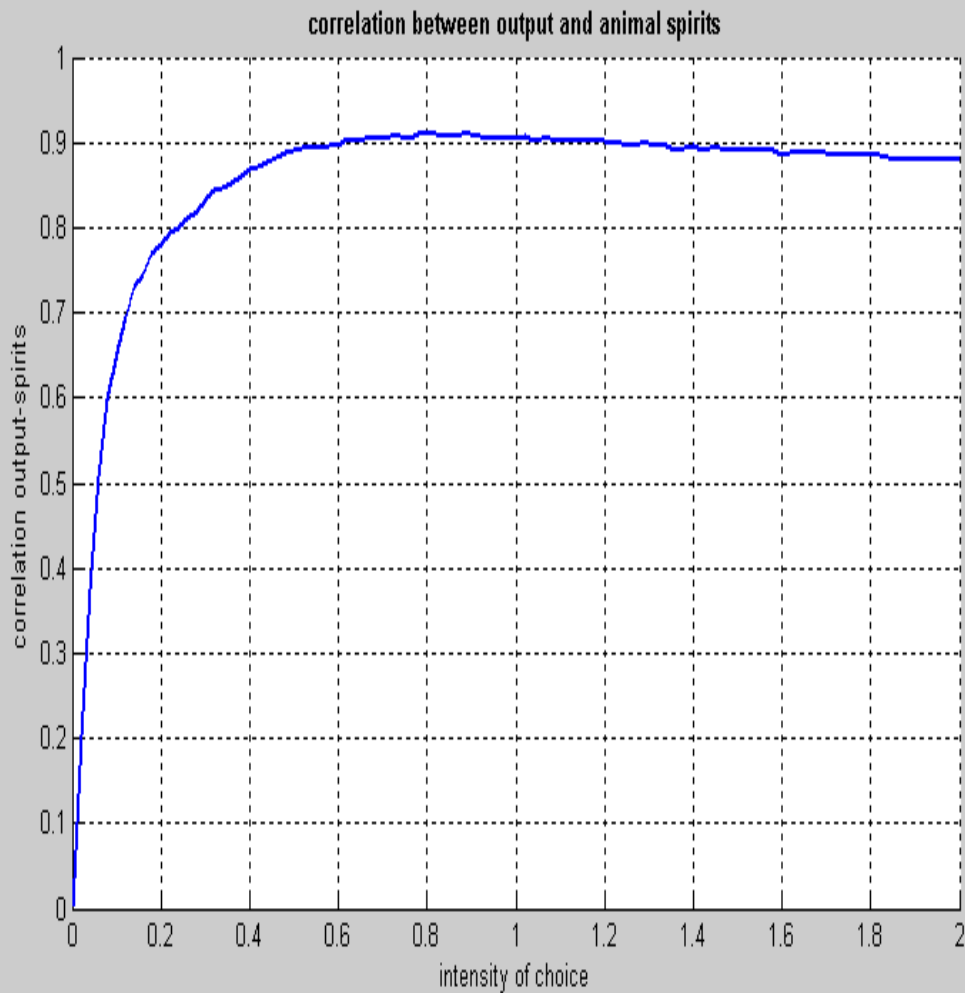
- Previous simulations assumed a given set of numerical values of the parameters of the model
- How does this correlation evolve when one changes the parameter values of the model.

- I concentrate on two parameter values here,
 - the intensity of choice parameter, γ ,
 - and the memory agents have when calculating the performance of their forecasting.
- This sensitivity analysis will allow us to detect under what conditions “animal spirits” can arise.

A willingness to learn

- I first concentrate on the intensity of choice parameter, γ (intensity of choice)
 - intensity with which agents switch from one rule to the other when the performances of these rules change.
- When γ is zero the switching mechanism is purely stochastic. They learn nothing from past mistakes.
- As γ increases they are increasingly sensitive to past performance of the rule they use and are therefore increasingly willing to learn from past errors.

- To check importance γ in creating animal spirits I simulated the model for consecutive values of γ starting from zero.
- For each value of γ I computed the correlation between the animal spirits and the output gap.
- I show the results of this exercise in next figure.



Agents should be willing to learn

In an environment in which agents learn from their mistakes, animal spirits arise

Thus, one needs a minimum level of rationality for animal spirits to emerge and to influence the business cycle

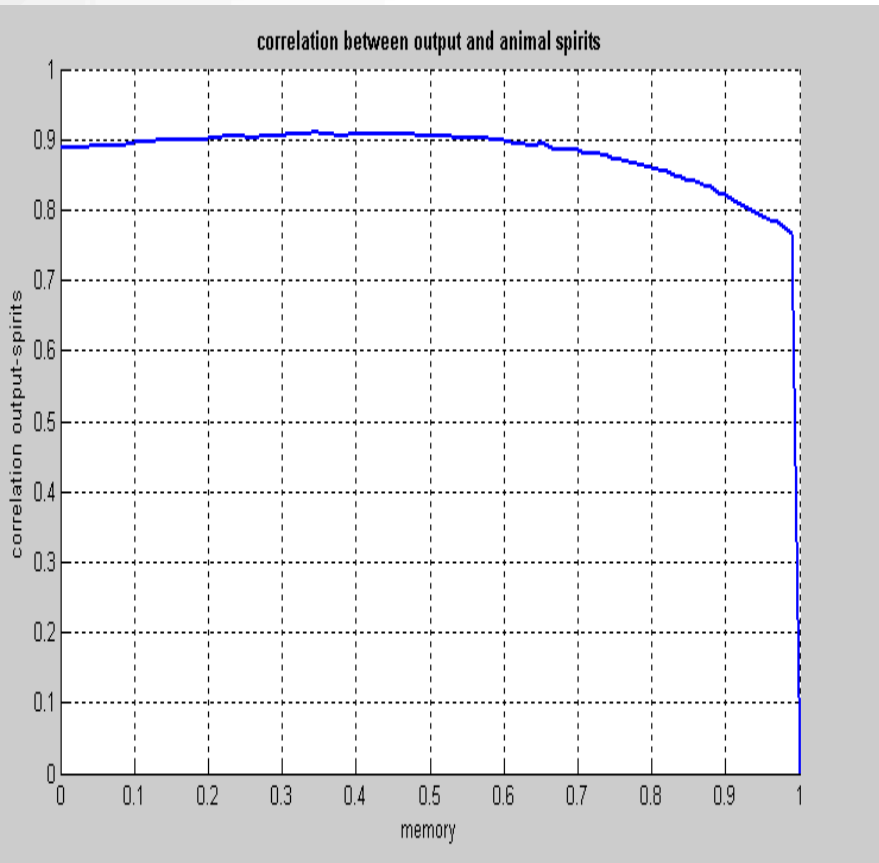
this is achieved with relatively low levels of γ .

- Thus surprisingly animal spirits arise not because agents are irrational.
- On the contrary animal spirits can only emerge if agents are sufficiently rational.

A capacity to forget

- When agents test the performance of the forecasting rules they compute past forecasting errors.
- In doing so, they apply weights to these past forecast errors.
- I assume that these weights decline exponentially measured by ρ .

- When $\rho = 0$ there is no memory; i.e. only last period's performance matters in evaluating a forecasting rule;
- when $\rho = 1$ there is infinite memory, i.e. all past errors, however far in the past, obtain the same weight.
- I computed the correlation between animal spirits and the output gap for consecutive values of ρ .
- The results are shown in next figure

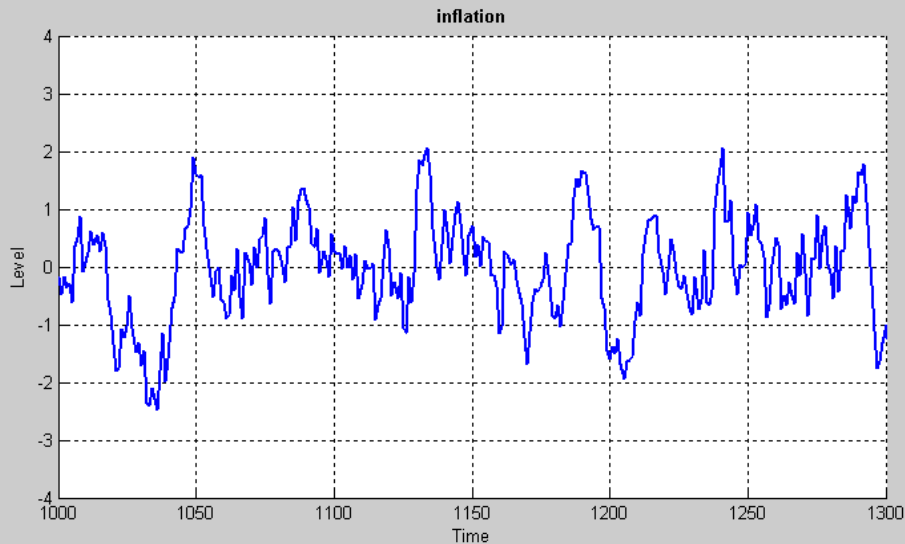


- when $\rho = 1$ the correlation is zero.
- i.e. agents attach the same weight to all past observations; however, far in the past they occur.
- Put differently, when agents have infinite memory; they forget nothing. In that case animal spirits do not occur.
- Thus one needs some forgetfulness (which is a cognitive limitation) to produce animal spirits.
- Note that degree of forgetfulness does not have to be large.

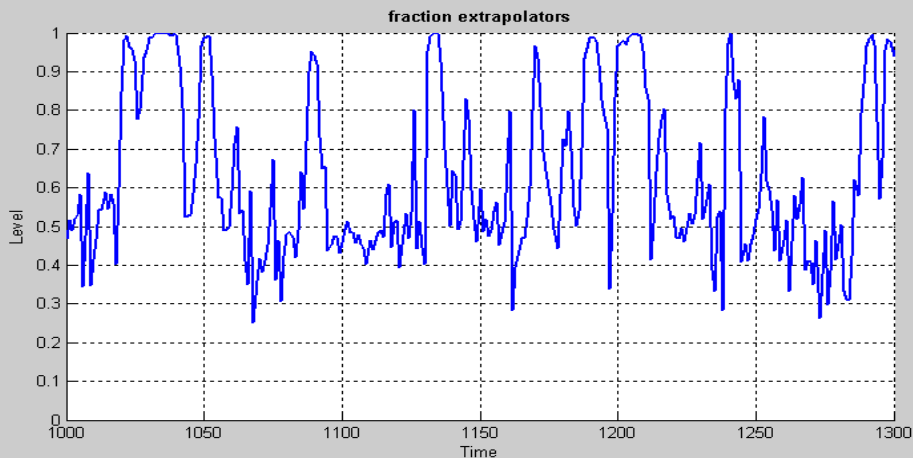
Interpretation

- This and the previous results lead to an interesting insight.
- Animal spirits emerge when agents behave rationally (in the sense of a willingness to learn from mistakes) and when they experience cognitive limitations.
- They do not emerge in a world of either super-rationality or irrationality.

Inflation: credibility is fragile



- When fraction of extrapolators and targeters fluctuates around 50%
- rate of inflation remains within a narrow band around the central bank's inflation target.
- When the extrapolators are dominant inflation fluctuates significantly more.

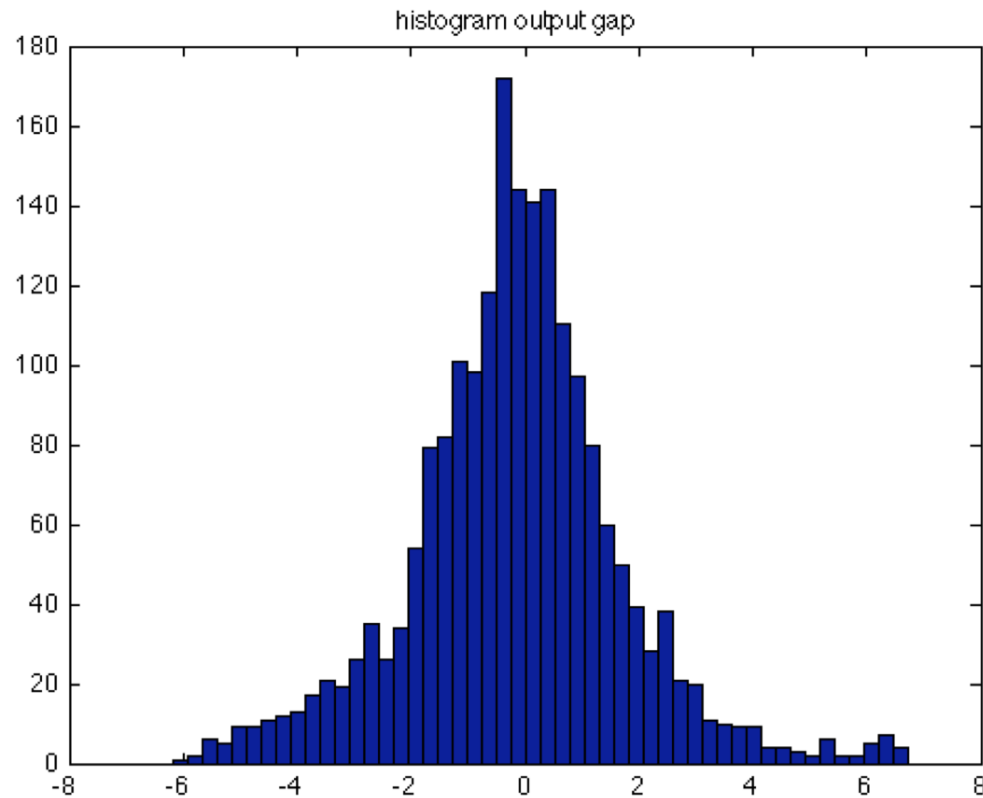


- Thus the inflation targeting of the central bank is fragile.
- Central banks can however strengthen credibility
- This will be analyzed later

Two different business cycle theories

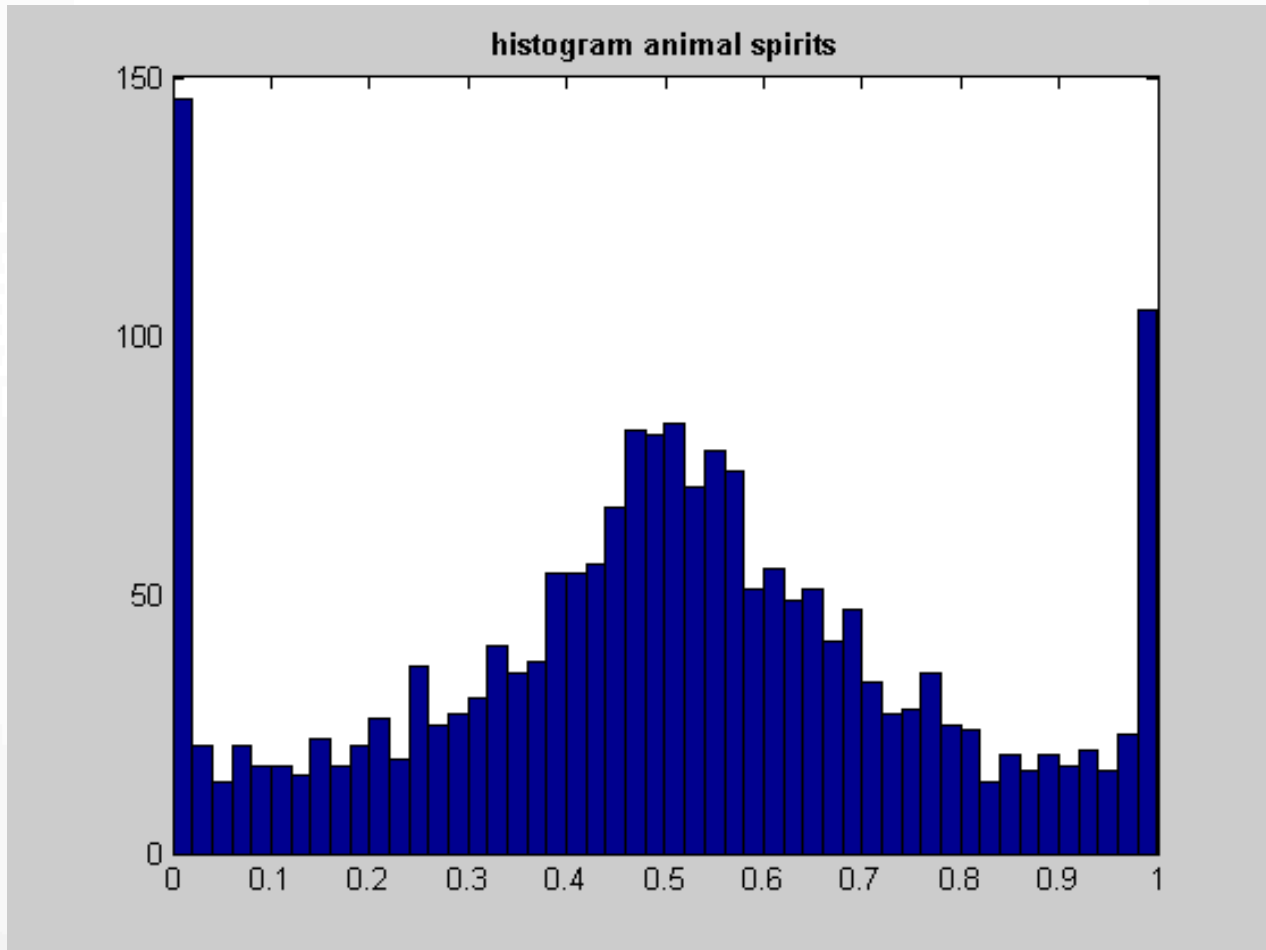
- Are the behavioural and the New-Keynesian models capable of mimicking empirical regularities?
- We first focus on the behavioural model.
- First finding: strong autocorrelation output gap, i.e. = 0.95
- Second finding: output gap non-normally distributed (despite the fact that shocks are normally distributed)

Output gap non-normally distributed

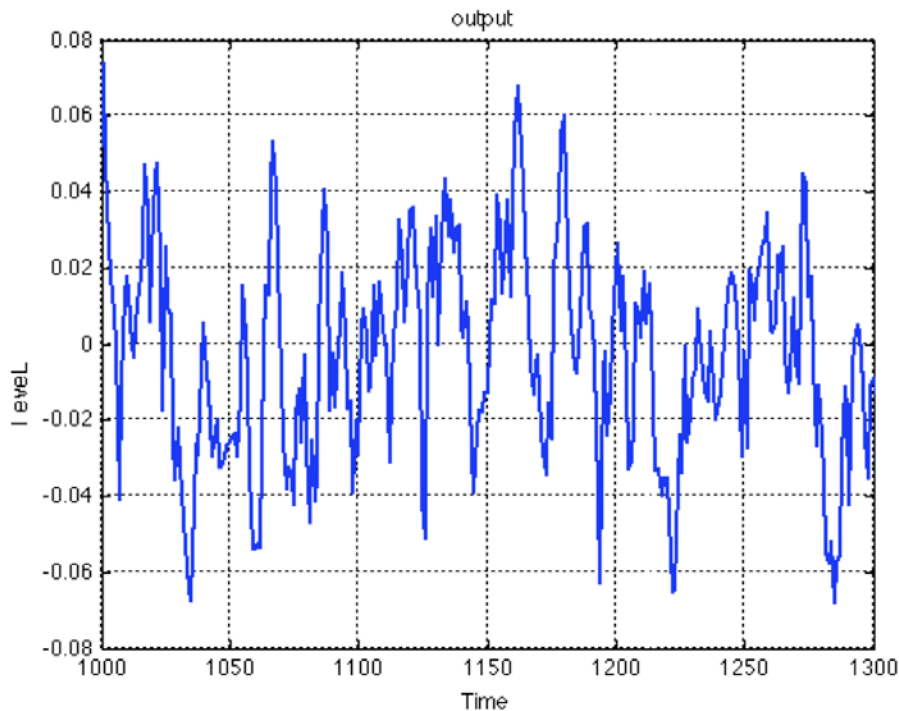


Kurtosis=4.4, Jarque-Bera = 178.4
(p-value = 0.001)

Non-normality created by animal spirits



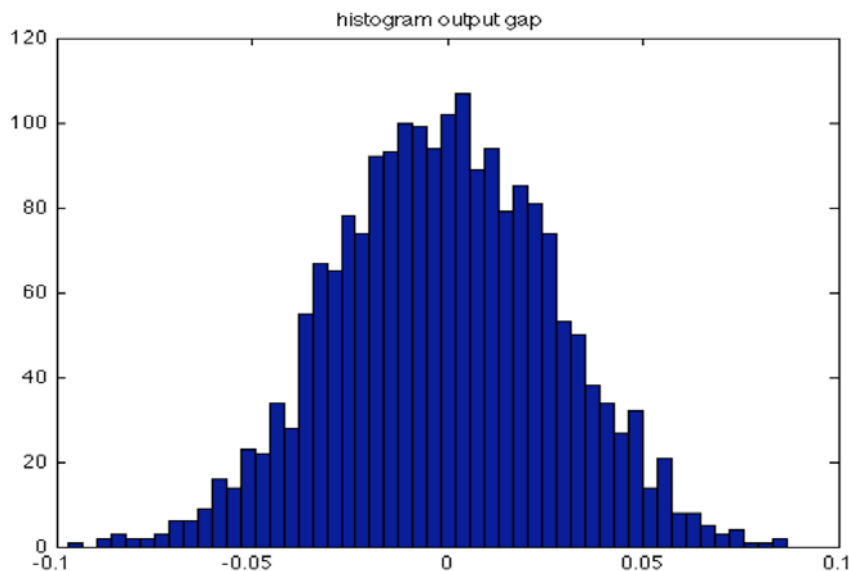
- Behavioral model correctly predicts that large swings in output gap are a regular feature of reality.
- And that this is made possible by dynamics of animal spirits
- What about the DSGE rational expectations model?
- I show results of simulation of DSGE-model



autocorrelation in the output gap is 0.77

Output gap in mainstream macroeconomic model (DSGE) is normally distributed

One has to introduce non-normality in the error term to produce non-normality in output gap



- Standard practice has been to add autocorrelation in error terms (scientifically questionable procedure) to improve the empirics
- I do this with DSGE model assuming AR1 error terms.
- autocorrelation output gap (not surprisingly) increases to 0.98
- But output gap remains normally distributed

Contrast between two models

- In DSGE model business cycles are the result of combination of external shocks and slow transmission due to inertia
- leading to waves in output gap and inflation
- Large booms and busts can only occur because of large exogenous shocks: they are not created internally
- Thus business cycle theory is **exogenous**
- DSGE-model produces meteor theory of the business cycle

- Agents in behavioral model grope to understand the underlying structure and nature of shocks.
- They follow a procedure that functions as a “trial and error” learning mechanism
- This is a slow bottom-up process that leads to waves of optimism and pessimism
- It generates an **endogenous** business cycle into the model.
- Large booms and bust generated internally even in absence of large exogenous shocks

Applying these different views to Great Recession

- In top-down (RE) model: the Great Recession is result of exogenous and unpredictable increase in risk premia in August 2007
 - Not very satisfactory theory
- In bottom-up model the cause of the economic downturn must be found in the (excessive) boom prior to 2007.
 - Economic downturn is result of previous excesses
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The transmission of shocks

- Shocks do matter.
- How are exogenous shocks transmitted in behavioral model?
- I analyze
 - Productivity shock
 - Interest rate shock
- Using technique of impulse responses

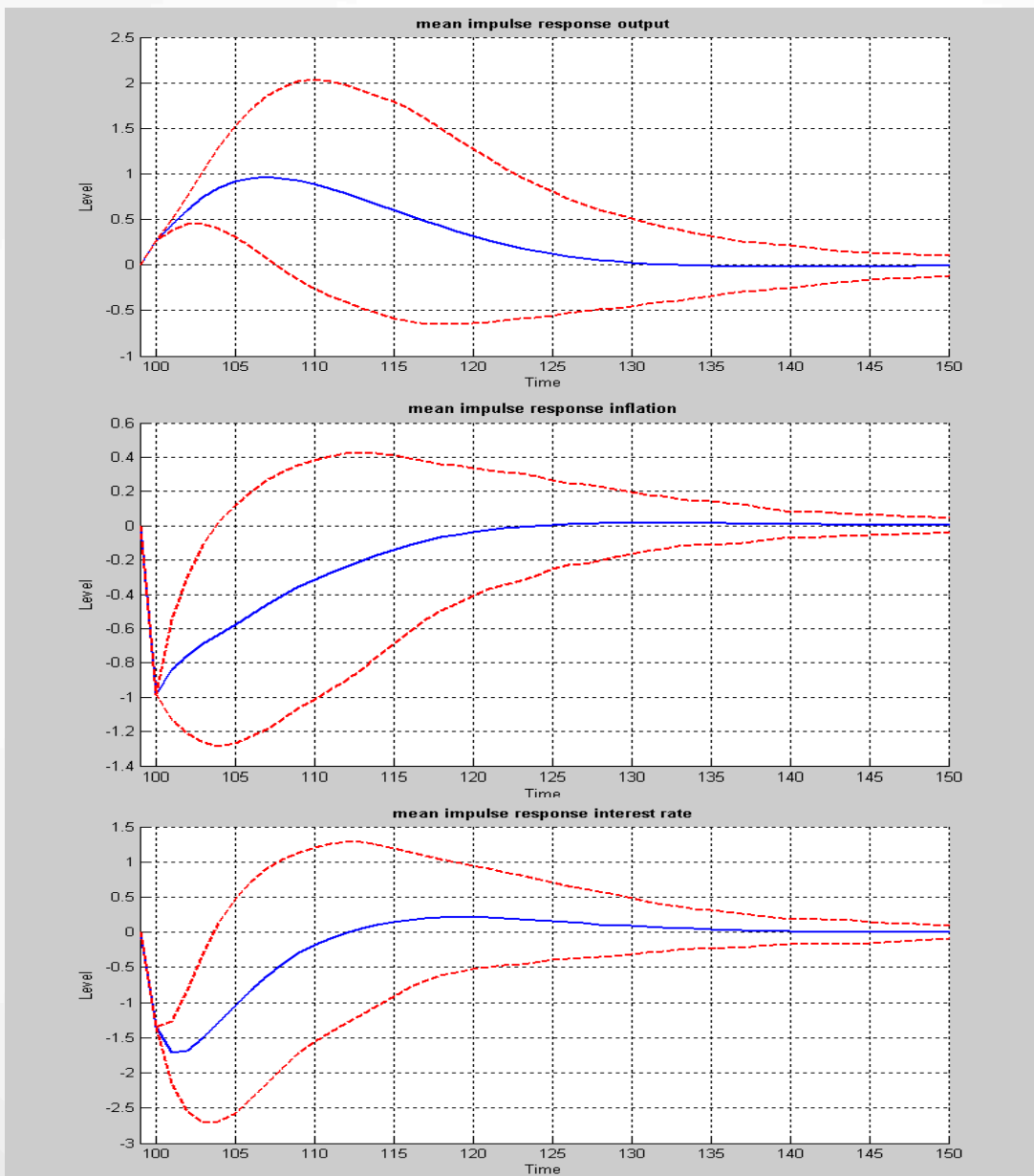
Impulse responses

- These describe the path of one of the endogenous variables (output gap, inflation) following the occurrence of the shock.
- In order to do so I simulate two series of these endogenous variables.
 - One is the series without the shock (the baseline series);
 - the other is the series with the shock.
 - I then subtract the first from the second one.
 - This yields the impulse response

- These impulse responses are expressed as “multipliers”, i.e. the output and inflation responses to the shock are divided by the shock itself (1 standard deviation)
- The behavioral model is non-linear. Therefore during the post-shock period I continue to allow for random disturbances.
- making sure that the random disturbances are the same for the series with and without the shock.

- The exercise was repeated 500 times with 500 different realizations of the random disturbances.
- The mean impulse response together with the standard deviation was then computed.

Impulse response to productivity shock

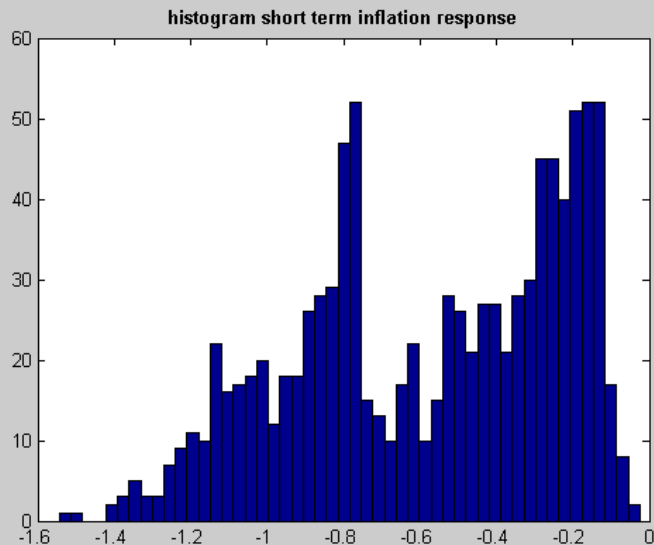
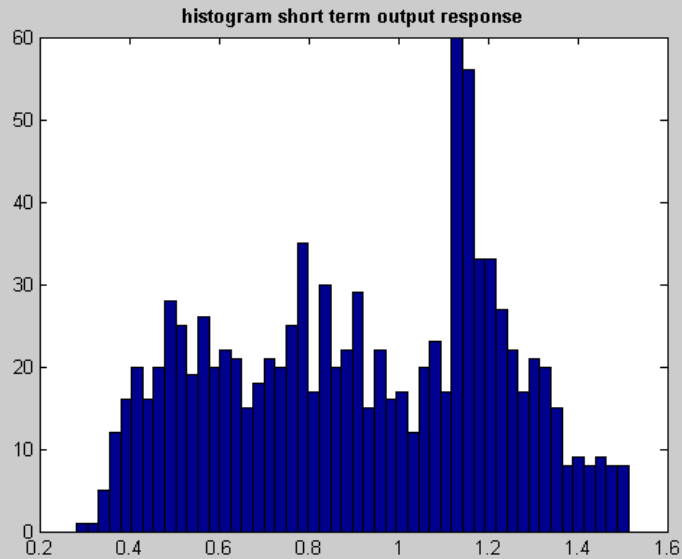


Results

- First, the positive productivity shock has the expected macroeconomic effects.
 - In the short-term the output gap increases and inflation declines.
 - the interest rate declines. This is so because the central bank follows a Taylor rule in which the weight attached to inflation is higher than the weight attached to the output gap (the coefficient of inflation is 1.5 while the coefficient of the output gap is 0.5).
 - As a result the decline in inflation leads the central bank to lower the interest rate so as to bring inflation back to its target.

- Third, and most importantly, there is a wide variation in the short-term effects of the productivity shock.
- This can be seen from the fact that dotted lines representing + and – two standard deviations from the mean are very far from the mean.
- Thus it is very difficult to predict how the same productivity shock affects the output gap and inflation in the short-run.
- This uncertainty can also be illustrated by presenting the frequency distribution of the short-term output gap and inflation effects of the productivity shock.

Frequency distribution of short-term output and inflation effect of productivity shock



statistical distribution of short-term effects is far from the normal distribution and exhibits fat tails.

the same productivity shock can lead to strong outlying effects.

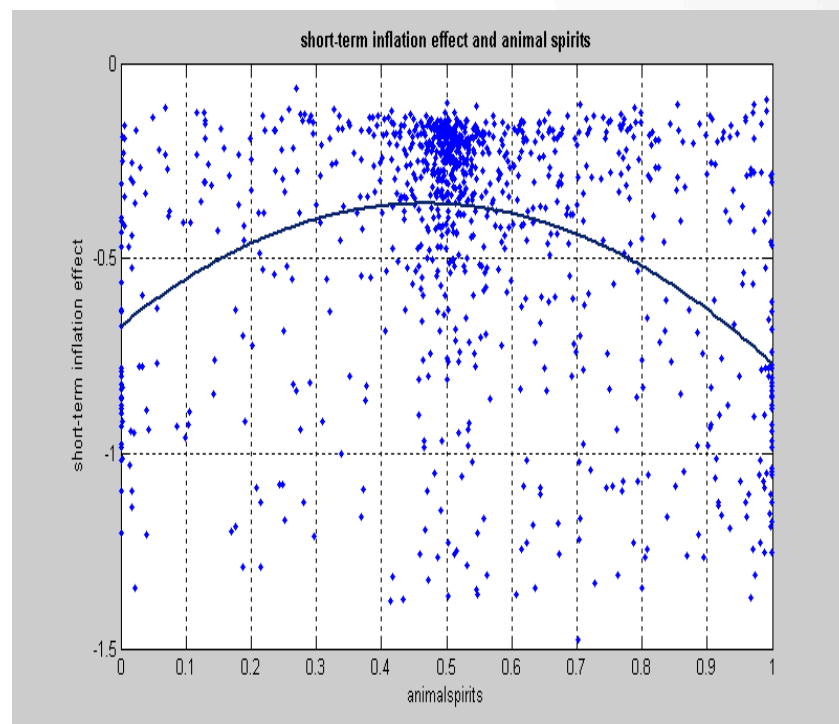
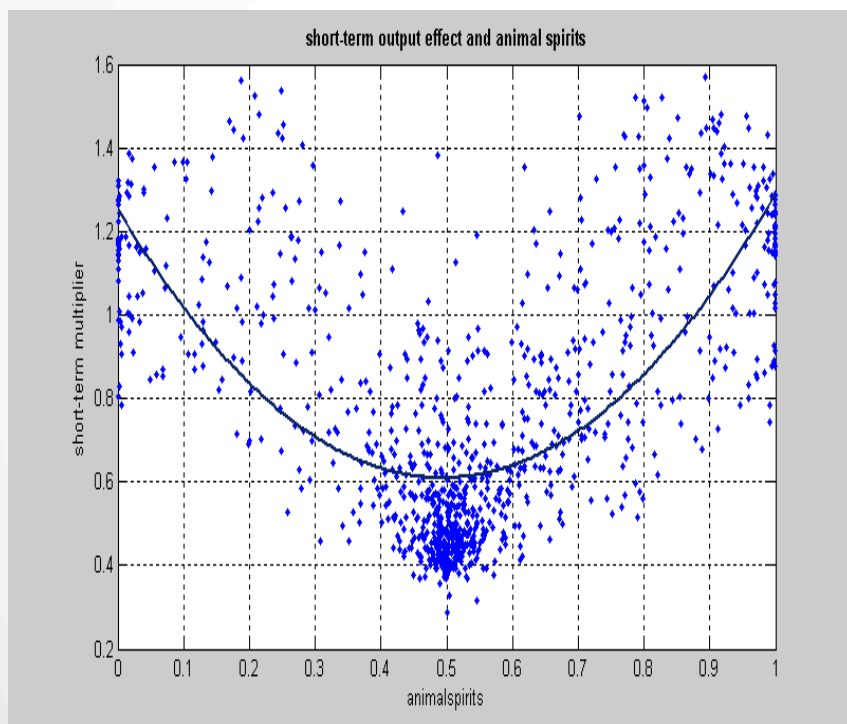
The non-normal distribution of the short-term effects adds to the unpredictability of these effects.

Thus, the transmission of the shock is shrouded by the veil of uncertainty (in the sense of Frank Knight).

See also Caballero: pretense of excessive precision of knowledge

Importance of “market sentiments”

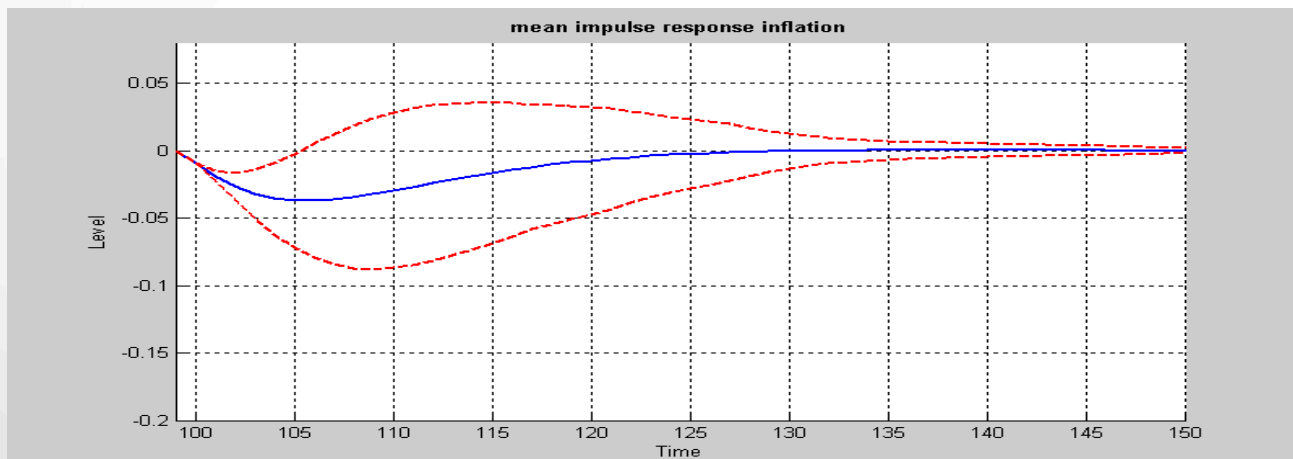
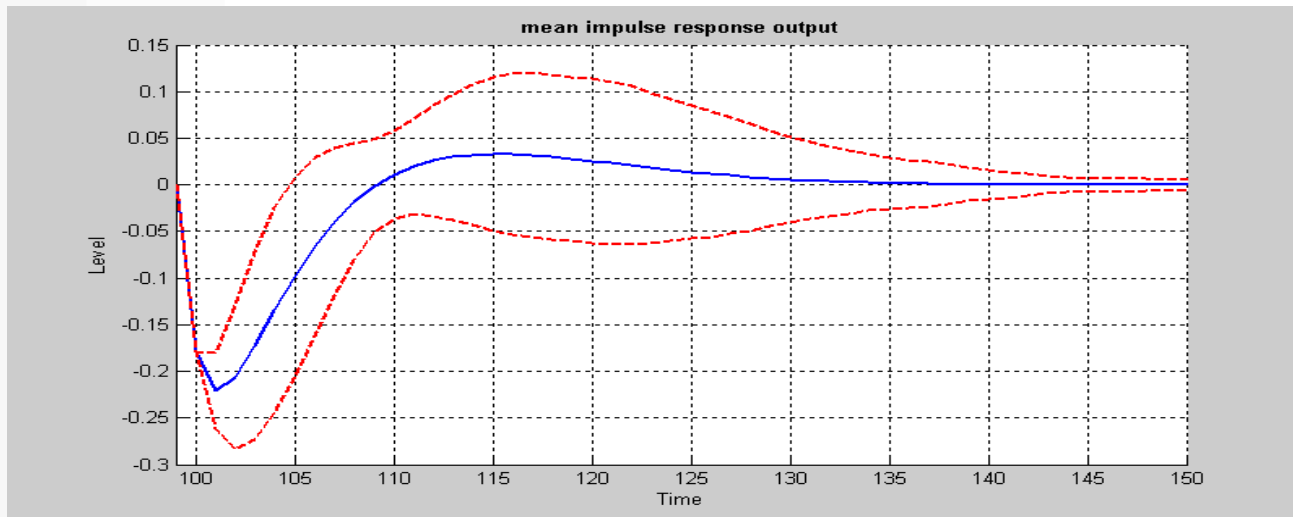
Effects of productivity shock depend on market sentiments



- There is amplification effect

Same uncertainty with effects of interest rate shocks

Impulse response to positive interest rate shock



Frequency distribution of short-term effects interest rate shock

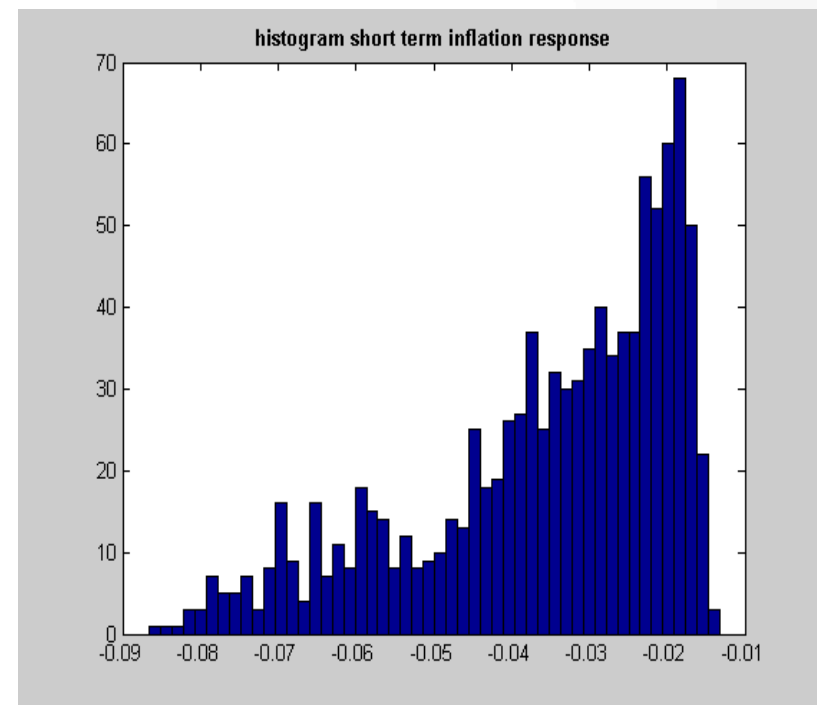
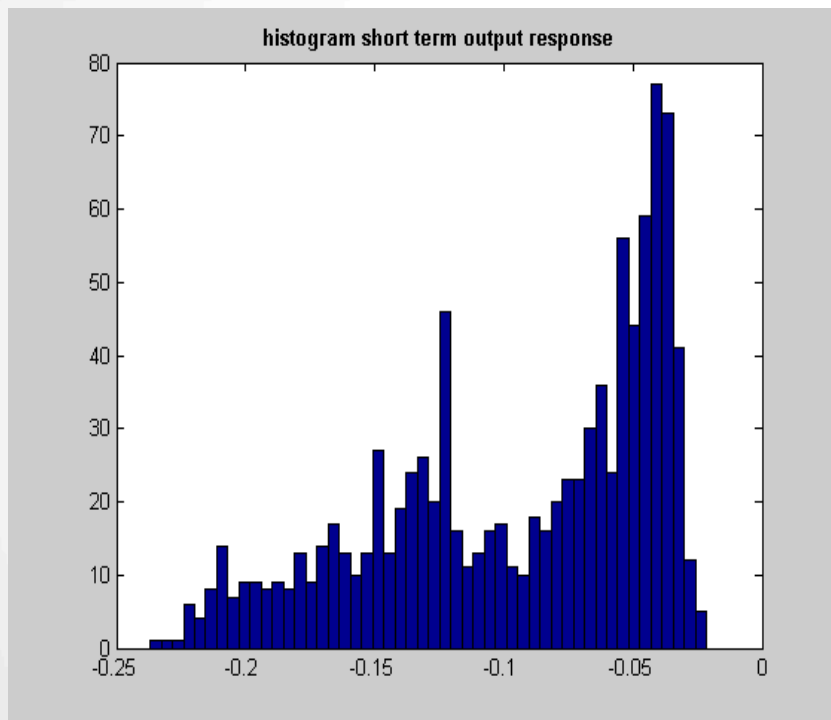
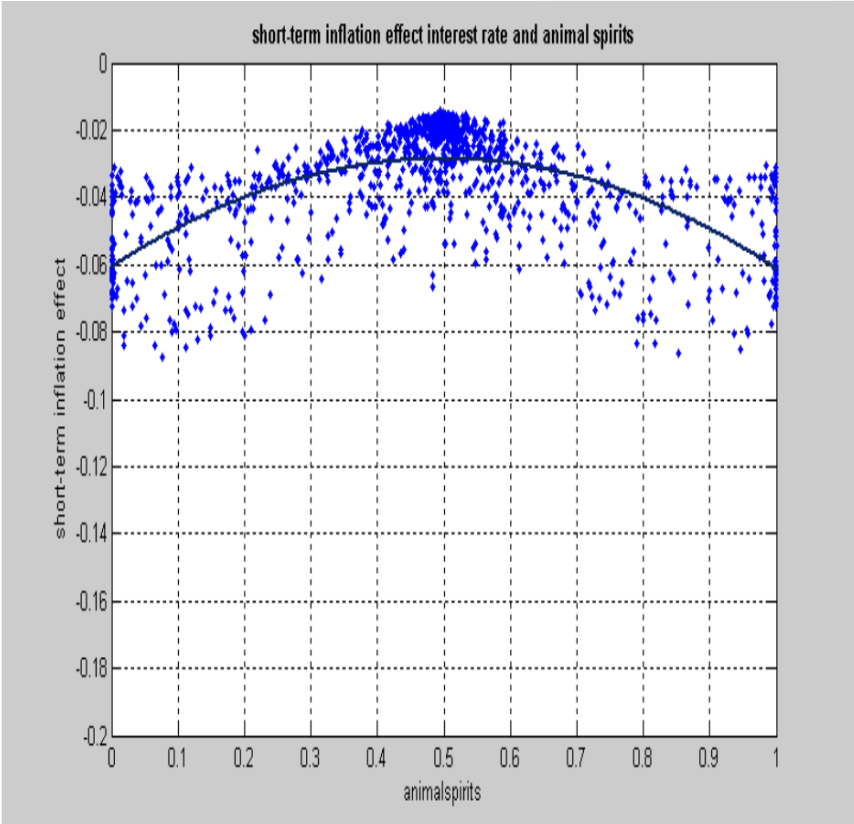
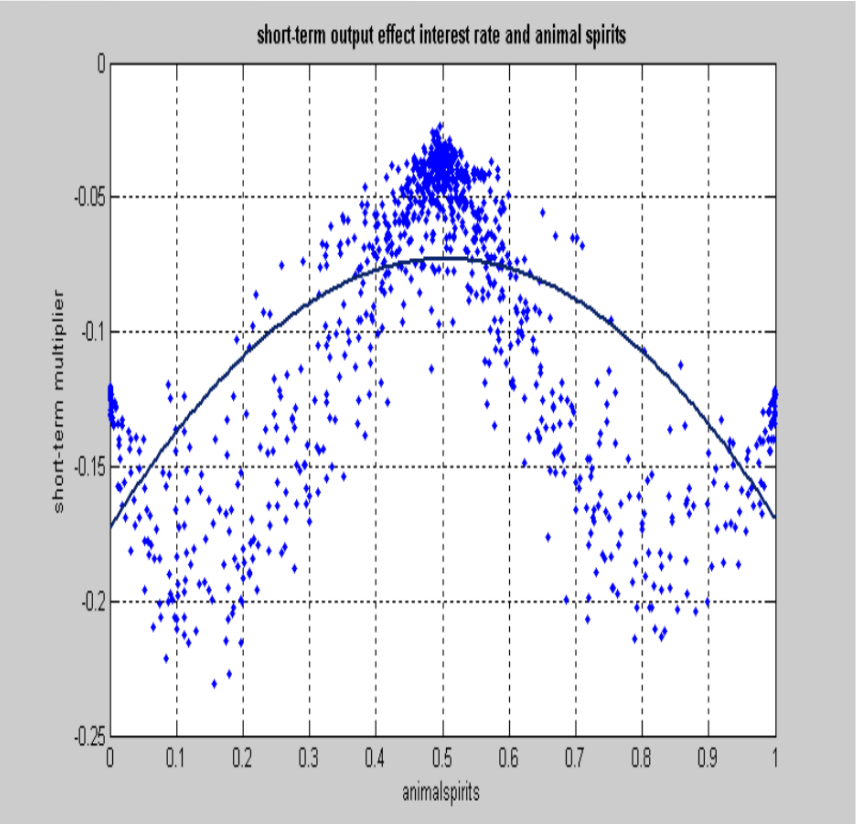


Figure 4.6: Effects of monetary policy depend on market sentiments



Interpretation

- Animal spirits have a strong impact on the short-term output effect of the same interest rate shock.
- In general, the stronger the animal spirits the greater is the short-term impact of the interest rate shock on output.
- When animal spirits are weak (the index is close to 0.5) the impact is weakest.
- Thus, when the market is dominated by either optimism or pessimism, the monetary authorities' interest rate instrument has the greatest impact on output (in the short run).
- Like in the case of a productivity shock animal spirits tend to amplify the short-term effects of monetary policies. These effects, however, tend to disappear in the long run.

The nature of the uncertainty in the two models is very different.

- In the top down structure of the rational expectations models, agents capable of overseeing the whole picture, compute with great precision how these shocks are transmitted.
 - The question that arises here is whether the precision obtained in this model does not create an illusion among the practitioners of these models about what one can know in economics.

Contrast with behavioral model:

- Agents with limited and heterogeneous information, follow rules of behaviour that when interacting with other rules
 - lead to great complexity
 - and a great amount of uncertainty about how shocks are transmitted.
- Even if one knows the parameters of the model with certainty, it will not be possible to predict how a given shock applied at a particular time will be transmitted in the economy.

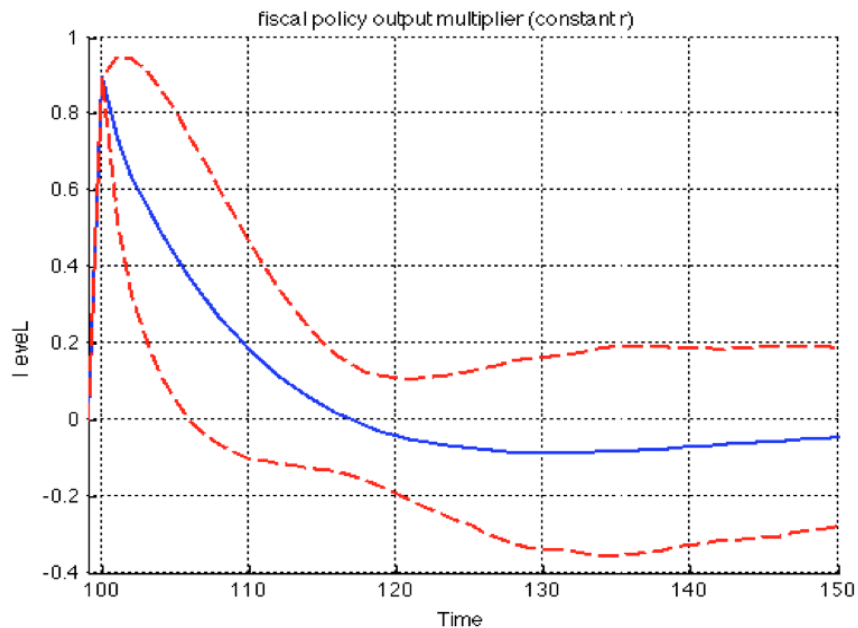
Some fiscal policy experiments

- Since eruption of the financial crisis governments have applied massive policies of fiscal stimulus.
- This has led to heated debate about the size of the fiscal policy multipliers.
- and has revealed how divergent economists' views are about the size of these multipliers (see Wieland, et al. (2009)).

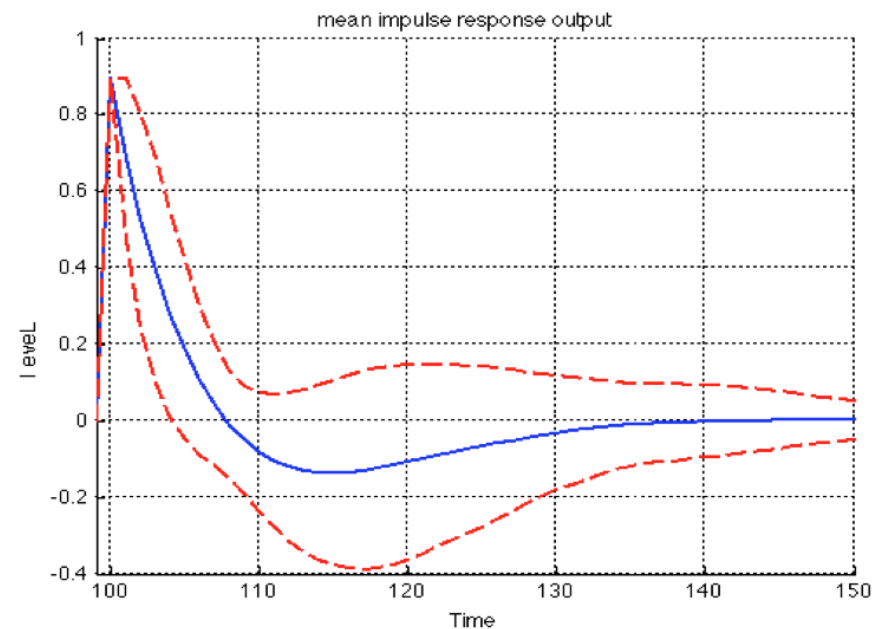
- Many reasons for this divergence
- Here I focus on only one of them
- I model fiscal policy as a positive shock in aggregate demand
- Assuming two different monetary policy regimes
 - Variable interest rate
 - Fixed interest rate

Impulse response to 1 s.d fiscal policy shock (extra spending)

Constant interest rate



Variable interest rate



Interpretation

- Large differences in effects of same fiscal policy shocks
- These effects of fiscal policy depend on animal spirits
- Differences are even more pronounced in fixed rate regime
- This is regime corresponding to present situation of liquidity trap (zero bound)
 - Since central bank in this regime is keeping interest rate constant, fewer constraints on animal spirits exist