INFLATION TARGETS AND THE ZLB IN A BEHAVIORAL MODEL

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Introduction

- An inflation target too close to zero risks pushing the economy into a negative inflation territory even when mild shocks occur.
- Such an outcome is generally considered to be dangerous.

- During periods of deflation the nominal interest rate is likely to hit the lower zero bound.
- When this happens the real interest rate cannot decline further.
- The central bank loses its capacity to stimulate the economy in a recession, thereby risking prolonged recessions (Eggertson and Woodford(2003), Blanchard, et al. (2010), Ball(2014)).

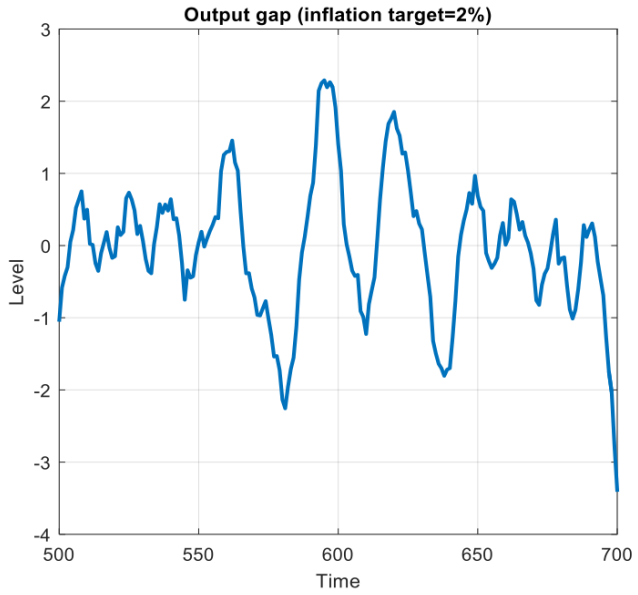
- This has led to proposals to increase the level of the inflation target (e.g. Blanchard, et al. (2010), Ball(2014))
- Purpose of this research:
  - Revisiting the issue of the optimal level of the inflation target
  - when nominal interest rate is subject to zero lower bound
  - using a behavioral macroeconomic model

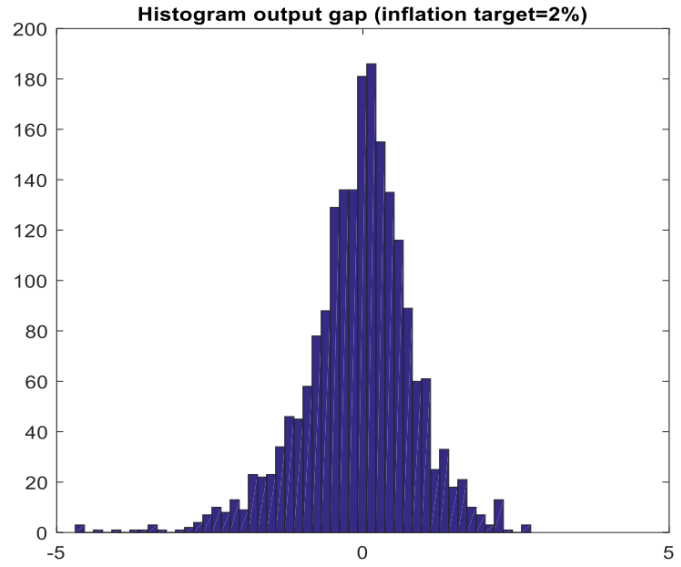
- Standard linear DSGE models have tended to underestimate the probability of hitting the ZLB as was shown by Chung, et al., (2012).
- Most of these models have led to the prediction that when the central bank keeps an inflation target of 2%, it is very unlikely for the economy to be pushed into the ZLB._ (Coenen(2003), Schmitt-Grohe and Uribe(2007)).

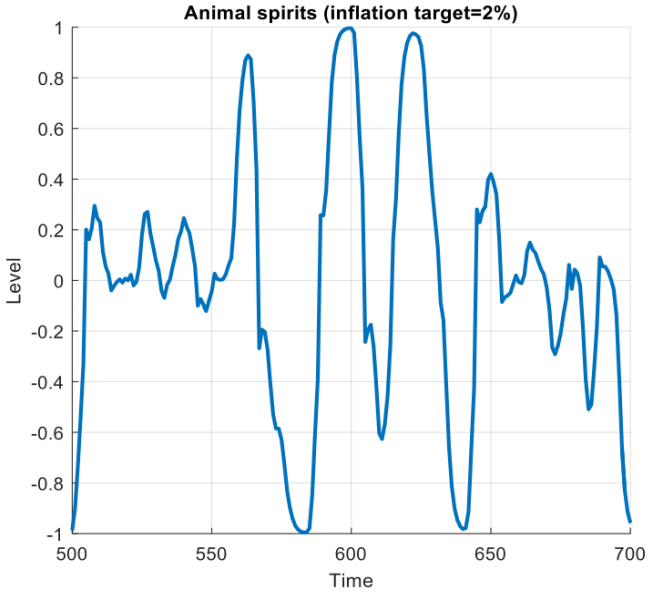
- We use same behavioral macroeconomic model to shed new light on the nature of this risk.
- We now add:

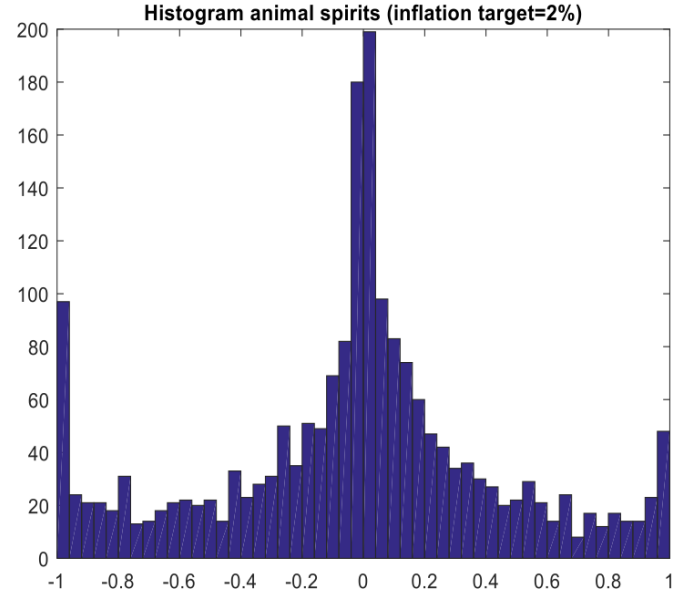
$$r_t \geq 0$$

Figure 1: Output gap and animal spirits in time and frequency domains (Inflation target = 2%)







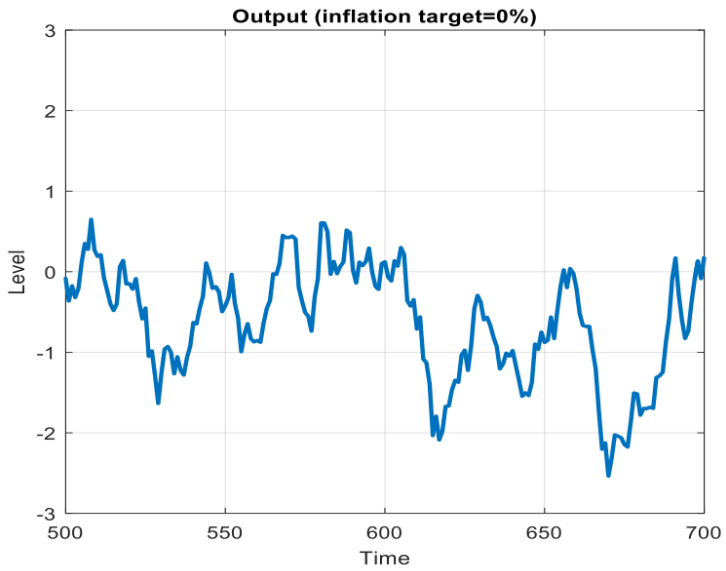


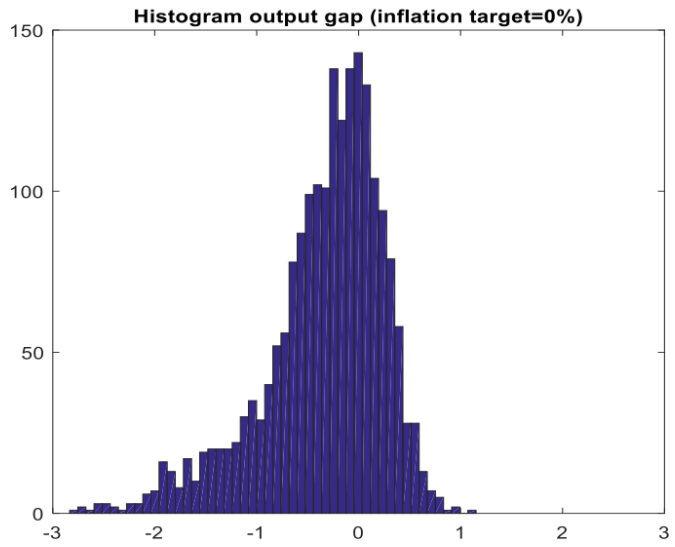
Implications: non-normality

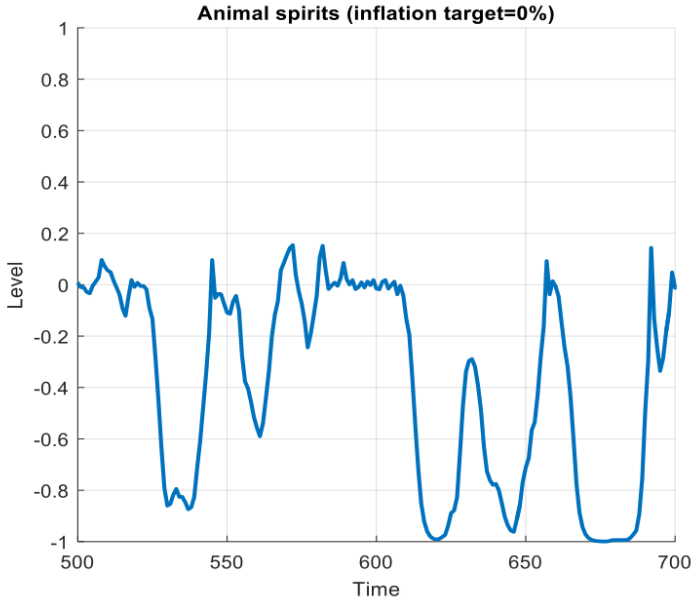
- Model produces non-normally distributed output gaps
  - Excess kurtosis
  - Fat tails
- These are produced by animal spirits
  - Most of the time: great moderation; market sentiments neutral
  - Regularly and unpredictably there is strong optimism (pessimism) that in self-fulfilling way creates boom (bust)
  - Two way causality output gap-animal spirits

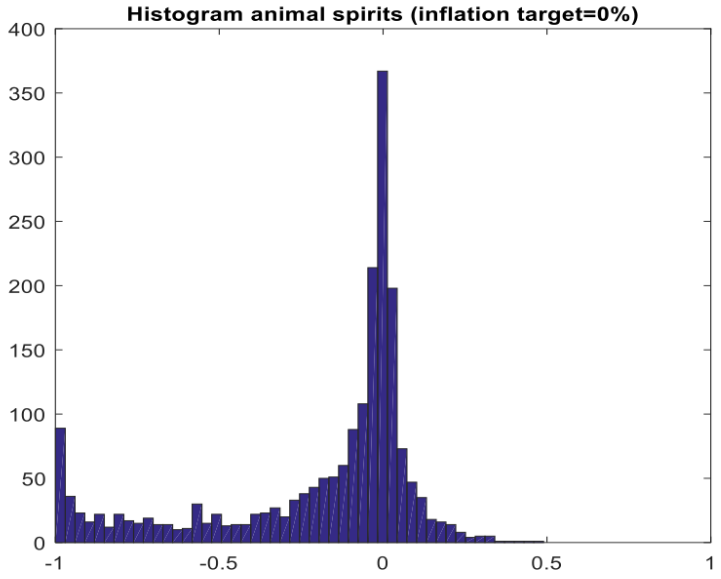
- How are these results are affected by the level of the inflation target?
- We start by noting that the output gap in Figure 1 is slightly skewed to the left. (skewness = -0.66).
- This skewness finds its origin in the fact that the distribution of animal spirits is also skewed to the left, i.e. there are more periods of pessimism than optimism.

Figure 2: Output gap and animal spirits in time and frequency domains (Inflation target = 0%)





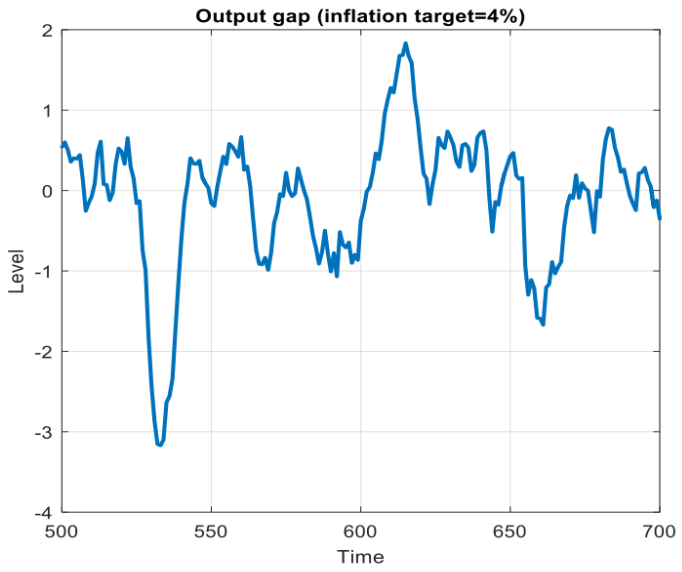


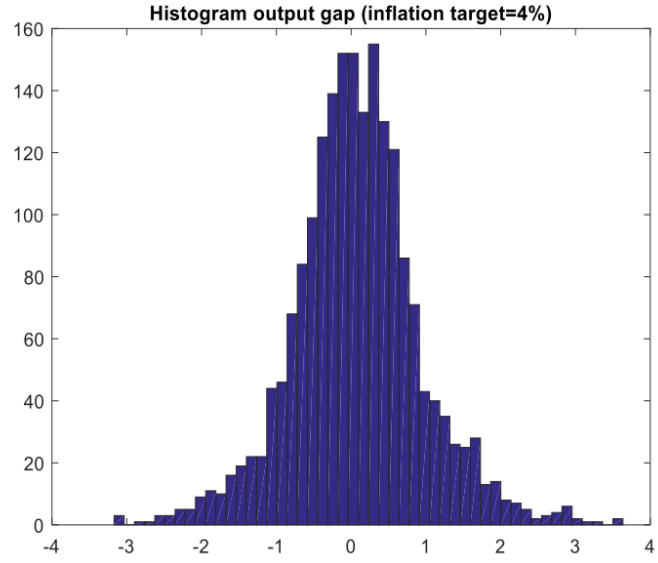


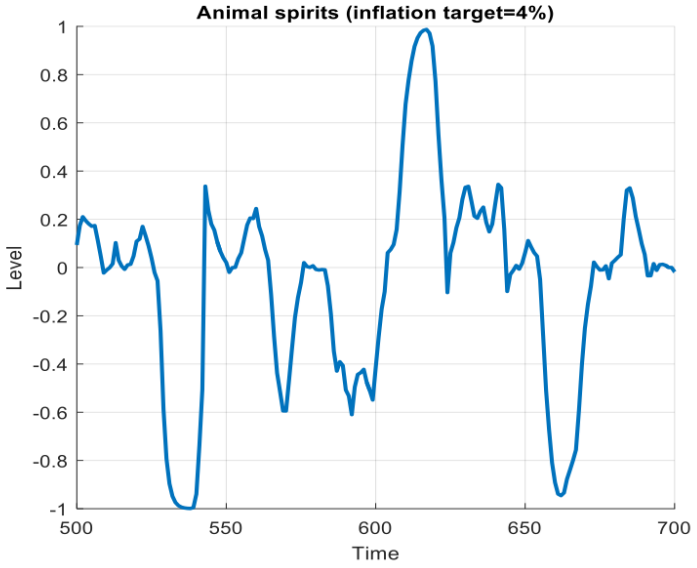
Inflation target =0%

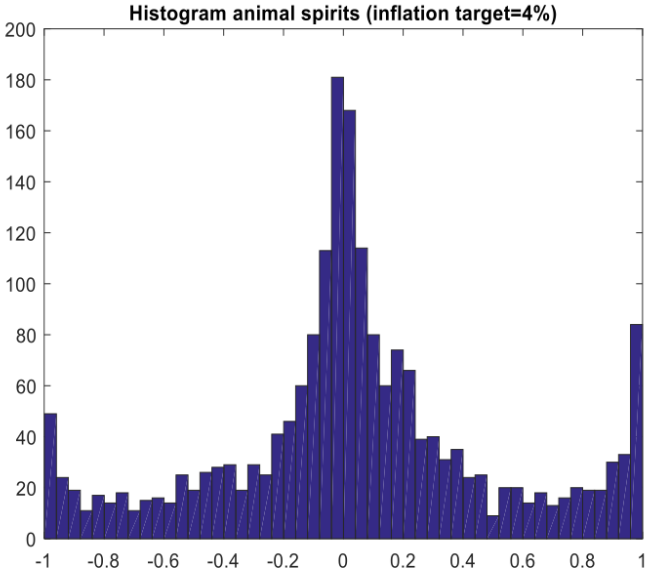
- Most of the time animal spirits are negative with many periods of extreme pessimism.
- Thus when the central bank sets an inflation target equal to zero pessimism prevails most of the time
- and recession is a chronic feature of the business cycle with very few periods of optimism and optimism.

Figure 3: Output gap and animal spirits in time and frequency domains (Inflation target = 4%)









Inflation target = 4%

- the distribution output gap and animal spirits is symmetric.
- Skewness of output gap is not statistically different from 0 and animal spirits are 0 on average.
- Periods of optimism and pessimism occur equally frequently.

Sensitivity analysis

Figure 4:

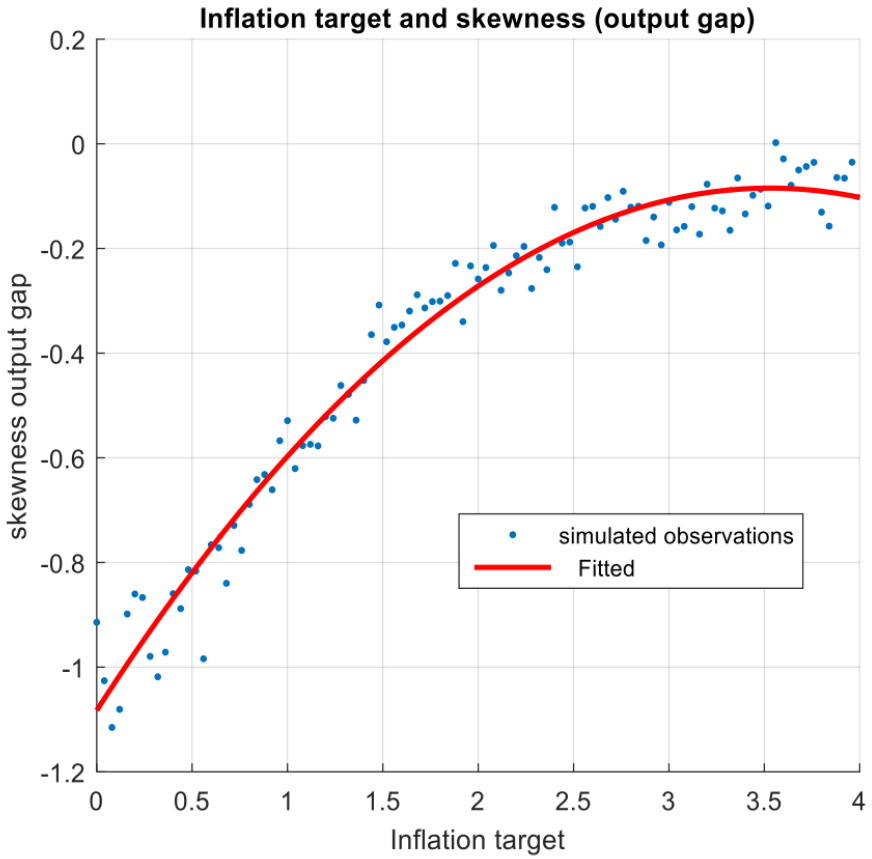
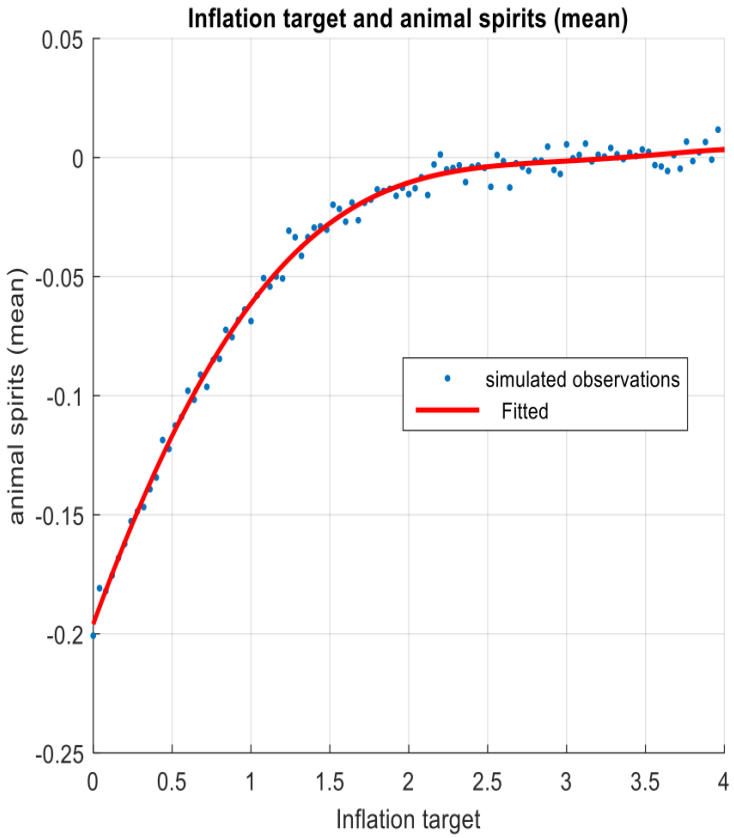


Figure 5


Inflation target and animal spirits (mean)
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
animal spirits (mean)
0
0.5
1
1.5
2
2.5
3
3.5
4
Inflation target
simulated observations
Fitted

Interpretation

- When inflation target is 0% cyclical movements in output gap and animal spirits lead to recessions that drive inflation into negative territory.
- When that happens the zero bound constraint makes it impossible for the central bank to lower the real interest rate.

Chronic pessimism

- If the recession is deep and deflation intense the real interest rate is likely to increase significantly.
- Thus the recession becomes protracted.
- Pessimism sets in and amplifies the recession, deflation and validates pessimism.
- As the central bank loses its stabilizing capacity the economy gets stuck in pessimism, recession and deflation.

- We conclude that an inflation target of 0% becomes a breeding ground for pessimism and recession.
- The way out is to increase the inflation target.
- Such an increase pulls the economy out of the chronic pessimism trap.

- Our results suggest that an inflation target of 3%-4% is probably better than 2% in making sure that the economy does not get stuck in the chronic pessimism trap.

Optimal monetary policies and LZB

- We construct tradeoffs between inflation and output variability

Figure 6: Output variability and Taylor output parameter

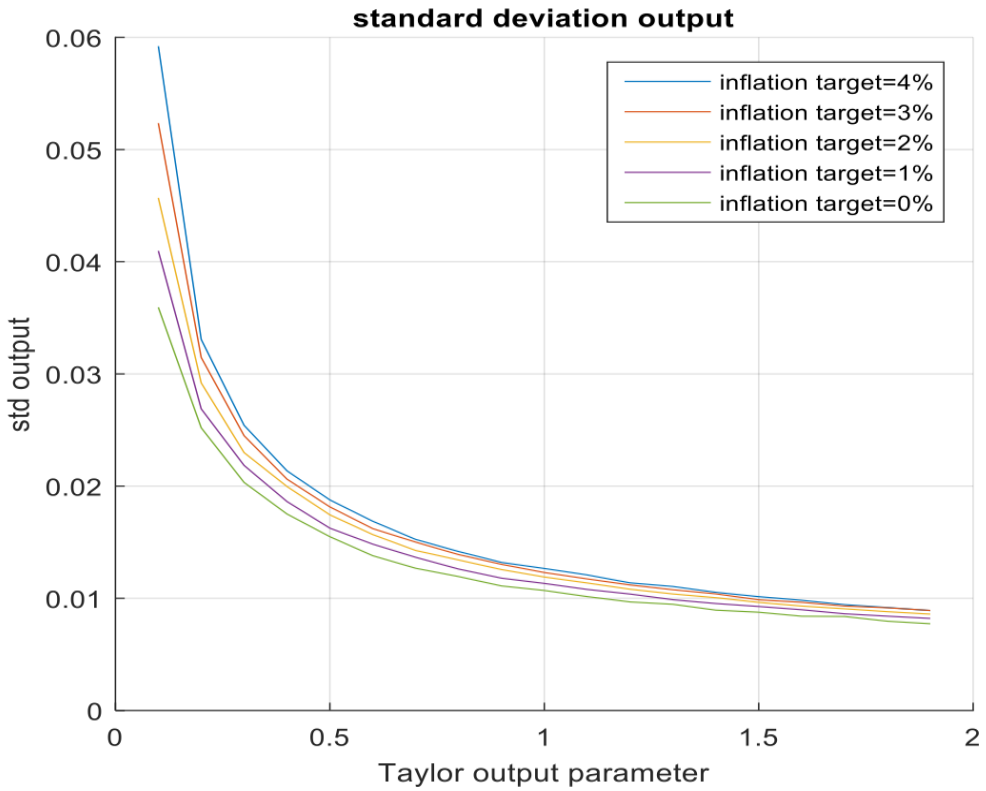
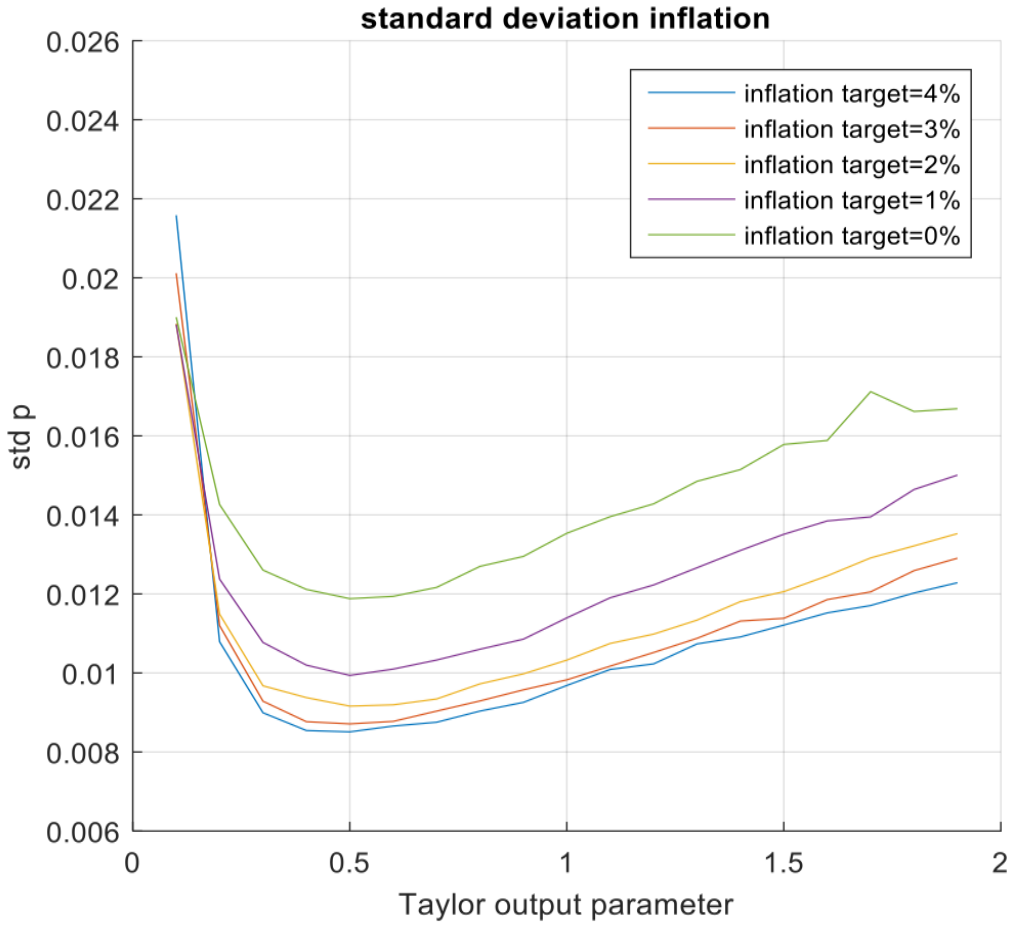
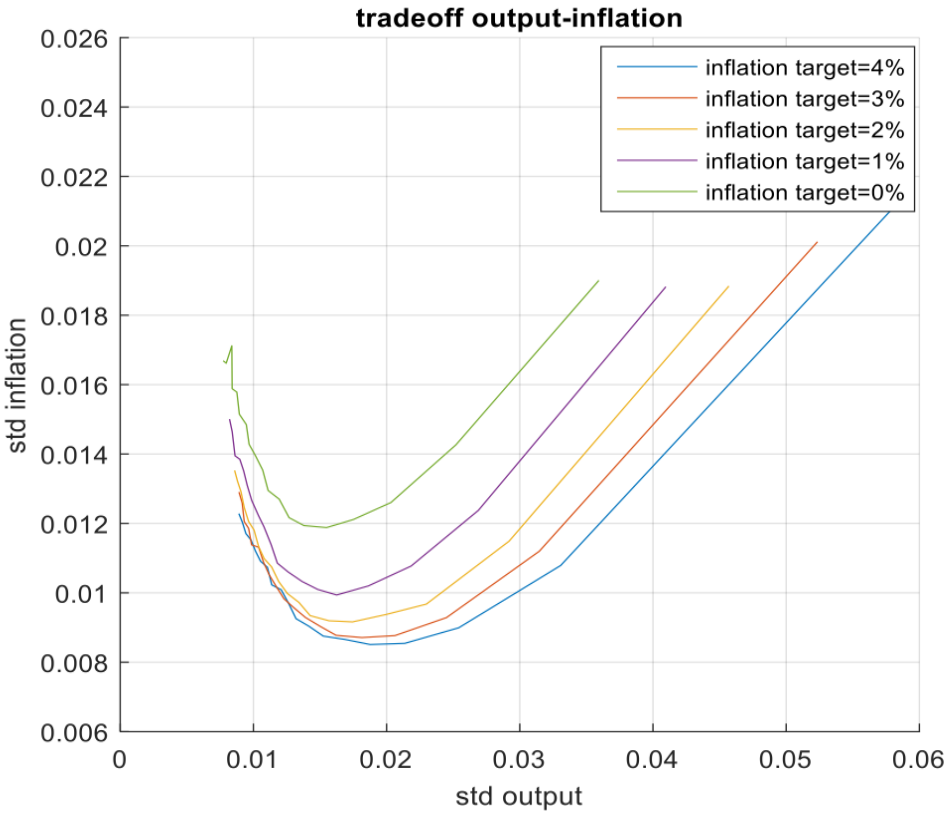


Figure 7: Inflation variability and Taylor output parameter



- There is a range of Taylor output parameter (from 0 to 0.5) that leads to decline in both inflation and output variability
- By stabilizing output the central bank also reduces the amplitude of the waves of optimism and pessimism (animal spirits) thereby stabilizing not only output but also inflation.

Figure 8


tradeoff output-inflation
inflation target=4%
inflation target=3%
inflation target=2%
inflation target=1%
inflation target=0%
std inflation
std output
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0
0.01
0.02
0.03
0.04
0.05
0.06

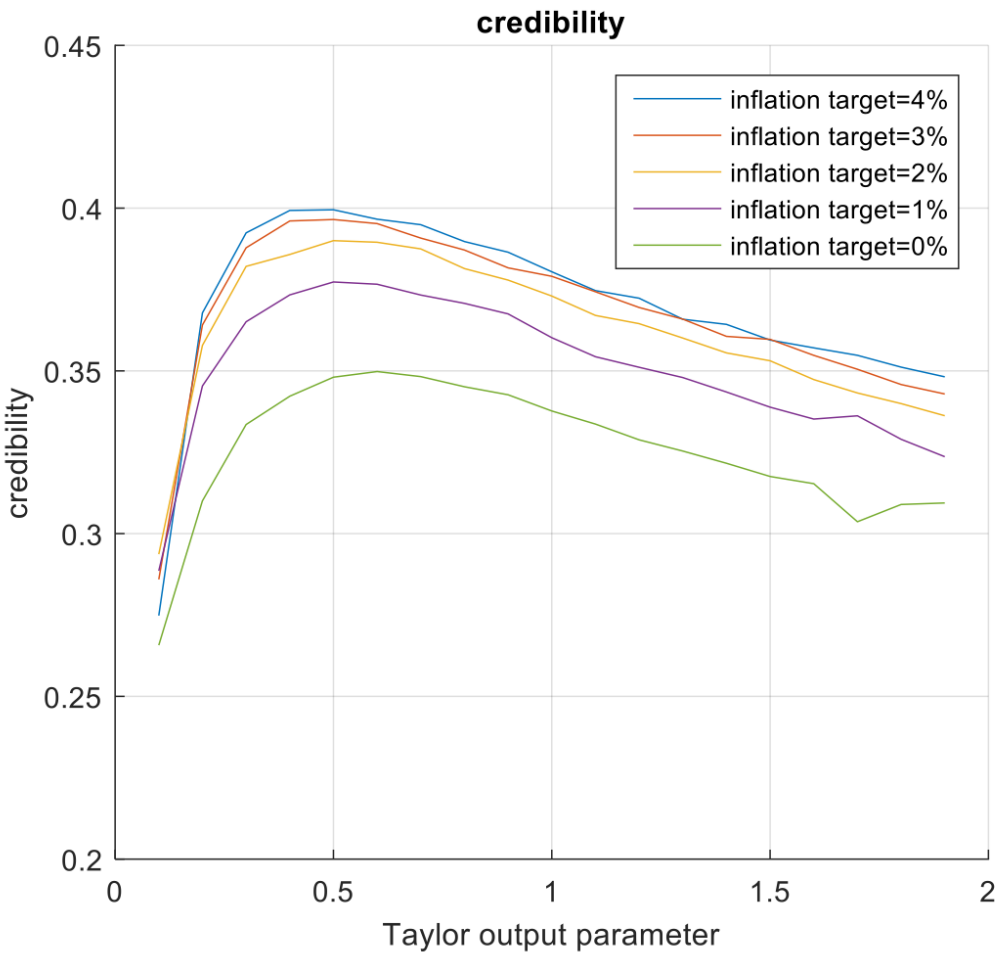
Interpretation

- When the inflation target increases from 0% to 4% the tradeoff shifts downwards, i.e. the central bank improves the tradeoff by raising the inflation target.
- These improvements become smaller as the inflation target is raised.
- Going beyond 4% does not improve the tradeoff in a significant way anymore.

Credibility of inflation target and ZLB

- Model allows to define credibility in very precise way
- i.e. as the fraction of agents using the announced inflation target as their forecast for inflation

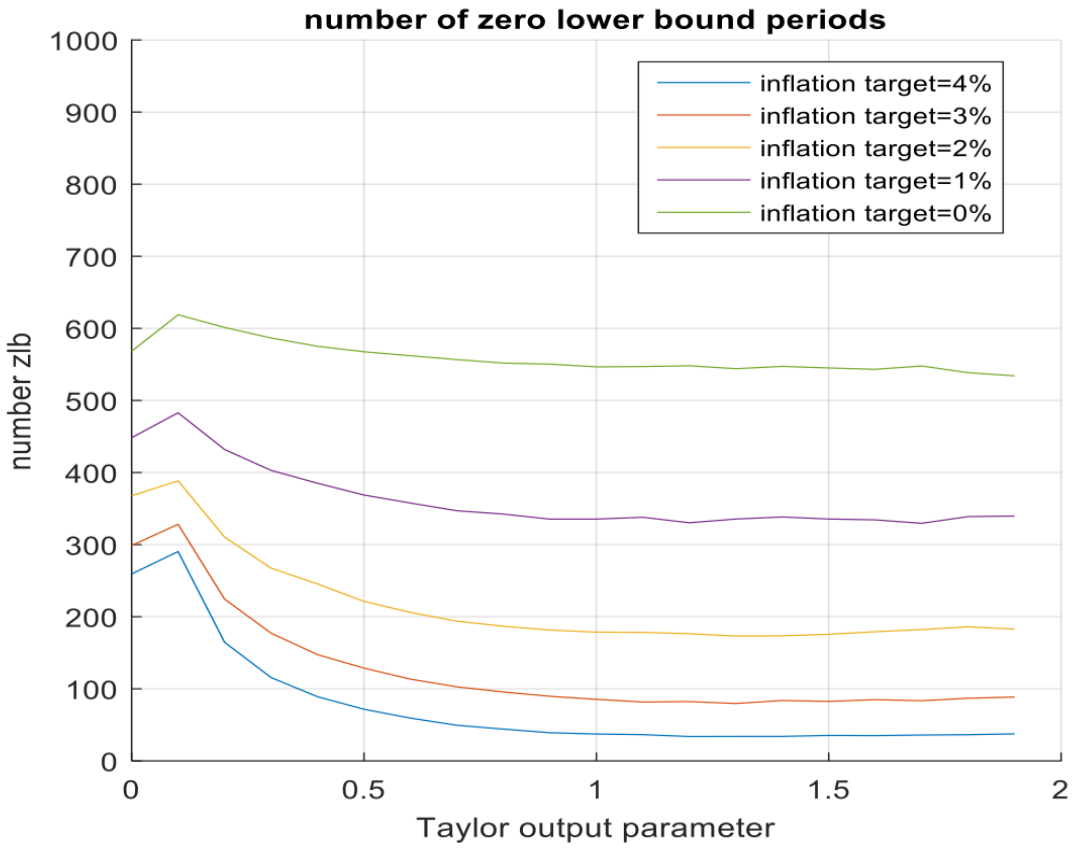
Figure 9: Credibility and inflation targets



Interpretation

- when the central bank increases its stabilization efforts, this has at first a positive effect on the credibility of its inflation target.
- This increases its inflation credibility.
- This positive effect on credibility disappears when the Taylor output parameter reaches 0.5.
- It can be seen that there is a relation between the tradeoff and credibility.

Figure 10: Number of ZLB periods, stabilization and inflation targets

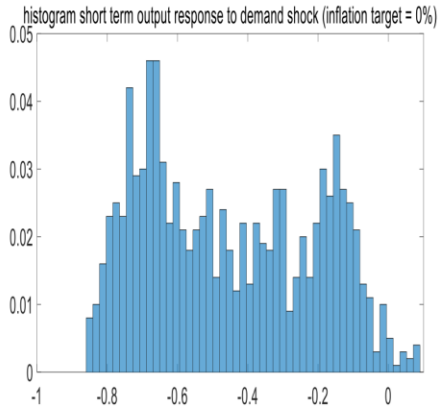


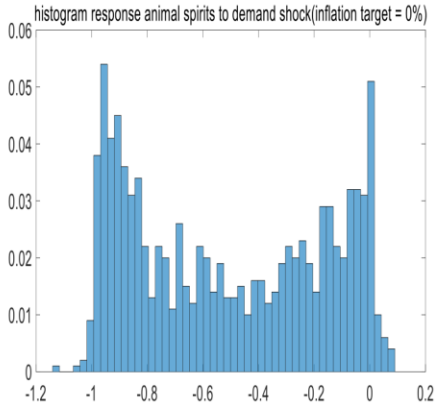
Responses to demand and supply shocks

- We analyse the impulse responses to demand and supply shocks
- We concentrate on the short-term effects (after 4 periods)
- And represent these in frequency domain

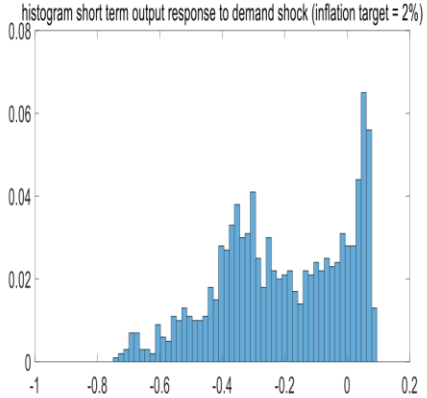
Output responses **Responses animal spirits**

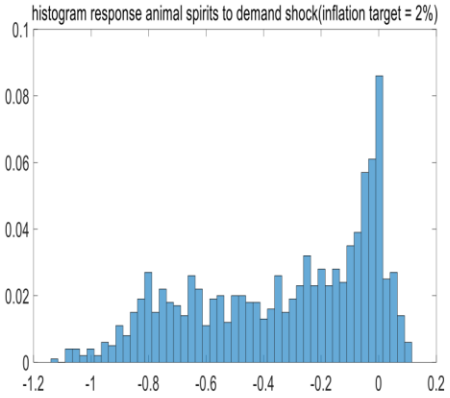
Inflation target=0%



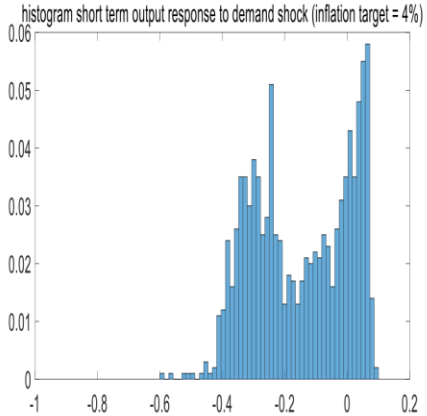


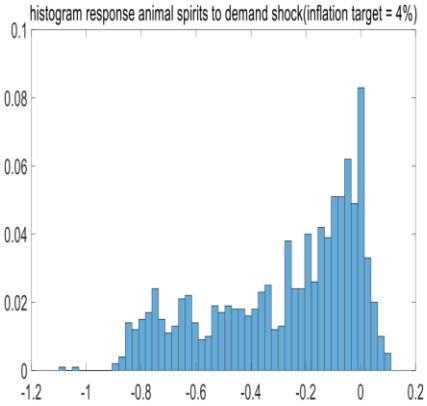
Inflation target=2%





Inflation target=4%

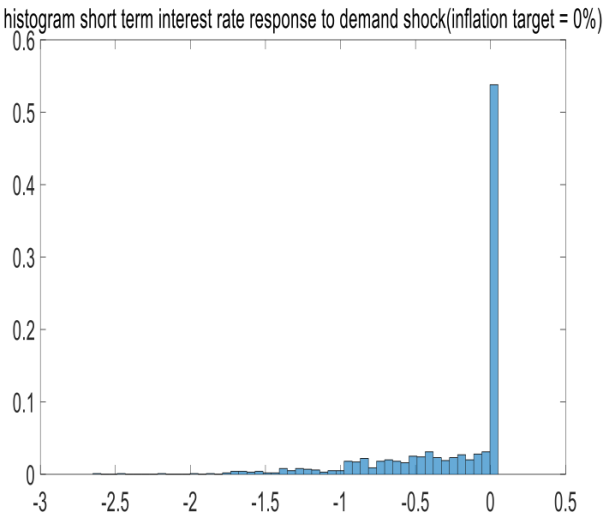




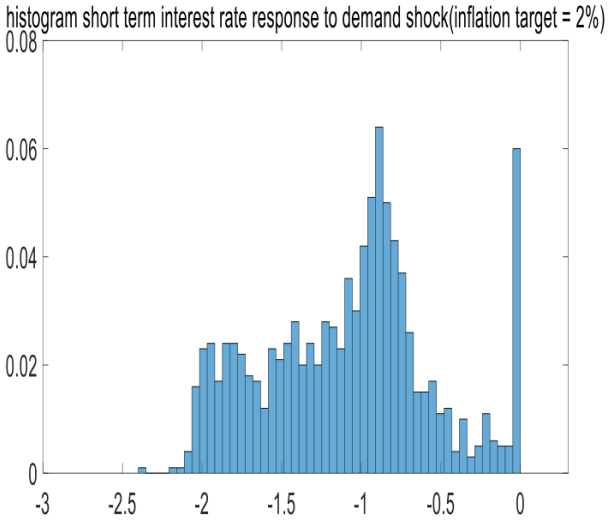
- The most striking result is the fact that when the inflation target *increases* the negative impact on output following a negative demand shock *declines* significantly, *on average*.
- The short-term responses in animal spirits are on average more negative with a low inflation target than with a high one.

- But as mentioned earlier, there is a wide variation in the short-term effect of the same demand shock on output and animal spirits

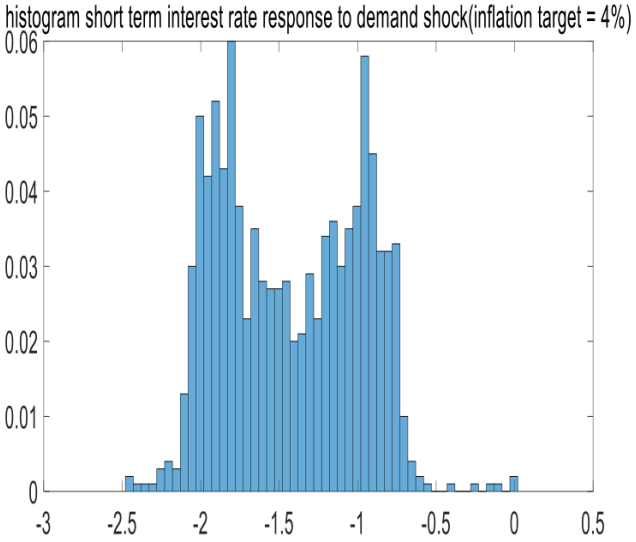
Inflation target = 0%



Inflation target = 2%



Inflation target = 4%



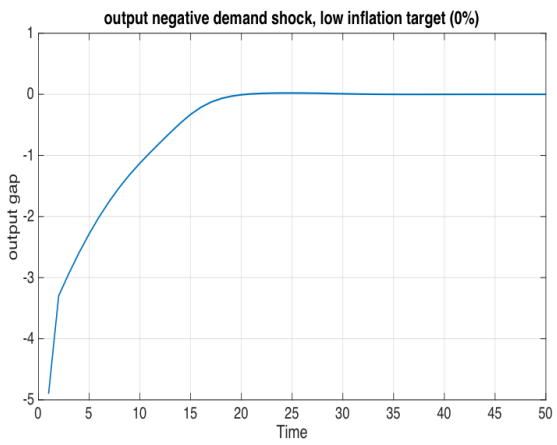
- When inflation target is zero, the negative demand shock leads the interest rate to hit the ZLB in more than half of the cases.
- When the inflation target increases to 2% we see that the number of times the interest rate is constrained by the ZLB is reduced significantly.
- It almost completely disappears when the inflation target is 4%.

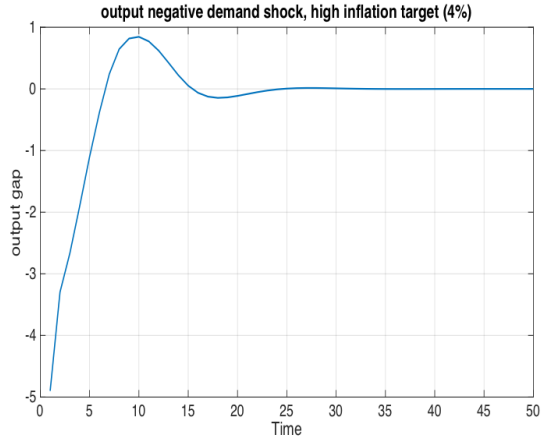
Analysis of the deterministic model

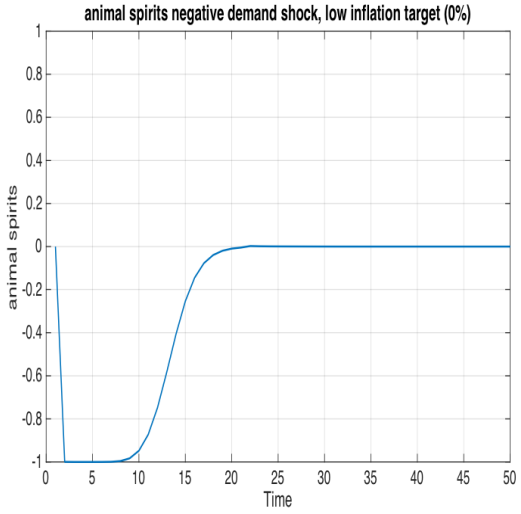
- We analyze the deterministic version of the model, i.e. we strip the model of all the stochastic shocks.
- This allows us to shed some light on the steady state characteristics of the model
- and the speed with which the variables return to their steady state values after an initial disturbance
- We assume an initial shock in demand

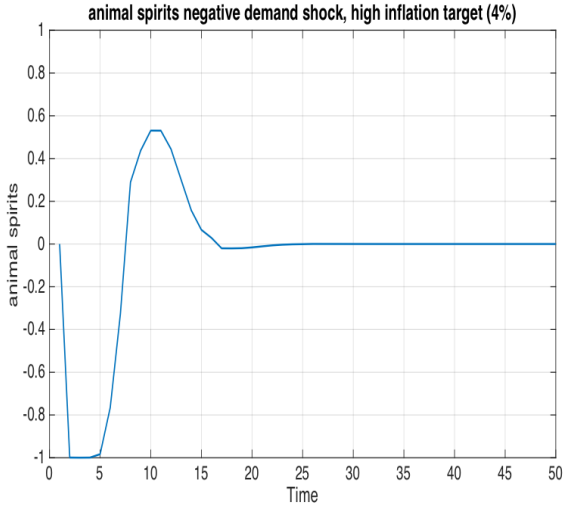
Initial negative shock in demand

Figure 12: Initial negative demand shock









Interpretation

- Negative demand shock has a significantly more protracted negative effect on the output gap in the low inflation target regime as compared to the high inflation target regime.
- In the low inflation target regime animal spirits are kept in negative territory longer than in the high inflation target regime.

- Thus, when the central bank sets a relatively high inflation target, the capacity of the system to lift itself out of the recession is stronger than when it sets a low inflation target.
- This is made possible by the stabilizing properties of monetary policies and by the ensuing elimination of self-fulfilling pessimism.

Conclusion

- The use of this behavioral model has allowed us to shed new light on the optimal level of the inflation target when a lower zero bound constraint on the nominal interest rate exists.
  - When inflation target is too close to zero, the economy can get gripped by "chronic pessimism"
  - that leads to a dominance of negative output gaps and recessions,
  - and in turn feeds back on expectations producing long waves of pessimism.

- Put differently, when the inflation target is set too close to zero the distribution of the output gap is skewed towards the negative territory.

- The question is what "too close to zero" means.
  - The simulations of our model, using parameter calibrations that are generally found in the literature, suggests that 2% is too low, i.e. produces negative skewness in the distribution of the output gap.
  - We find that an inflation target in the range of 3% to 4% comes closer to producing a symmetric distribution of the output gap.

- We also found that in the high inflation target regime the persistence of the recession is much shorter than in the low inflation target regime.
- i.e. when the central bank sets a relatively high inflation target, the capacity of the system to lift itself out of the recession is stronger than when it sets a low inflation target.

- All this leads to the conclusion that central banks should raise the inflation target from 2% to a range between 3% to 4% (see also Blanchard, et al. (2010) and Ball(2014) on this).

Extension to two countries

Introduction: Some facts II

- Let us look at some facts about international correlations of business cycles

Bilateral correlations business cycle components GDP growth

	Austria	Belgium	Finland	France	Germany	Greece	Ireland	Italy	Netherl	Portugal	Spain
Austria	1,00										
Belgium	0,97	1,00									
Finland	0,97	0,98	1,00								
France	0,93	0,95	0,97	1,00							
Germany	0,69	0,57	0,55	0,59	1,00						
Greece	0,73	0,82	0,84	0,74	0,09	1,00					
Ireland	0,85	0,89	0,92	0,95	0,41	0,81	1,00				
Italy	0,91	0,96	0,98	0,96	0,50	0,86	0,93	1,00			
Netherlands	0,93	0,94	0,93	0,91	0,60	0,75	0,86	0,90	1,00		
Portugal	0,98	0,89	0,89	0,87	0,37	0,82	0,87	0,90	0,94	1,00	
Spain	0,85	0,91	0,94	0,87	0,27	0,97	0,90	0,95	0,86	0,90	1,00

Bilateral correlations business cycle components GDP growth

ustralia	Canada	Czech	Denmark	Hungary	Japan	Korea	Norway	Poland	Sweden	Switzerland	UK	US
1,00												
0,81	1,00											
0,41	0,24	1,00										
0,84	0,90	0,61	1,00									
0,83	0,79	0,67	0,88	1,00								
0,48	0,60	0,63	0,71	0,69	1,00							
0,63	0,75	0,48	0,76	0,81	0,54	1,00						
0,85	0,87	0,56	0,95	0,87	0,66	0,69	1,00					
0,07	-0,09	0,50	0,20	-0,04	0,01	-0,06	0,14	1,00				
0,80	0,87	0,62	0,96	0,86	0,80	0,78	0,87	0,21	1,00			
0,22	0,29	0,67	0,57	0,29	0,47	0,27	0,51	0,75	0,55	1,00		
0,88	0,91	0,52	0,93	0,95	0,73	0,80	0,92	-0,10	0,90	0,30	1,00	
0,87	0,96	0,33	0,93	0,83	0,64	0,67	0,92	-0,04	0,88	0,30	0,93	1,00

Figure 1: Business cycle components of GDP growth

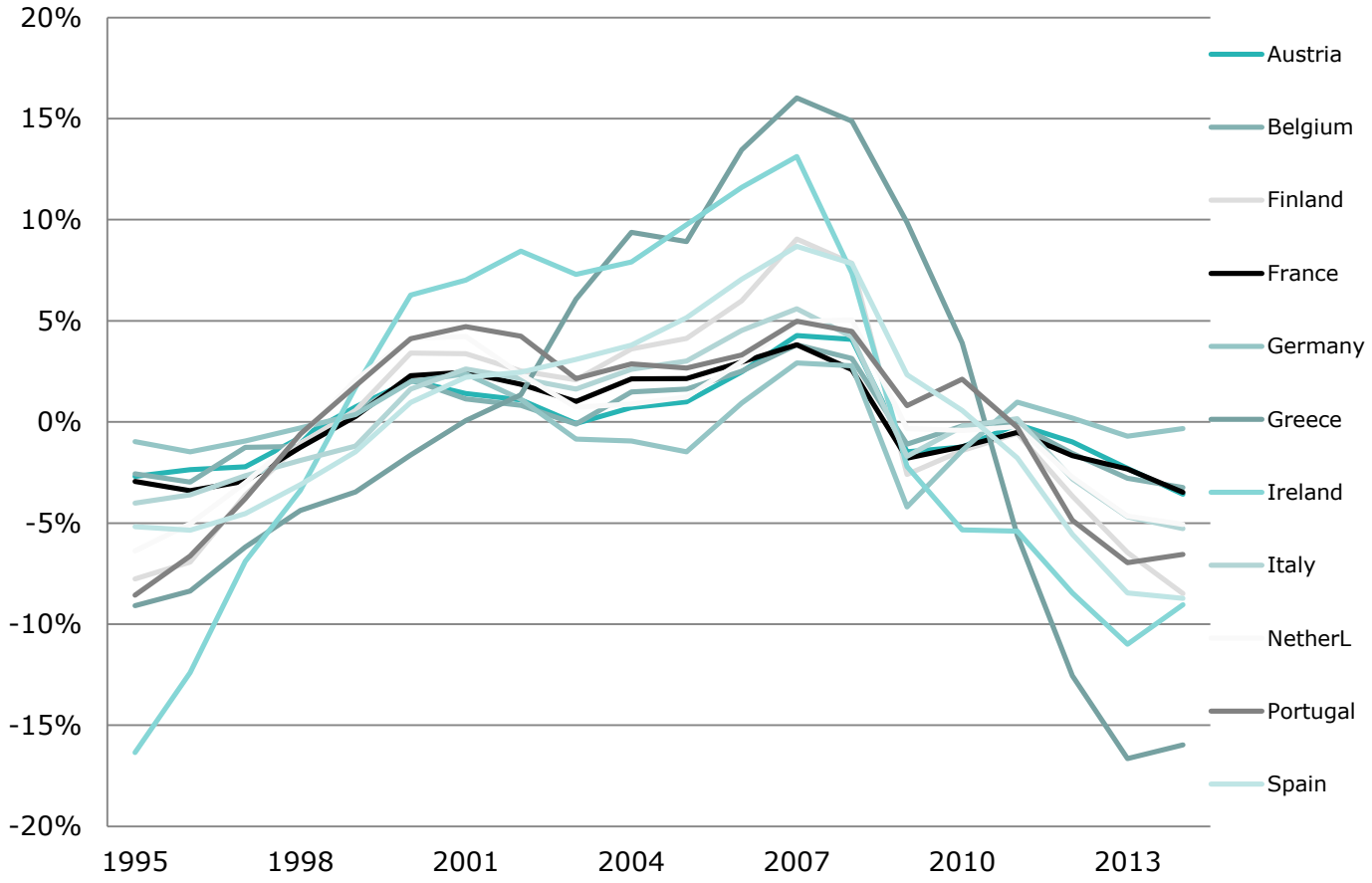


Figure 2: Correlation of business cycle and trade links in 11 Eurozone countries

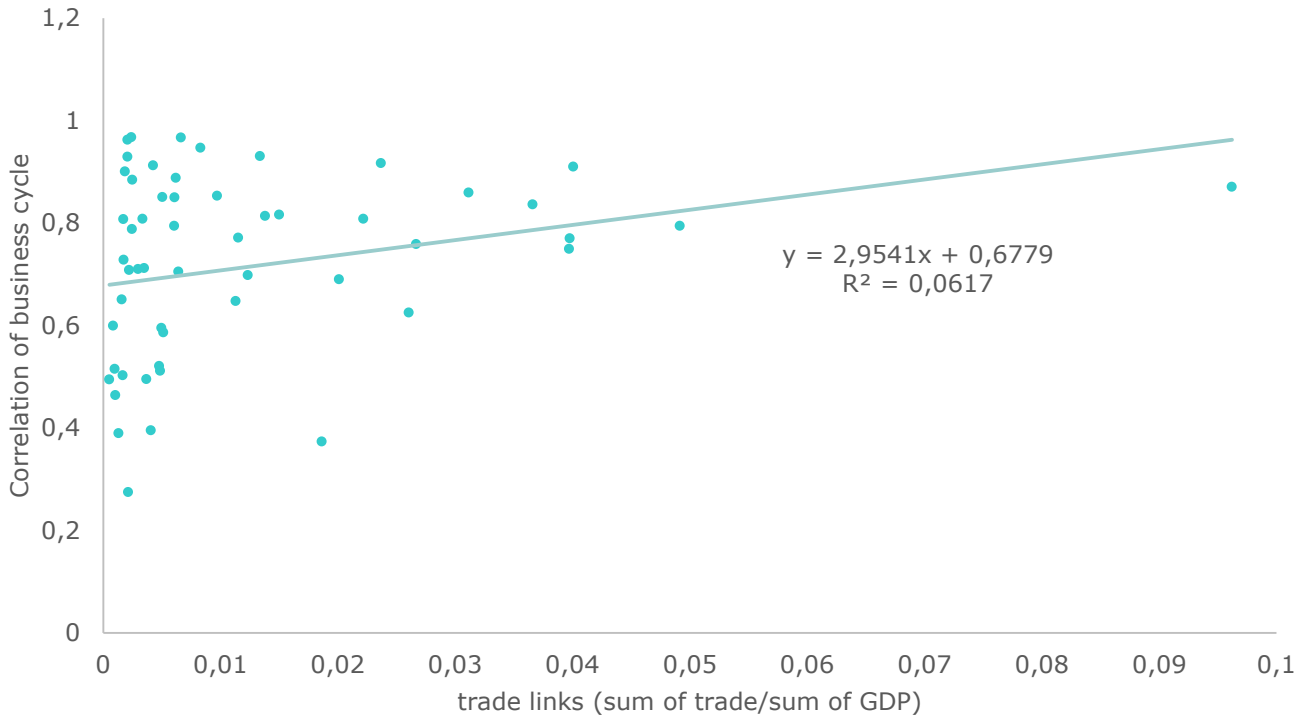
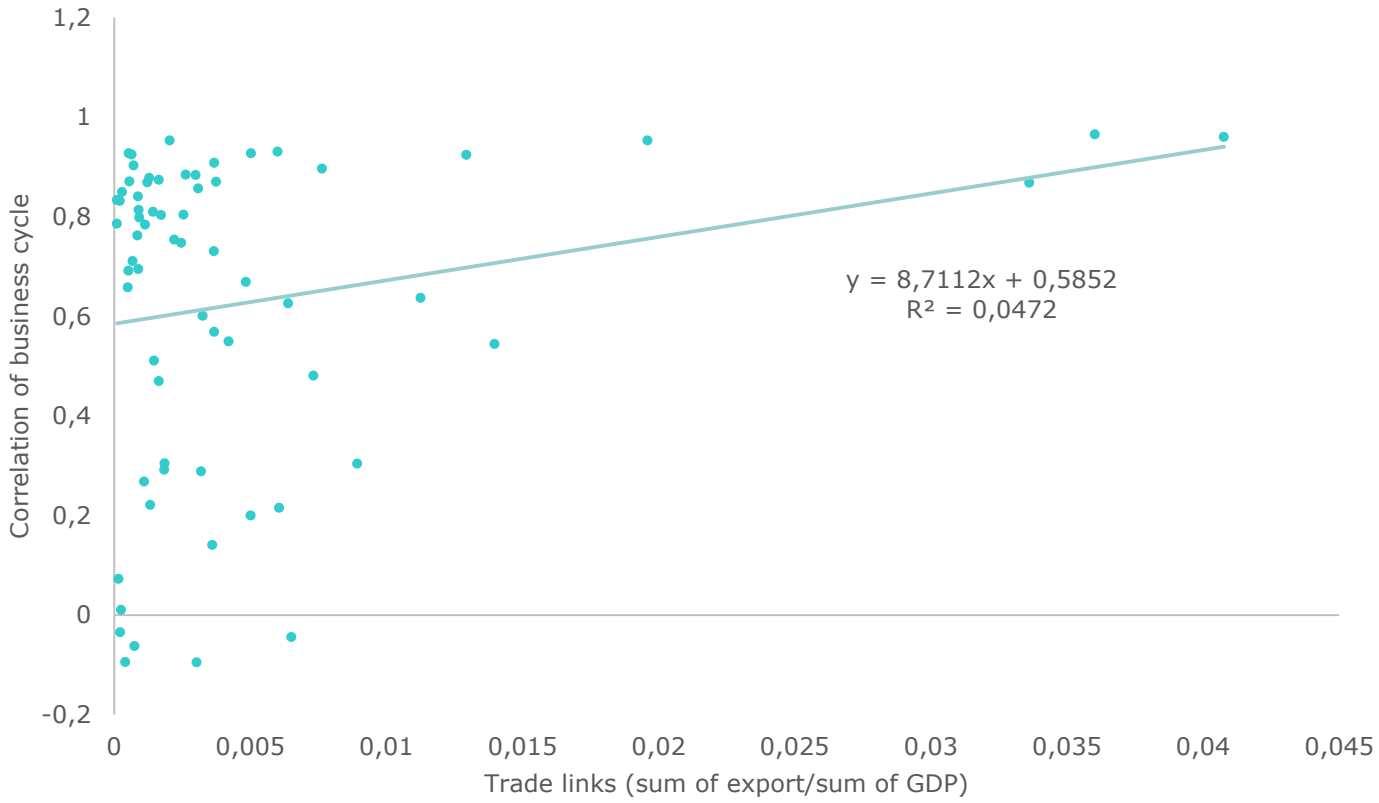


Figure 3: Correlation of business cycle and trade links in 12 stand-alone countries



- Mainstream open economy DSGE-models have been struggling to provide a good explanation.
- Of course one can “solve” these problems by assuming high positive correlations of exogenous shocks.
- But this is not really an explanation
  - it forces the designers of these models to admit that high correlations of the business cycles across countries are produced outside their models.

- There have been attempts to explain the high synchronization of the business cycles across countries by introducing financial integration in the models
- This goes some way in explaining this synchronization.
- But again too much is “explained” by introducing highly correlated exogenous financial shocks.

A behavioral model approach

- We want to go further
- And make the explanation endogenous in the model
- i.e. not having to rely exclusively on correlation of exogenous shocks across countries

Monetary union model

$$y_t^1 = a_1 \tilde{E}_t y_{t+1}^1 + (1 - a_1) y_{t-1}^1 + a_2 \left(r_t - \tilde{E}_t \pi_{t+1}^1 \right) + (x_t^1 - m_t^1) + \varepsilon_t^1 \qquad (1)$$

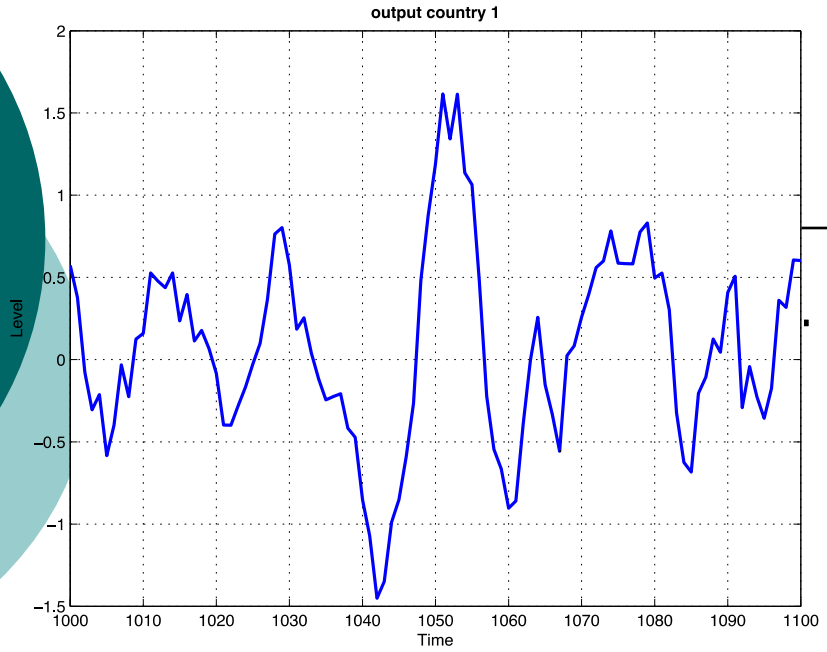
$$y_t^2 = a_1 \tilde{E}_t y_{t+1}^2 + (1 - a_1) y_{t-1}^2 + a_2 \left(r_t - \tilde{E}_t \pi_{t+1}^2 \right) + (x_t^2 - m_t^2) + \varepsilon_t^2 \qquad (2)$$

$$\pi_t^1 = b_1 \tilde{E}_t \pi_{t+1}^1 + (1 - b_1) \pi_{t-1}^1 + b_2 y_t^1 + \eta_t^1 \qquad (5)$$

$$\pi_t^2 = b_1 \tilde{E}_t \pi_{t+1}^2 + (1 - b_1) \pi_{t-1}^2 + b_2 y_t^2 + \eta_t^2 \qquad (6)$$

$$r_t = c_1 (\overline{\pi_t} - \pi^*) + c_2 \overline{y_t} + c_3 r_{t-1} + u_t \qquad (7)$$

where $\overline{\pi_t} = \frac{1}{2} * (\pi_t^1 + \pi_t^2)$ and $\overline{y_t} = \frac{1}{2} * (y_t^1 + y_t^2)$,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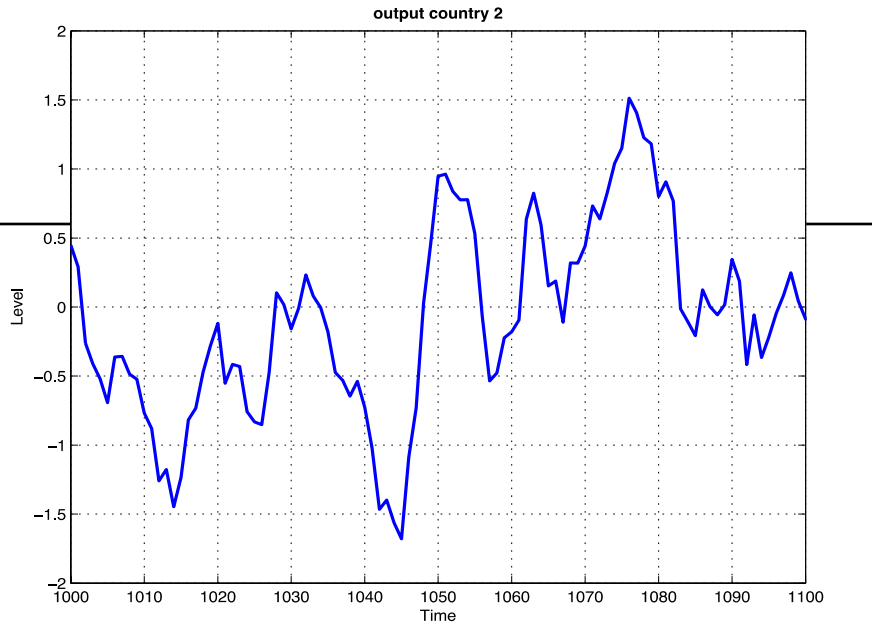
Level
Time
2
1.5
1
0.5
0
−0.5
−1
−1.5
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
1100


output country 2
Level
Time
2
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−1
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−2
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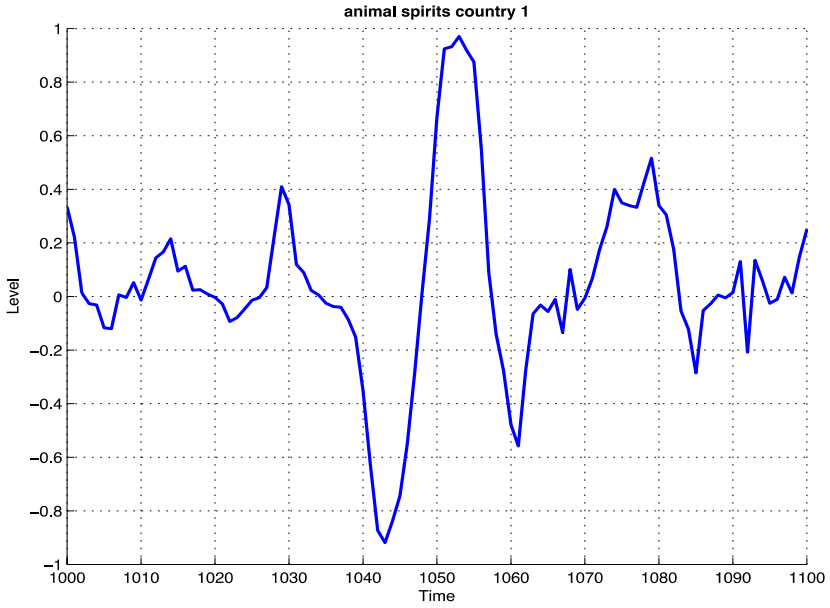
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Level
Time
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
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−0.8
−1
1000
1010
1020
1030
1040
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1060
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1080
1090
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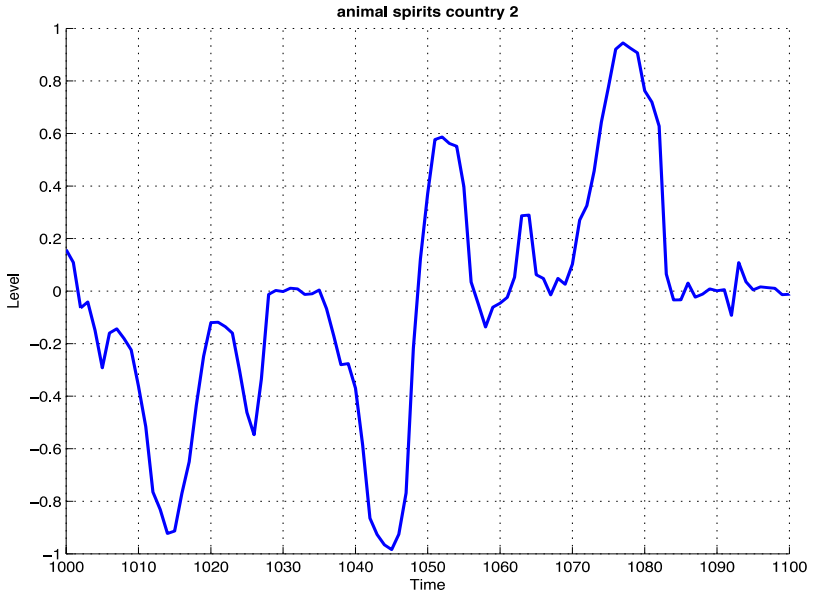
animal spirits country 2
Level
Time
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0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
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1000
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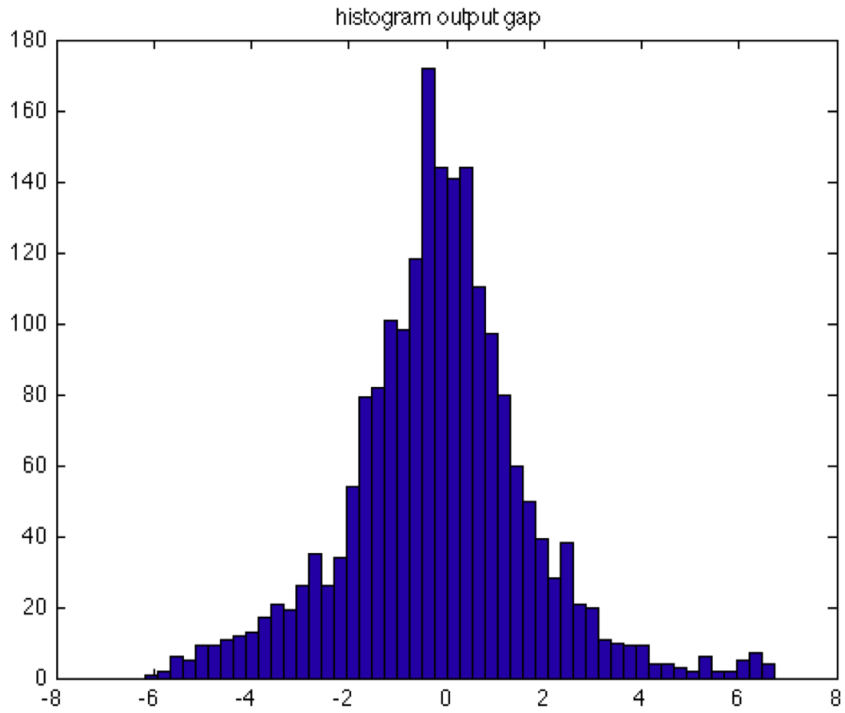
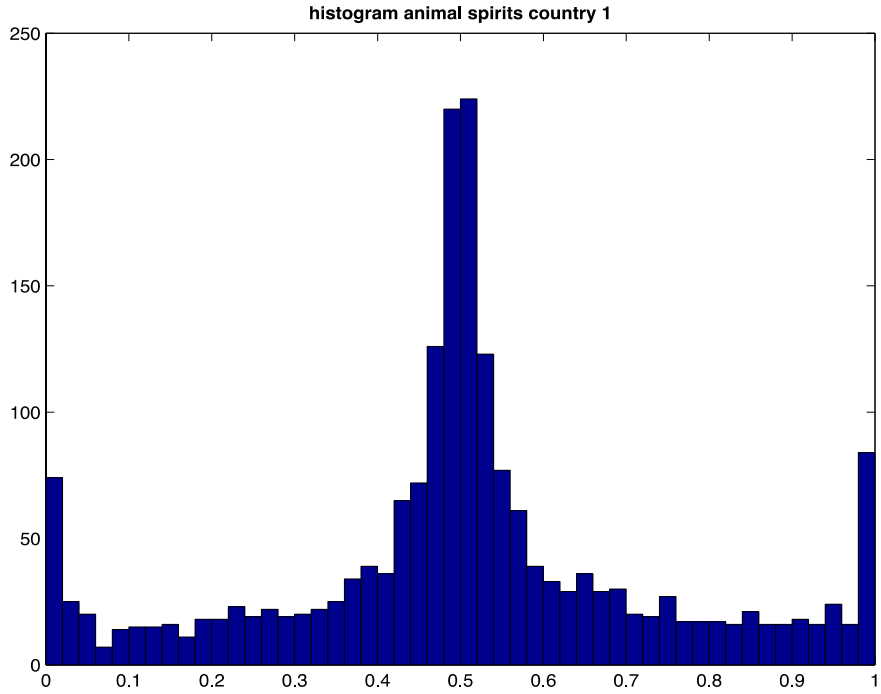
Frequency distribution output gap and animal spirits





Implications: international contagion

- Model produces international contagion of animal spirits.
- Animal spirits are highly correlated between the two countries reaching 0.95.
- Why? When a wave of optimism is set in motion in country 1, it leads to more output and imports in that country, thereby increasing output in country 2.

Positive transmission, even if small, makes it more likely that agents in country 2 that make optimistic forecasts are vindicated, thereby increasing the fraction of agents in country 2 that become optimists.

- We obtain transmission dynamics that triggered by trade flows is amplified leading to strong synchronization of the business cycles across countries.
- Similar result in model with monetary independence

Correlation is non-linear

Figure 30: Animal spirits in country 1 and 2

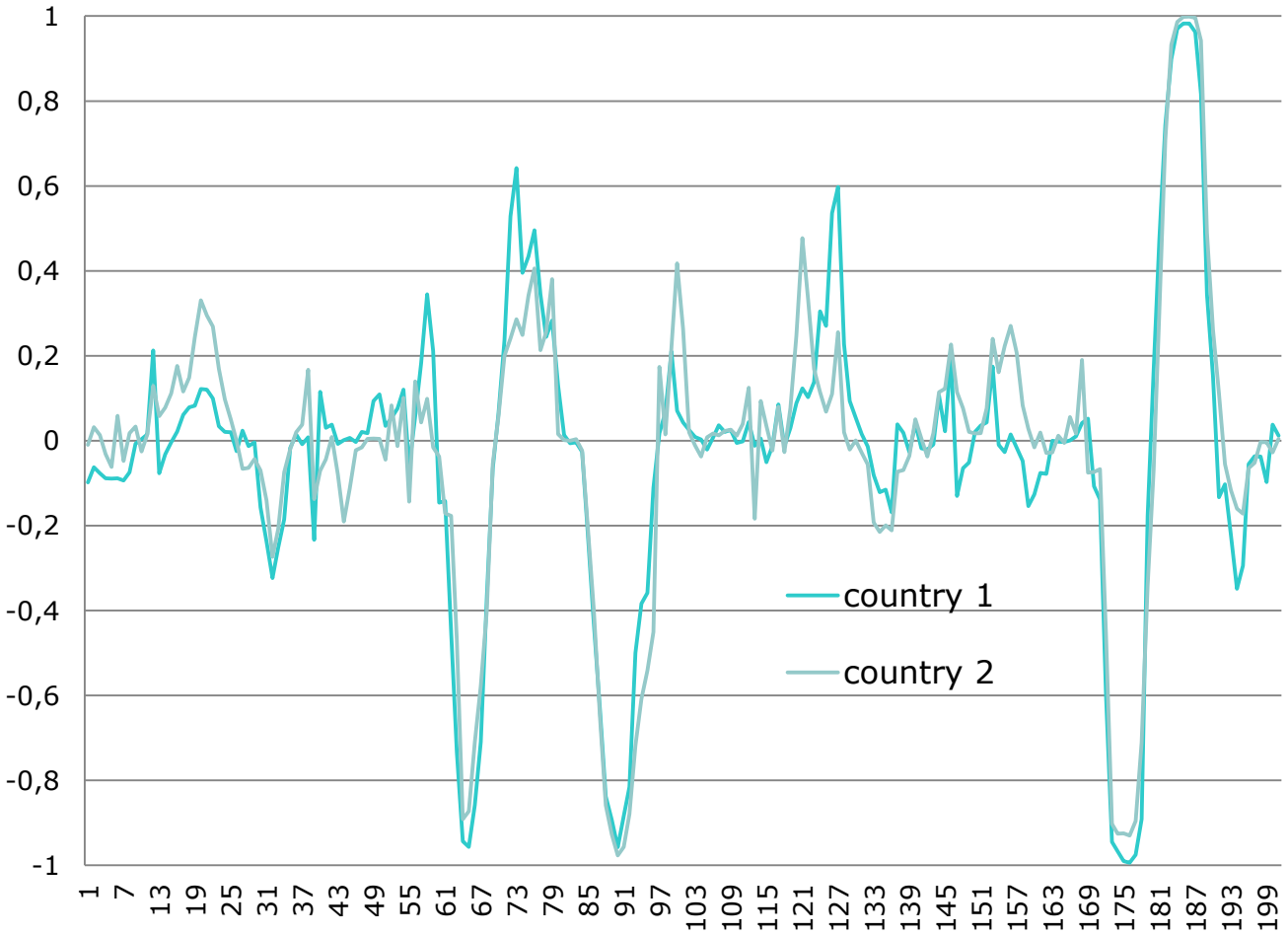


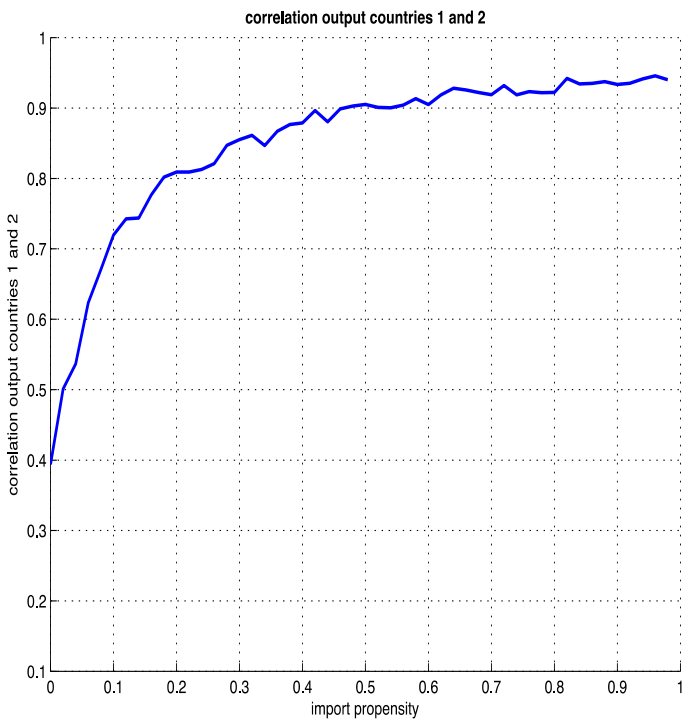
Table 5: Correlation animal spirits countries 1 and 2

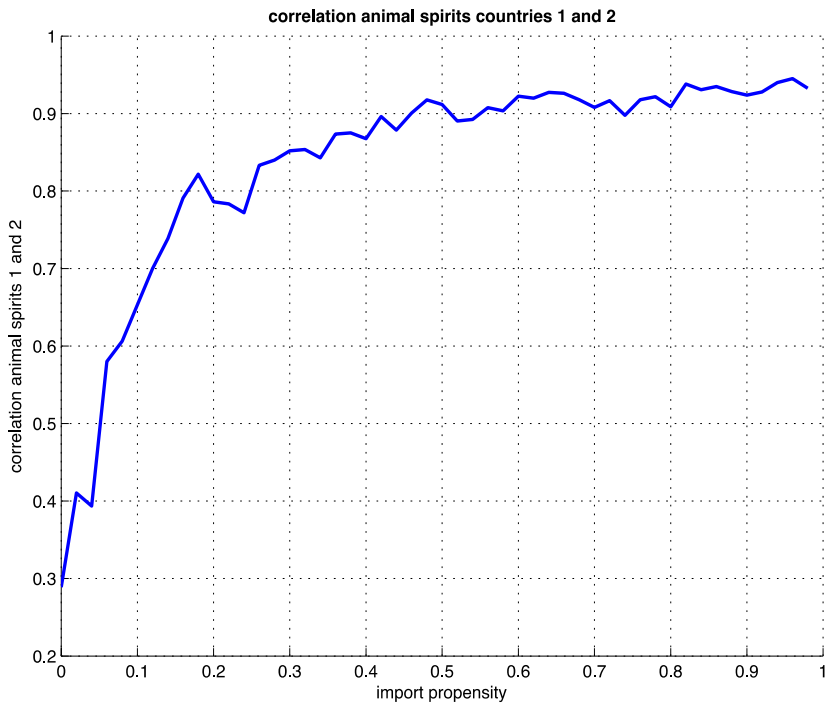
Animal spirit: from low to high	Correlation	Number of observations
|Anspirit1|<0.01	0,0901	180
|Anspirit1|<0.05	0,2493	595
|Anspirit1|<0.1	0,442	832
|Anspirit1|<0.2	0,6044	1118
|Anspirit1|<0.5	0,791	1497
Full sample	0,9417	1998
|Anspirit1|>0.5	0,9732	501
|Anspirit1|>0.8	0,986	299
|Anspirit1|>0.9	0,9906	234
|Anspirit1|>0.95	0,9953	180
|Anspirit1|>0.99	0,9998	93

Implications

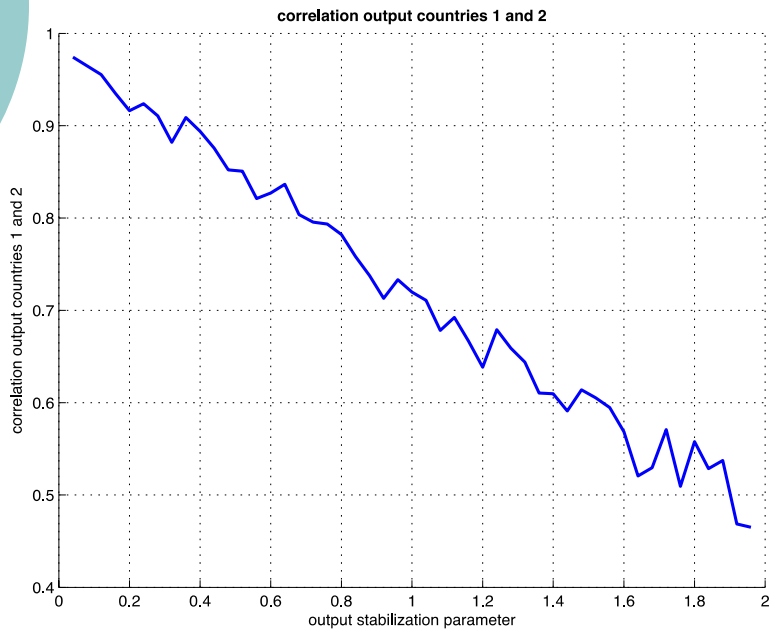
- International correlation of business cycles is dominated by extreme movements in animal spirits
- Extreme optimism gets easily propagated internationally
- The same is true with extreme pessimism

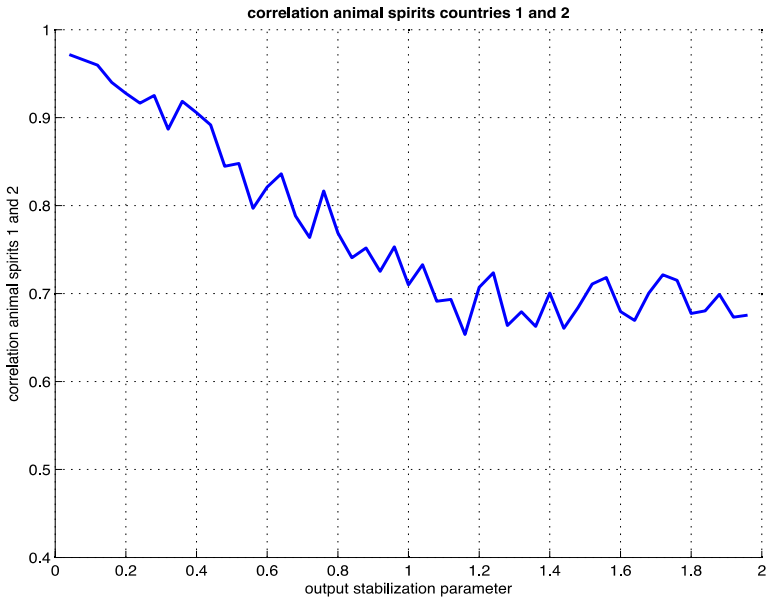
Factors affecting synchronization of business cycle: trade





Factors affecting synchronization of business cycle: output stabilization





Conclusion

- Main channel of international synchronization business cycles occurs through a propagation of "animal spirits",
  - i.e. waves of optimism and pessimism that get correlated internationally.
  - this propagation occurs with relatively low levels of trade integration.
  - and is more intense when optimism and pessimism are extreme
- Degree of synchronization is influenced by the intensity with which the central bank stabilizes output.

Empirical Issues

Introduction

- A theoretical model can only convince if it passes some form of empirical testing.
- This is also the case with the behavioural model discussed in these lectures.
- The problem in macroeconomics is how to devise a credible empirical test of the model.
- The history of macroeconomics is littered with examples of models which passed econometric testing procedures with flying colors, to be found wanting later. The DSGE-models are no exceptions to this rule.

- I will follow the approach of indirect inference, i.e. I ask the question what the predictions of the theoretical model are and confront these predictions with the data.
- Of course, it should be stressed from the start that a lot of uncertainty will continue to prevail about the empirical validity of the behavioural model.

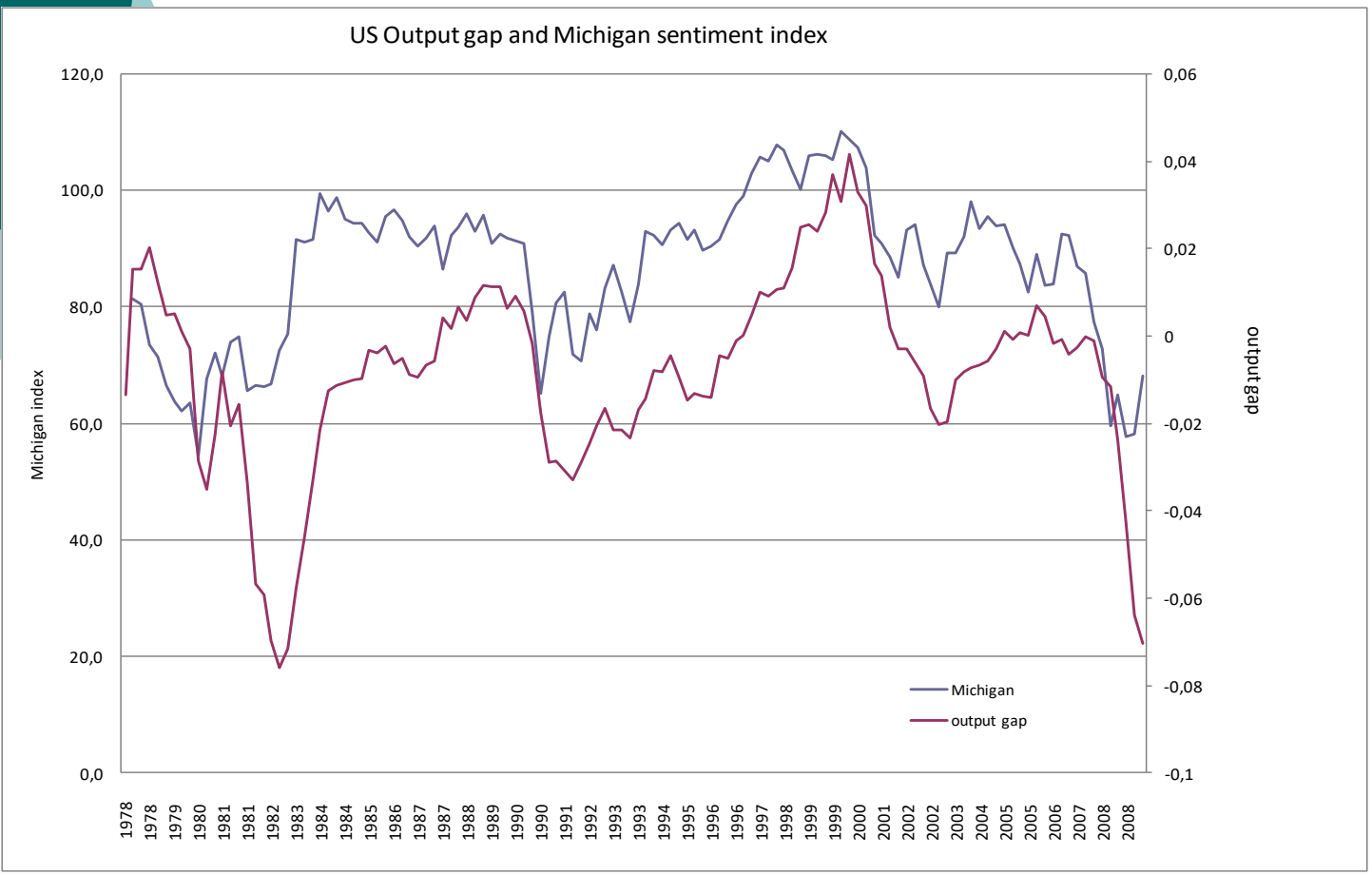
Main predictions of the behavioural model.

1. Output movements are correlated with measures of optimism and pessimism
2. Output movements are not normally distributed and show fat tails.
3. Interest rate increase leads to temporary decline in output and inflation (like in other models). These effects, however, are time dependent (depend on market sentiments). This leads to different impulse responses depending on the time of the shock.

Correlation output movements and animal spirits

Concept of animal spirits, i.e. waves of optimism and pessimism, plays a central role in our model

- Is there an empirical counterpart for this concept?
- There is one: Many countries use survey based consumer and/or business sentiment indicators as a tool of analyzing the business cycle and as a predictive instrument.
- How well do these indicators correlate with output movements?



Source: US Department of Commerce, Bureau of Economic Analysis, and University of Michigan: Consumer Sentiment Index.

Correlation is 0.6

Causality goes both ways

This is confirmed by Granger causality tests

We also find this feature in our behavioral model

Table 1: Pairwise Granger Causality Tests

Null Hypothesis:	Obs	F-Statistic	Probability
Output does not Granger Cause optimism	1948	31.0990	5.1E-14
Optimism does not Granger Cause output		32.8553	9.3E-15

Table 2: Pairwise Granger Causality Tests

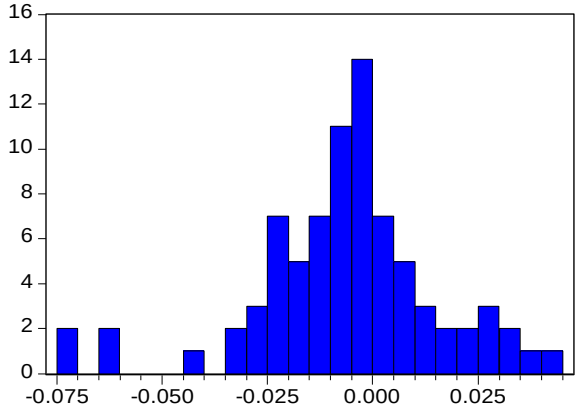
Null Hypothesis:	Obs	F-Statistic	Probability
MICHIGAN does not Granger Cause GDP	123	15.83	0.00001
GDP does not Granger Cause MICHIGAN		4.83	0.0096

Model predictions: higher moments

- In Lecture 1 we showed that the behavioral model predicts that the output gap is not normally distributed and exhibits fat tails.
- This feature of the higher moments of the output gap is generated endogenously in the model.
- It is not the result of imposing such a feature on the stochastic shocks hitting the economy.
- We interpreted this result to mean that the model predicts that occasionally extreme movements in output can occur as a result of an endogenous dynamics.

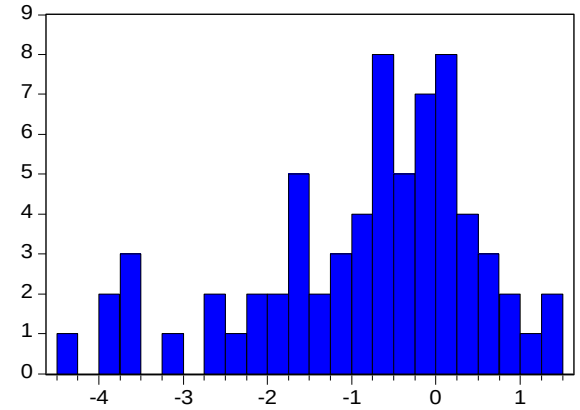
- We already confronted this prediction with data from the US and concluded that indeed the distribution of the US output gap during the postwar period was not normal.
- We now look at other countries, i.e. the UK and Germany. Unfortunately the sample period is shorter and only starts in 1990.
- For the sake of comparability we also present the US data for this shorter period.

Figure 10.2: Frequency distribution of US output gap



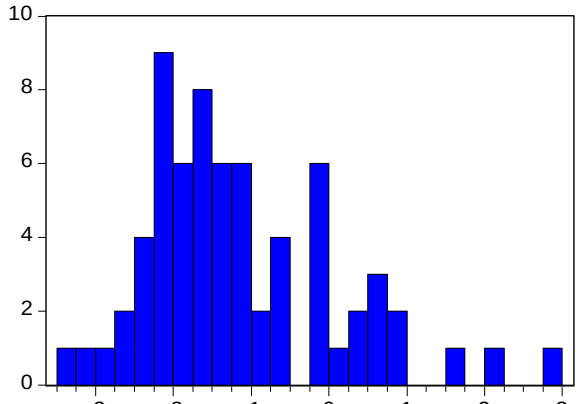
Series: USGAP	
Sample 1990:1 2009:4	
Observations 80	
Mean	-0.006394
Median	-0.004803
Maximum	0.041474
Minimum	-0.070291
Std. Dev.	0.021906
Skewness	-0.599819
Kurtosis	4.360329
Jarque-Bera	10.96542
Probability	0.004158

Figure 10.3: 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 10.4: 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

Transmission of monetary policy shocks

- Empirical testing in macroeconomics has been very much influenced by Sims(1980) seminal contribution.
- The basic idea is that theoretical models make predictions about the effects of policy shocks and that these predictions can be confronted with the data.
- The way this can be done is to estimate a VAR of the macroeconomic variables and the policy variable.
- In the context of our model this consists in estimating a VAR of inflation, output gap and the interest rate.

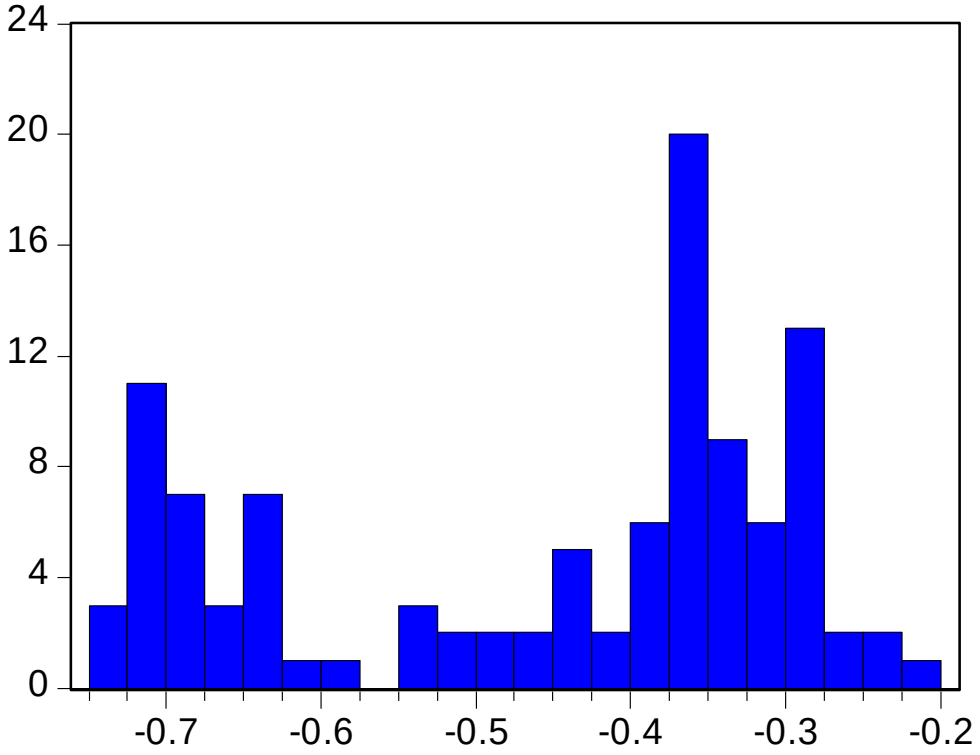
- This VAR then allows to estimate an impulse response of inflation and output gap on interest rate shocks.
- This impulse response obtained from the data is then compared with the impulse response predicted by the theoretical model.
- It is important that, in doing so, the empirical impulse response is theory-free, i.e. does not use theory to impose identifying restrictions.

- In practice, this is not always easy to do, because restrictions on the parameters of the VAR must be imposed to be able to identify the impulse responses.
- The condition therefore has been to impose restrictions that use the least possible theory, or put differently, that are used in the largest possible class of theoretical model.
- The Choleski decomposition is generally considered as the most theory-free set of restrictions.

- We now confront the theoretical impulses obtained from our behavioral model with the empirical ones.
- As a first step, we estimated a VAR-model with three variables (output, inflation and short term interest rate) for the US, using a Choleski decomposition (with ordering of inflation, output, interest rate).
- We then computed the impulse responses of output to an increase in the short-term interest rate (the Federal Funds rate).
- One of the main predictions of the behavioral model is that the impulse responses are very much influenced by the timing of the shock.

- We tested the empirical validity of this prediction by computing different impulse responses over different sample periods.
- We allowed for rolling sample periods of 30 years starting in 1972, and moving up each month.
- For each of these sample periods we computed the shot-term output effect of an increase in the Federal Fund rate, where short-term refers to the effect after one year.

Figure 10.5: Distribution short-term output response to shock fed fund rate



Series: OUTPUTRESPONSE	
Sample 1 108	
Observations 108	
Mean	-0.458938
Median	-0.375850
Maximum	-0.215400
Minimum	-0.739700
Std. Dev.	0.163445
Skewness	-0.514876
Kurtosis	1.705925
Jarque-Bera	12.30758
Probability	0.002125

- We find a wide range of short-tem effects to the same policy shock (between -0.2% and -0.7% for a 1 standard deviation shock in the interest rate).
- In addition, we find that the distribution of theses output responses is not normal. The Jarque-Bera test overwhelmingly rejects normality.
- empirical results confirm the theoretical prediction of the behavioral model, i.e. the timing of the shock matters a great deal and affects how the same policy shock is transmitted into the economy.
- In addition, the non-normality in the distribution of these shocks transforms risk into uncertainty.

- It must be admitted that evidence of a non-normal distribution of the short-term output effects of monetary policy shocks is not necessarily in contradiction with the DSGE-model.
- In the framework of that model, the evidence provided here can be interpreted as arising from changes in policy regime.
- It is well-known since the famous Lucas critique (Lucas(1976)), that changes in policy regime change the structural parameters of the standard demand and supply equations, and thus also change the transmission of policy shocks (the impulse responses).

- In this interpretation, the evidence of non-normal distribution of the short-term output effects of a monetary policy shock is consistent with the view that there have been different changes in the policy regime during the sample period.
- These changes then produce non-normal distributions of these effects.

- Again we have two radically different interpretations of the same empirical evidence (which is not unusual in economics).
- However, interpretation given in the behavioral model is simpler than the one provided in the DSGE-model.
- In the latter, the theoretical model predicts that provided the policy regime does not change, a policy shock will always have the same effect.
- With noise in the data, the estimated effects of these shocks should be normally distributed.

- If we observe non-normality, this must be produced outside the model, in this case by exogenous changes in the policy environment.
- Thus for every deviation from normality, the DSGE-modelers must invoke a special event that has occurred outside the model.
- Such a model has little predictive power, because deviations from the predicted normality is always due to special circumstances.
- In contrast, in our behavioral model, non-normality of the effects of policy shocks are not deviations from the rule, they are the rule.