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JEL Classification: N/A

Keywords: Taylor rule, behavioural macroeconomics, animal spirits

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We show that in a world where agents have limited cognitive abilities and, as a result, are prevented from having rational expectations the answer to this question is negative. We find that in "tranquil periods" when market sentiments (animal spirits) are neutral a forward-looking Taylor rule produces similar results as current-looking Taylor rule in terms of output and inflation volatility. However, when the economy is in a regime of booms and bust produced by extreme values of animal spirits the forward-looking central bank will make many policy errors that have to be corrected afterwards. Thus in a regime of extreme uncertainty the use of a forward Taylor rule reduces the quality of policy-making, leading to greater variability of the output and inflation. It is then better for the central bank to use currently observed output and inflation to set the interest rate. The empirical evidence suggests that central banks are often not forward looking. Our model provides the theoretical justification for this.

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1. Introduction

The Taylor rule has played an important role in macroeconomic analysis and in actual policymaking. When it was first proposed by Taylor(1993) it was seen more as a description of how central banks behave. Later when it was introduced in macroeconomic models (e.g. the DSGE-models) it was interpreted as a rule that could be derived from optimizing behaviour of the central bank based on a quadratic central bank loss function (see Svensson(1997, 2003))

When originally proposed by Taylor the rule described how the central bank sets the interest rate as a function of currently observed variables such as inflation and output gap. This was later criticized. The central bank should make decisions about the interest rate based not on currently observed values but on the forecasts (expectations) of future inflation and output gap (see Clarida, Gali, Gertler(2000), Batini, N. and Haldane, A., 1999, Svensson(1997)). This conclusion should not really be surprising. In a world of rational expectations where agents have the cognitive ability to understand the complexity of the underlying model and where they know the distribution of the shocks that will hit the economy in the future, it would not be rational not to use all the available information. This requires having a forward-looking outlook also for the central bank. In such a world the central bank would fail in its duties if it did not use all the available information.

Things look different in a world where agents have cognitive limitations that prevent them from having rational expectations. In such a world agents understand very little of the complex world and they have no clue about the future shocks that will hit them. It is not obvious that in such a world a central bank that is forward looking will follow better monetary policies than one which just looks at current output and inflation to set the interest rate.

There is a large literature contrasting the different dynamics obtained from "current-looking" and forward-looking Taylor rules (for an overview of the literature see Taylor and Williams (2010)). Notably, Rudebusch and Svensson, (1999), Levin et al. (2003), and Orphanides and Williams (2007) investigated the optimal choice in the policy rule in various models (i.e. rational expectations and learning models) and did not find a significantly large benefit from forward-looking policy rules. Levin et al. (2003) also showed that in rational expectations models rules that respond to inflation forecasts are prone to generating indeterminacy.

There are also a large amount of empirical studies on identifying the central banks Taylor rule reaction functions, i.e. whether the central banks use forward-looking or current-looking rules in their policy decisions. The empirical evidence so far in this field is mixed. For example, Orphanides (2001) uses ex post data and finds that during 1987–1993, forward-looking specifications describe the Federal Reserve policy better than current-looking Taylor-type specifications. Taylor and Williams (2010) surveyed the recent literature and they find evidence that the current looking Taylor rule works well and are often used by central banks. Empirical studies related to the behaviour of the European Central Bank are also mixed, see for example Gorter et al (2008), Belke and Klose (2011)and Blattner and Margaritov (2010). One important issue Orphanides (2001) points out is there are information problems (i.e. real-time data availability) associated with forward-looking policy rules.

In this paper we ask the theoretical question of whether central banks should be forward looking, i.e. whether they should set the interest rate using forecasts/expectation of future output and inflation. The novelty of our paper is to use a behavioural macroeconomic model to analyse whether a forward looking Taylor rule performs better than a Taylor rule that uses current values of output and inflation.

The model is characterized by the fact that agents experience cognitive limitations preventing them from having rational expectations. Instead they use simple forecasting rules (heuristics) and evaluate the forecasting performances of these rules ex-post. This evaluation leads them to switch to the rules that perform best. Thus, it can be said that agents use a trial-and-error learning mechanism[1]. This heuristic switching model produces endogenous waves of

[1] There is a large literature on learning (see Evans (2001)). While some modelers adopt some weaker

optimism and pessimism (animal spirits) that drive the business cycle in a self-fulfilling way, i.e. optimism (pessimism) leads to an increase (decline) in output, and the increase (decline) in output in term intensifies optimism (pessimism), see De Grauwe(2012), and De Grauwe and Ji(2019). (See also Brock and Hommes (1997), Branch and McGough (2010), De Grauwe (2012), Hommes and Lustenhouwer (2019)) and many others).

The organization of the paper is as follows. Section 2 describes the basic behavioural model and the two Taylor rules we use in this paper. Section 3 provides the stability condition of the model. Section 4 presents the basic results, compares the performance (i.e. output and inflation stabilization) of two Taylor rules and analyzes the underlying mechanism that explains the differences. Sections 5 provides sensitivity analysis on how different factors of the behavioural models affect the performance of the two Taylor rules. Sections 6 and 7 discuss the policy choices of central banks and the impulse response analysis under the two Taylor rules. We conclude in section 8.

2. The model

We begin by describing the two versions of the Taylor rule. Both versions follow the idea that monetary policy should respond to both inflation and output gap.

(a) The current-looking Taylor rule:

$$r_t = (1 - c_3)[c_1(\pi_t - \pi^*) + c_2 y_t] + c_3 r_{t-1} + u_t \quad (1)$$

where r_t is the interest rate in period t, π_t is the inflation rate , π^* is the target rate of inflation and y_t is the output gap.

Thus the central bank increases (reduces) the interest rate when inflation exceeds (falls short of) the target and when the output gap is positive (negative) We assume that the central bank wants to smoothen interest rate changes (see Levin et al. (1999) and Woodford (1999, 2003)). This is shown by including a lagged interest rate. When no smoothing occurs c_3 = 0 and we obtain the original Taylor rule. Note also that we set the natural rate of interest equal to zero.

(b) The forward-looking Taylor rule:

$$r_t = (1 - c_3)\left[c_1\left(\widetilde{\mathrm{E}}_t \pi_{t+1} - \pi^*\right) + c_2 \widetilde{\mathrm{E}}_t y_{t+1}\right] + c_3 r_{t-1} + u_t \quad (2)$$

In this formulation of the Taylor rule the central bank makes a market forecast of inflation and output gap and raises (reduces) the interest rate when the future expected rate of inflation exceeds (is below) the target and when the future expected output gap is positive (negative). We will assume that the central bank makes the same forecasts as those made by market participants. How the latter make their forecasts is explained in the behavioural model.

The next step is to embed these two alternative Taylor rule in a standard behavioural macroeconomic model as described by De Grauwe (2011) and De Grauwe and Ji(2019). The aggregate demand equation can be expressed in the following way:

$$y_t = a_1 \widetilde{\mathrm{E}}_{\mathrm{t}} y_{t+1} + (1 - a_1) y_{t-1} + a_2 \left(r_t - \widetilde{\mathrm{E}}_{\mathrm{t}} \pi_{t+1} \right) + v_t \tag{3}$$

where y_t is the output gap in period t, r_t is the nominal interest rate, π_t is the rate of inflation and two forward looking components, , $\widetilde{\mathrm{E}}_{\mathrm{t}}\pi_{t+1}$ and $\widetilde{\mathrm{E}}_{\mathrm{t}} y_{t+1}$. The tilde above E refers to the fact that expectations are not formed rationally. How exactly these expectations are formed will be specified subsequently.

We assume the aggregate supply equation in (4). This New Keynesian Philips curve includes a forward looking component, $\widetilde{\mathrm{E}}_{\mathrm{t}}\pi_{t+1}$, and a lagged inflation variable. Inflation π_t is sensitive to the output gap y_t. The parameter b_2 measures the extent to which inflation adjusts to changes in the output gap.

$$\pi_t = b_1 \widetilde{\mathrm{E}}_{\mathrm{t}} \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 y_t + \eta_t \tag{4}$$

We have added error terms in each of the equations. These components describe the nature of the different shocks that can hit the economy. There are interest rate shocks, u_t, demand shocks, v_t , and supply shocks, η_t. It is assumed that these shocks are normally distributed with mean zero and a constant standard deviation.

How exactly are the forecast of output gap $\widetilde{\mathrm{E}}_{\mathrm{t}} y_{t+1}$ and inflation $\widetilde{\mathrm{E}}_{\mathrm{t}}\pi_{t+1}$ formed? The rational expectations hypothesis requires agents to understand the complexities of the underlying model and to know the frequency distributions of the shocks that will hit the economy. We take it that the cognitive limitations of agents prevent them from understanding and processing this kind of information. These cognitive limitations have been confirmed by laboratory experiments and survey data (see Carroll, 2003; Branch, 2004; Pfajfar, D. and B. Zakelj, (2011 &2014); Hommes, 2011).

We assume two types of rules agents follow to forecast the output gap. A first rule is called a "fundamentalist" one. Agents estimate the steady state value of the output gap (which is normalized at 0) and use this to forecast the future output gap. A second forecasting rule is a "naïve" one. This is a rule that does not presuppose that agents know the steady state output gap. They are agnostic about it. Instead, they extrapolate the previous observed output gap into the future. There is ample evidence from laboratory experiments that support these assumptions that agents use simple heuristics to forecast output gap and inflation. See Pfajfar and Zakelj, (2011 &2014), Kryvtsov and Petersen (2013) and also Assenza et al.(2014a) for a literature survey. The fundamentalist and extrapolator rules for output gap are specified as follows:

$$\widetilde{\mathrm{E}}_{\mathrm{t}}^{\mathrm{f}} \mathrm{y}_{\mathrm{t}+1} = 0 \qquad (4)$$

$$\widetilde{\mathrm{E}}_{\mathrm{t}}^{\mathrm{e}} y_{\mathrm{t}+1} = y_{t-1} \qquad (5)$$

This kind of simple heuristic has often been used in the behavioral macroeconomics and finance literature where agents are assumed to use fundamentalist and chartist rules (see Brock and Hommes(1997), Branch and Evans(2006), De Grauwe and Grimaldi(2006), Brazier et al. (2008)). It is probably the simplest possible assumption one can make about how agents who experience cognitive limitations, use rules that embody limited knowledge to guide their behavior. They only require agents to use information they understand, and do not require them to understand the whole picture. In De Grauwe (2012) more complex rules are used, e.g. it is assumed that agents do not know the steady state output gap with certainty and only have biased estimates of it. This is also the approach taken by Hommes and Lustenhouwer (2019).

The market forecast can be obtained as a weighted average of these two forecasts, i.e.

$$\widetilde{\mathrm{E}}_{\mathrm{t}} y_{t+1} = \alpha_{f,t} \widetilde{\mathrm{E}}_{\mathrm{t}}^{\mathrm{f}} \mathrm{y}_{\mathrm{t}+1} + \alpha_{e,t} \widetilde{\mathrm{E}}_{\mathrm{t}}^{\mathrm{e}} \mathrm{y}_{\mathrm{t}+1} \qquad (6)$$

$$\alpha_{f,t} + \alpha_{e,t} = 1 \qquad (7)$$

where $\alpha_{f,t}$ and $\alpha_{e,t}$ are the probabilities that agents use the fundamentalist, respectively, the naïve rule.

As indicated earlier, agents in our model are willing to learn, i.e. they continuously evaluate their forecast performance. We specify a switching mechanism of how agents adopt specific rule. As shown in Appendix 1, we follow the discrete choice theory (see Anderson, de Palma, and Thisse, (1992) and Brock & Hommes (1997)) to work out the probability of choosing a particular rule. We obtain:

$$\alpha_{f,t} = \frac{exp(\gamma U_{f,t})}{exp(\gamma U_{f,t}) + exp(\gamma U_{e,t})} \tag{8}$$

$$\alpha_{e,t} = \frac{exp(\gamma U_{e,t})}{exp(\gamma U_{f,t}) + exp(\gamma U_{e,t})} \tag{9}$$

where $U_{f,t}$ and $U_{e,t}$ the past forecast performance (utility) of using the fundamentalist and the naïve rules. The parameter γ measures the "intensity of choice". It can also be interpreted as expressing a willingness to learn from past performance. When $\gamma = 0$ this willingness is zero; it increases with the size of γ.

The forecast performance affects the probability of using a particular rule. For example, as shown in Equation (8), as the past forecast performance (utility) of the fundamentalist rule improves relative to that of the naïve rule, agents are more likely to select the fundamentalist rule for their forecasts of the output gap.

Agents also have to forecast inflation. Similar heuristics rules as in the case of output forecasting are described in Appendix 2. This allows us to use the switching mechanism similar to the one specified equations (8) and (9).

The procedure to solve the model is shown in Appendix 3. Our behavioural model can be micro-founded. For readers who are interested in the microfoundation of the model, we refer to the discussions in De Grauwe and Ji (2020) and Hommes and Lustenhouwer (2019).

As our model has strong non-linear features we use numerical methods to analyze the dynamics created by the model. In order to do so, we have to calibrate the model, i.e. to select numerical values for the parameters of the model. In Appendix 3 Table 1 we show these numerical values.

3. Stability of the model

We start by analyzing the conditions under which the model produces stable outcomes. The model is simulated over 10,000 periods. We proceed as follows. We allow the parameters in the Taylor rule to vary. We first do this for the parameters c1 (inflation parameter) and c2 (output gap parameter) while keeping c3 (the interest smoothing parameter) constant. In a second stage we fix c1 and c2 and allow c3 to vary.

Tables 1 and 2 show the results of the first exercise. We have fixed c3=0.5 and allow c1 and c2 to change over a broad range of parameter values. We find in both Taylor regimes the crucial role of c1 in maintaining stability of the model. The parameter $c1 \geq 1$ to ensure stability in both Taylor rule regimes. This so-called Taylor principle is found in most macroeconomic models.

The parameter c2 that expresses the central bank's preference for output stabilization also matters. We find that when c2=0 the model is chaotic (in the current Taylor rule regime) or unstable (in the forward Taylor rule regime). Chaos is a deterministic dynamics leading to cyclical movements of output gap that are aperiodic, i.e. each cycle differs from any other one. It produces a "strange attractor". We show an example in Figure A1 in appendix 4. We note that the fluctuations of the output gap are quite extreme when the model produces a chaotic dynamics.

There is a contrast here between the two Taylor rule regimes. Under the current Taylor rule regime the model produces stable solutions for all values of $c1 \geq 1$ and $c2 \geq 0$, (although for c2=0, the underlying volatility is extremely high). Under the forward-looking Taylor rule regime, a value of c2=0 leads to instability and there is a range of positive values of c2 that produces chaotic dynamics. Thus the forward Taylor regime produces more problems of instability and high volatility than the current Taylor regime.

Table 1: Stability analysis, current Taylor rule

	output parameter c2									
inflation parameter c1	0	0,1	0,2	0,4	0,6	0,8	1	1,2	1,3	1,4
0	U	U	U	U	U	U	U	U	U	U
0,3	U	U	U	U	U	U	U	U	U	U
0,6	U	U	U	U	U	U	U	U	U	U
0,9	U	U	U	U	U	U	U	U	U	U
0,95	U	U	U	U	U	U	U	U	U	U
0,99	U	U	U	U	U	U	U	U	U	U
1	U	S	S	S	S	S	S	S	S	S
1,3	C	S	S	S	S	S	S	S	S	S
1,6	C	S	S	S	S	S	S	S	S	S
1,9	C	S	S	S	S	S	S	S	S	S
2,2	C	S	S	S	S	S	S	S	S	S
2,5	C	S	S	S	S	S	S	S	S	S
2,8	C	S	S	S	S	S	S	S	S	S

Table 2: Stability analysis, forward Taylor rule

	output parameter c2									
inflation parameter c1	0	0,1	0,2	0,4	0,6	0,8	1	1,2	1,3	1,4
0	U	U	U	U	U	U	U	U	U	U
0,2	U	U	U	U	U	U	U	U	U	U
0,4	U	U	U	U	U	U	U	U	U	U
0,6	U	U	U	U	U	U	U	U	U	U
0,8	U	U	U	U	U	U	U	U	U	U
0,9	U	U	U	U	U	U	U	U	U	U
0,99	U	U	U	U	U	U	U	U	U	U
1	U	C	S	S	S	S	S	S	S	S
1,3	U	C	S	S	S	S	S	S	S	S
1,6	U	C	S	S	S	S	S	S	S	S
1,9	U	C	S	S	S	S	S	S	S	S
2,2	U	C	S	S	S	S	S	S	S	S
2,5	U	C	S	S	S	S	S	S	S	S

Our second exercise consists in fixing c1 and c2 while allowing c3 to vary. We do this so as to find out how the desire of the central banks to smooth interest rate changes affects the stability of the model. The results are shown in Table 3. We find that too high a smoothing parameter, c3, leads to instability. Again we observe that the forward Taylor produces more instability than the current Taylor regime. There is also a small range of values of c3 that produces a chaotic dynamics with a strange attractor. We show an example of a strange attractor in Figure A2 in appendix 4.

Table 3: Stability analysis

c3-parameter	Current Taylor	Forward Taylor
0	**S**	**S**
0,2	**S**	**S**
0,4	**S**	**S**
0,6	**S**	**S**
0,8	**S**	**S**
0,85	**S**	**C**
0,88	**C**	**U**
0,9	**U**	**U**
0,95	**U**	**U**
0,97	**U**	**U**
0,99	**U**	**U**

Note: c1=1.5 and c2=0.5 (These are the values used in the standard simulations)

4. Analysis of the model

4.1 basic results under two Taylor rules

We analyze the model for both the current and the forward Taylor rules. The results obtained using the current Taylor rule are presented in Figure 1, which shows the movements of the output gap and animal spirits in the time domain (left hand side panels). We show a sample of 300 periods (quarters) that is representative of the full simulation. The right hand side panel shows the output gap and animal spirits in the frequency domain for the full 10,000 periods.

We observe that the model produces waves of optimism and pessimism (animal spirits) that can lead to a situation where everybody becomes optimist (S_t = 1) or pessimist (S_t = -1)[2]. See appendix for a discussion of how these animal spirits are

[2]We use an index of market sentiments, called "animal spirits", which reflects how optimistic or pessimistic market forecasts are. This index can change between -1 and +1. It is obtained from fraction of extrapolators ($\alpha_{e,t}$) and fundamentalists ($\alpha_{f,t}$) as follows:

$$S_t = \begin{cases} \alpha_{e,t} - \alpha_{f,t} & if\ y_{t-1} > 0 \\ -\alpha_{e,t} + \alpha_{f,t} & if\ y_{t-1} < 0 \end{cases}$$

derived from the model. These waves of optimism and pessimism are generated endogenously, i.e. the i.i.d. shocks are transformed into serially correlated (persistent) movements in market sentiments.

As can be seen from the left hand side panels, the correlation of these animal spirits and the output gap is high, reaching 0.95. Underlying this correlation is the self-fulfilling nature of expectations (optimism and pessimism)[3]. When agents with optimistic forecasts happen to be more numerous than those with pessimistic forecasts, this will tend to raise the output gap (see equation (3)). The latter in turns validates those who made optimistic forecasts. This then attracts more agents to become optimists. When the market is gripped by a self-fulfilling movement of optimism (or pessimism) this can lead to a situation where everybody becomes optimist (pessimist). This then also leads to an intense boom (bust) in economic activity.

This self-fulfilling nature of the dynamics also leads to different frequency distribution of output and animal spirits from the conventional macroeconomic models. These results are shown in the right hand side panels. We find that the output gap is not normally distributed (despite the i.i.d. shocks), with excess kurtosis and fat tails. A Jarque-Bera test rejects normality of the distribution of the output gap. The origin of the non-normality of the distribution of the output gap can be found in the distribution of the animal spirits. We find that there is a concentration of observations of animal spirits around 0. This means that much of the time there is no clear-cut optimism or pessimism. We can call these "normal periods". There is also, however, a concentration of extreme values at either -1 (extreme pessimism) and +1 (extreme optimism). These extreme values of animal spirits explain the fat tails observed in the distribution of the output gap.

[3] In De Grauwe(2012) and De Grauwe and Ji(2018) empirical evidence is provided indicating that output gaps are highly correlated with empirical measures of animal spirits. It is shown that when performing causality tests on US and the Eurozone data one cannot reject the hypothesis that the output gap Granger causes the index of business confidence, and vice versa one cannot reject the hypothesis that the index of business confidence Granger causes the US and Eurozone output gap during 1999-2015. Thus there is a two-way causality between market sentiments and the output gap. This is also what we find in this model.

Figure 1. Output and animal spirits, Current Taylor

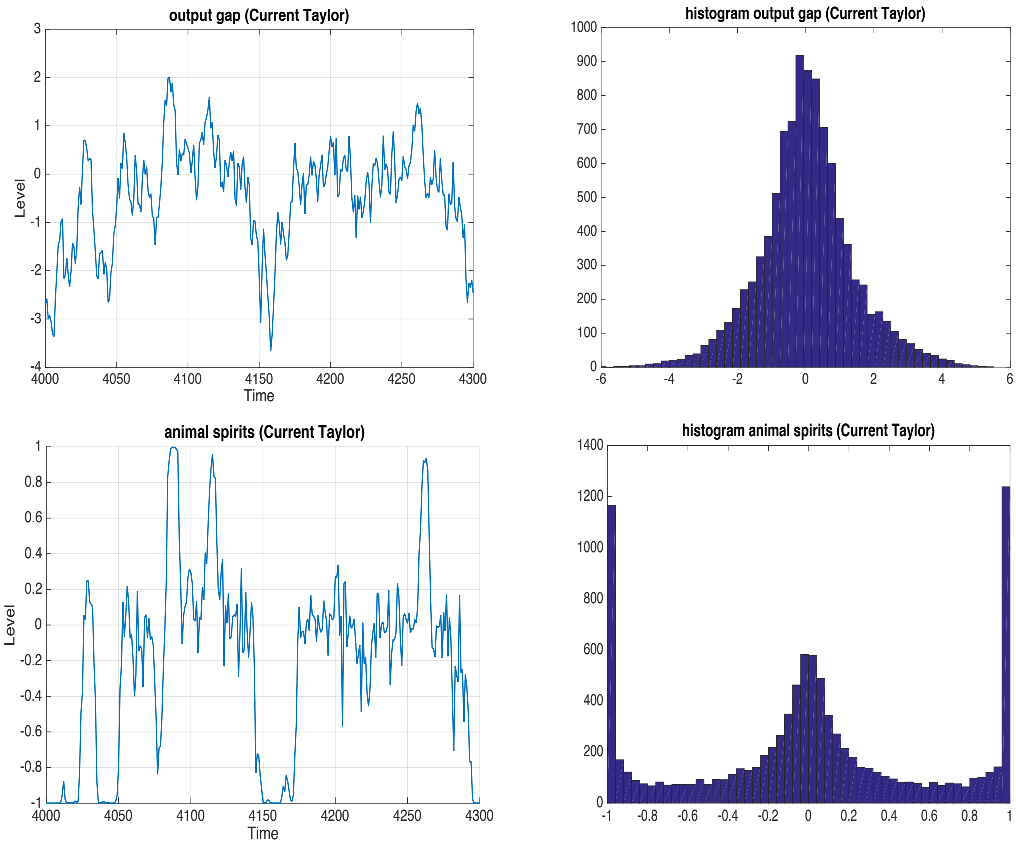
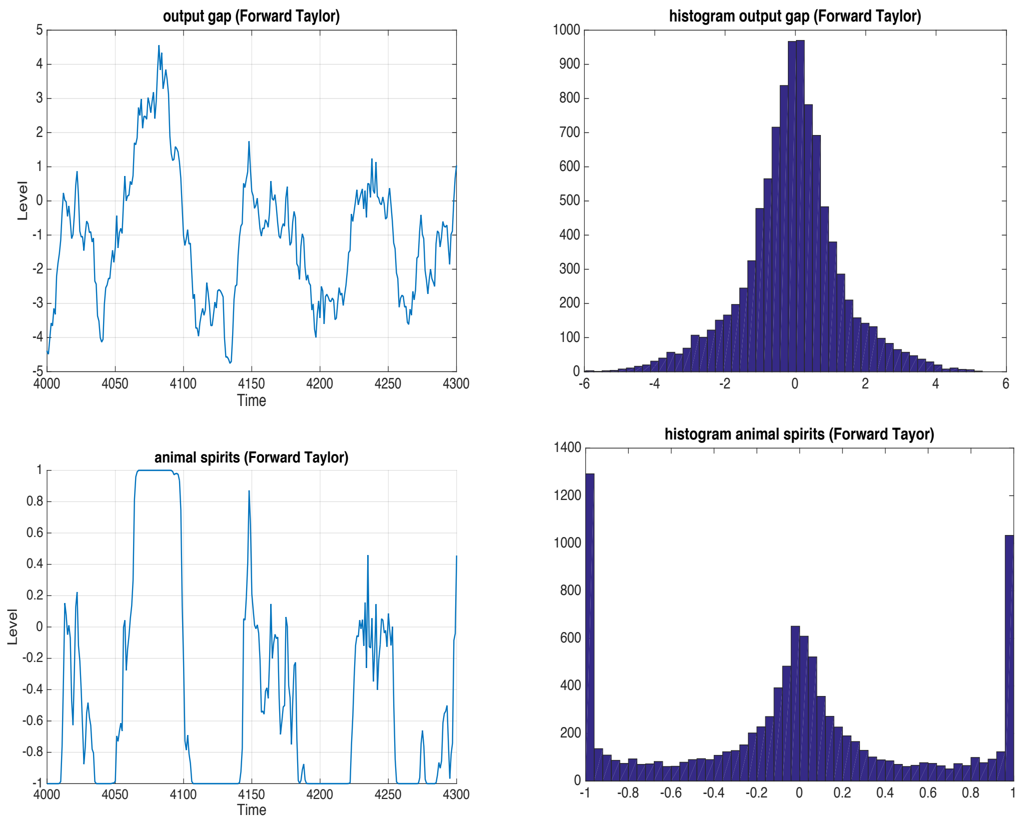


Figure 2. Output and animal spirits, Forward Taylor



When comparing these results obtained under the current Taylor rule regime with those obtained under the forward Taylor rule regime we find that we obtain similar results. This is shown in Figure 2. In Table 4 we present indicators of variability obtained under the two regimes, confirming these results. This comparison is in line with the findings from the RE models that current-looking and forward-looking policy rules produce similar results (see Taylor and Williams (2010)).

Table 4. Output gap and inflation volatilities (c2=0.5)

	std (y)	std(π)	Min(y)	Max(y)	Min (π)	Max(π)
Current Taylor	1.67	1.85	-7.4	7.6	-8.5	8.0
Forward Taylor	1.80	1.93	-7.8	8.1	-8.2	8.8

Significant differences in the dynamics produced by the two specifications of the Taylor rule occur when we assume different parameter values of the model. The parameter we explore here is the c2-parameter, which measures the degree with which the central bank reacts to changes in the output gap. We will now assume a low value of c2=0.1, i.e. we assume a central bank which attaches little importance in stabilizing the output gap. We show the results in Table 5. We now obtain an interesting result. The forward looking Taylor rule leads to significantly more variability of the output gap and of inflation than the current Taylor rule. The standard deviations and the extreme values (minimum and maximum) of the output gap and inflation are systematically higher when the central bank takes a forward-looking attitude than when it looks at current values only..

Table 5. Output gap and inflation volatilities (c2=0.1)

	std (y)	std(π)	Min(y)	Max(y)	Min (π)	Max(π)
Current Taylor	3.59	2.55	-13.2	14.8	-10.5	10.2
Forward Taylor	4.52	3.30	-18.0	19.5	-14.0	13.7

4.2 Forecast errors under two Taylor rules

How can the previous result be explained? We answer this question here. When the central banks put too little weight on output stabilization (a small c2) the boom-bust dynamics is frequent and intense. This produces extreme outcomes of animal spirits and fat tails in the distribution of the output gap. This feature is present in both Taylor rule regimes (see Figures 1 and 2). However, in the forward looking Taylor rule this feature is exacerbated. The reason is that when booms and busts occur, i.e. when there are fat tails and extreme values of animal spirits, forecast errors made both by private agents and by the central bank become very high. As a result, a forward-looking central bank will make many policy moves that turn out to be wrong ones. Put differently, the forward looking central bank will make many policy mistakes that have to be reversed, thereby exacerbating the volatility of output gap and inflation. Thus when the forward Taylor rule is used the quality of policy-making declines, leading to greater variability of the output gap.

We checked for this interpretation by calculating the forecast errors made by agents (and by the central bank) under the current and forward Taylor rules in Figures 3 and 4. We plot the squared forecast errors of output gap (Figure 3) and inflation (Figure 4) against the animal spirits. We find that when animal spirits are close to zero (tranquil times) the forecast errors tend to be the same in the two Taylor rule regimes. As animal spirits increase (in absolute values) the forecast errors increase and more so under the forward-looking Taylor rule.

Figure 3: Squared forecast errors output gap and animal spirits

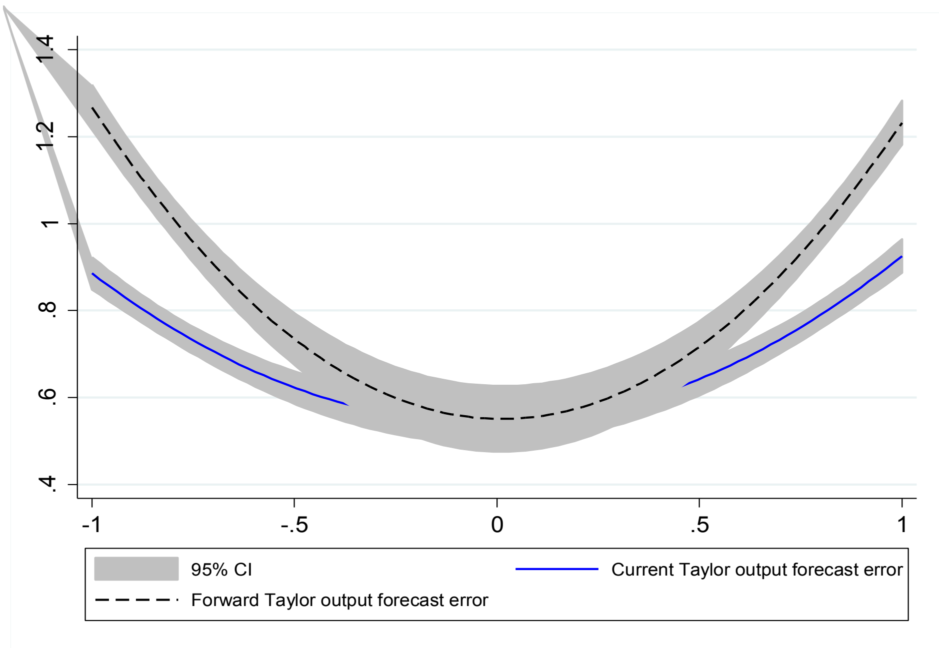
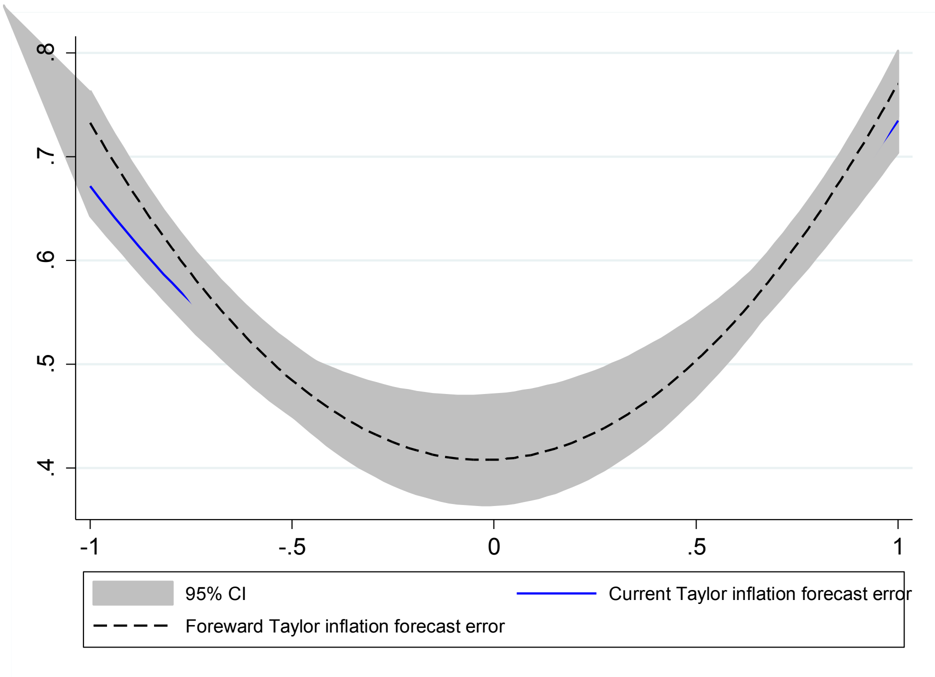


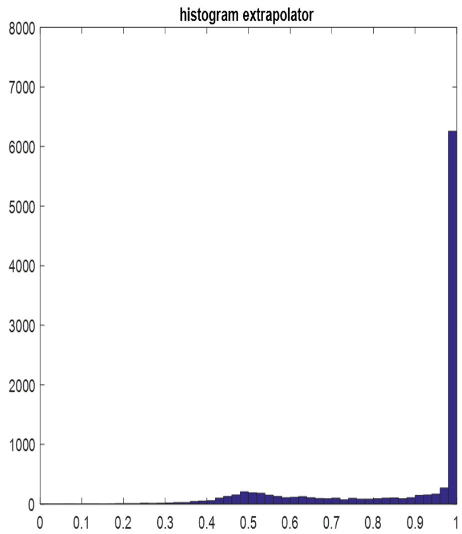
Figure 4: Squared forecast errors inflation and animal spirits



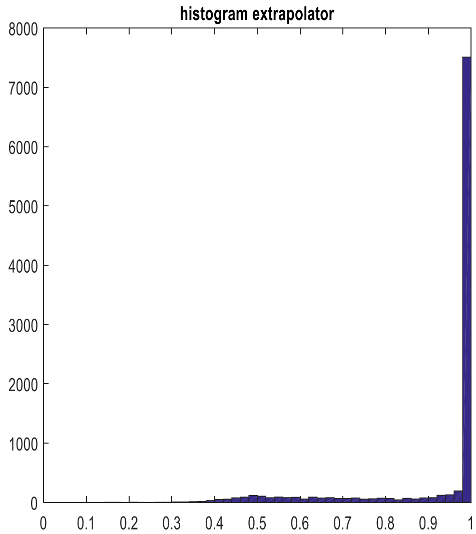
This leads to the following insight. Extreme moods of optimism and pessimism are the result of the fact that all agents tend to extrapolate what they observe today, a boom in the optimistic case or a decline in the pessimistic case. It is then better for the central bank to use currently observed output and inflation to set the interest rate, rather than to try to outwit these agents by making forecasts of output and inflation. Given the extreme volatility of these variables when animal spirits are intense, the forward-looking central bank will make many policy errors that have to be corrected afterwards. In fact we find that such a forward-looking central bank actually leads to more extrapolative behaviour of private agents. We show this in Figure 5. This presents the frequency distribution of the occurrence of extrapolative behaviour in the two Taylor rule regimes. We find that in the forward Taylor rule regime extrapolative behaviour by agents is significantly more frequent.

Figure 5. frequency distribution of extrapolative behaviour

Current Taylor rule



Forward Taylor rule



5. Sensitivity analysis.

The performance of the two Taylor rules may be affected by the parameters of our behavioural model. We analyze this question in this section.

5.1 Variability of exogenous shocks

It will be useful to analyze the behaviour of the model under different assumptions about the variability of shocks. As the model is highly non-linear, these shocks may be amplified, and the amplification process may be different in the two Taylor rule regimes. We analyze this issue in this section. The way we proceed is to simulate the model assuming increasing standard deviations of the demand and supply shocks in equations (3) and (4). For each standard deviation of these demand and supply shocks (which are assumed to be of the same size) we compute the standard deviations of output gap and inflation, and we do this for the two Taylor rule regimes. We show the results in Figures 6 and 7.

The results lend themselves to the following interpretation. When the demand and supply shocks are relatively small, both the forward looking and current looking Taylor rules produce similar results. Once the standard deviations of the shocks exceed 0.5 we observe that the forward looking Taylor rule produces stronger increases in the volatilities of output gap and inflation than the current Taylor rule.

The interpretation of these results goes along the same lines as discussed in the previous sections. As the variability of output and inflation amplified by animal spirits increases a forward looking Taylor rule becomes less attractive because it leads to increasingly large forecast errors for the central bank that is forward-looking. These in turn lead to large policy errors that have to be corrected with frequent policy reversals. This problem is less pronounced for a central bank that uses currently observed values of output and inflation in setting the interest rate.

Figure 6

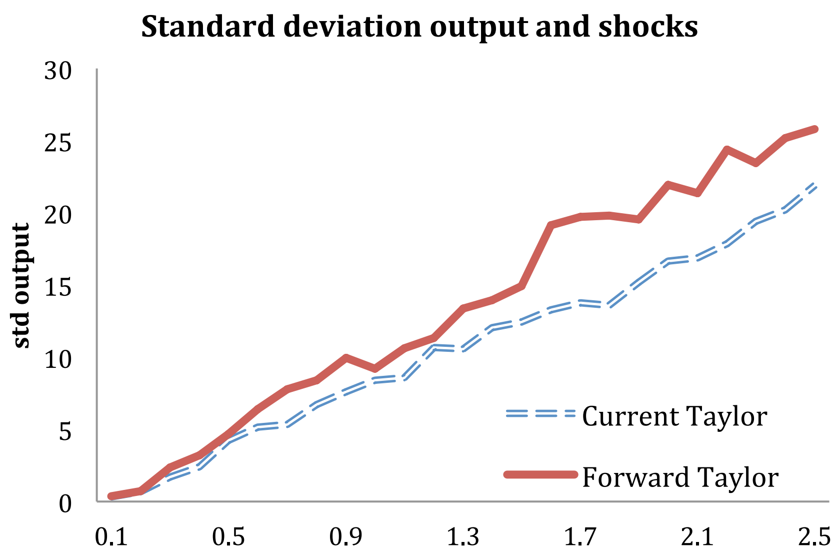
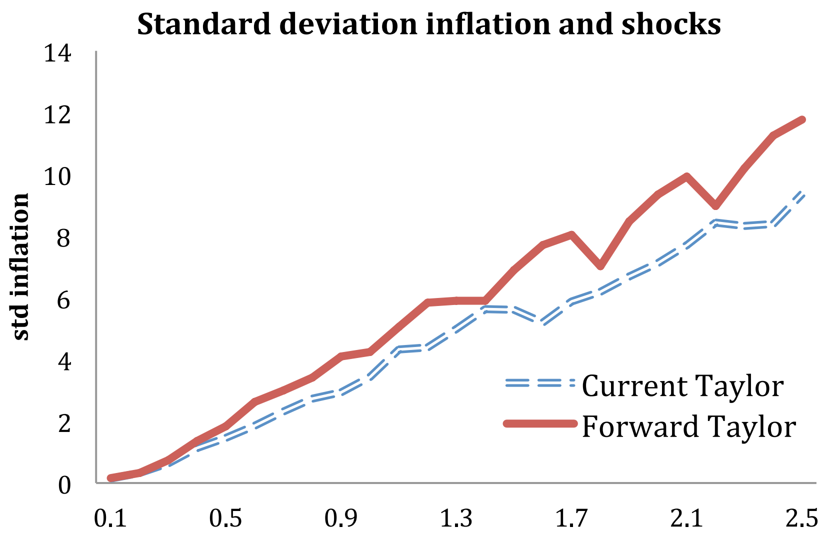


Figure 7



5.2 Output stabilizer c2

From the preceding analysis it follows that the preferences of the central bank regarding output stabilization matters when we compare the two Taylor rule regimes. We explore this matter further by analyzing the sensitivity of the standard deviations of the output gap and inflation for different values of the c2-parameter. We show the results in Figures 8 and 9. On the horizontal axis we present the c2 parameter; on the vertical axis the standard deviations of output gap (Figure 8) and inflation (Figure 9). We observe that when c2 is close to 0, i.e. the central bank does little output stabilization the forward looking Taylor rule produces more volatility of output and inflation. As c2 increases the volatilities obtained in the two regimes tend to converge. In section 6 we return to these results when we derive monetary policy tradeoffs?

Figure 8. Volatility of output

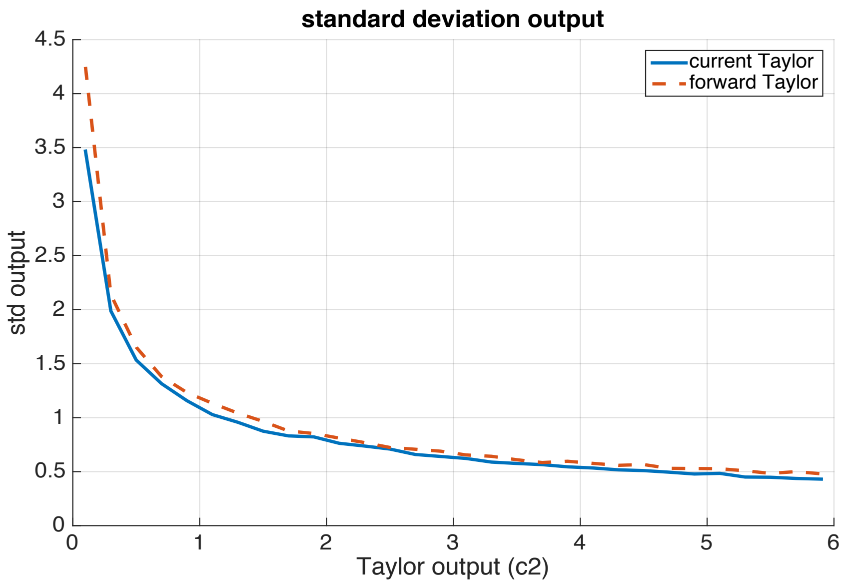
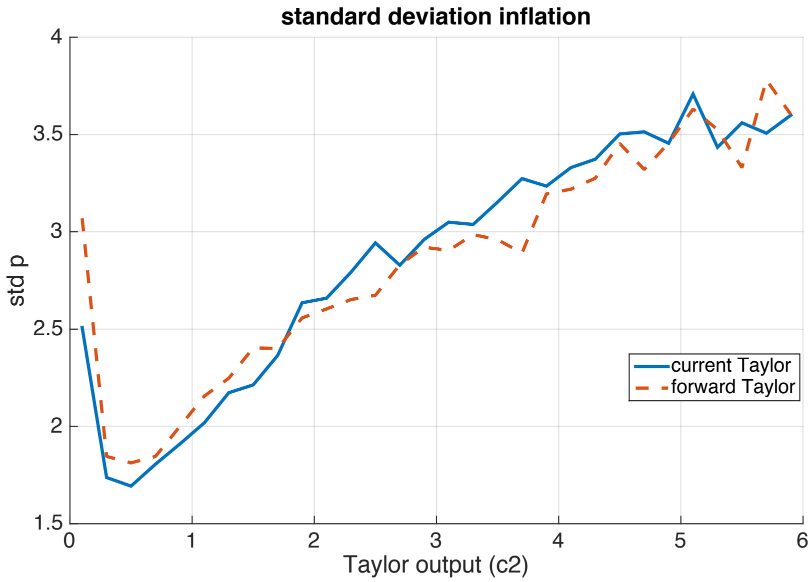


Figure 9. Volatility of inflation



5.3 Switching behaviour

The dynamics produced by our behavioural model is very much influenced by the intensity with which agents are willing to switch from one forecasting rule to the other. It will be remembered that agents do this as a result of changing performance (utility) of these rules. The intensity of this switching behaviour is measured by the parameter, γ, which we have called the "intensity of choice parameter" (see equations (8) and (9) in section 2). It can also be interpreted as a willingness to learn from past mistakes.

It was shown earlier that when $\gamma = 0$ there is no switching. As a result, the dynamics produced by animal spirits does not occur. As γ increases, the intensity of switching goes up and the dynamics of animal spirits that produces booms and busts becomes more important.

In order to gauge the importance of the parameter γ we perform the following simulation experiment. We simulate our model for different values of γ and computed the standard deviations of output gap and inflation for each of these parameter values. We performed this experiment for our two Taylor rule regimes (assuming that c2=0.1). We show the results in Figures 10 and 11. We find that when γ is close to 0, both Taylor rule regimes produce the same volatility of output and inflation. When γ increases beyond 1 the forward Taylor rule creates systematically more volatility of output and inflation. Thus it is when agents are actively switching between forecasting rules and thereby create intense animal spirits that the forward Taylor rule becomes less attractive than the current Taylor rule. The interpretation of this result is the same as the one we gave earlier. In an environment with strong boom-bust dynamics produced by changing animal spirits forecast errors are high. As a result, the central bank is likely to also make large forecast errors, necessitating frequent policy reversals. This adds to the volatility of output and inflation.

Figure 10

Standard deviation output and γ

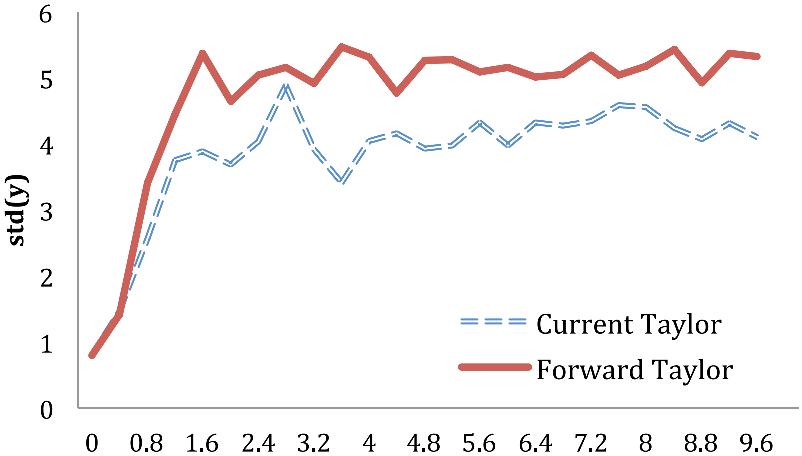
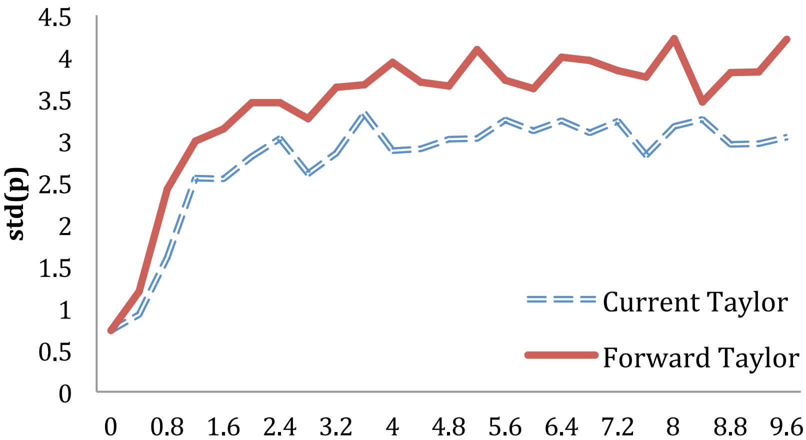


Figure 11

Standard deviation inflation and γ



5.4 Interest smoothing in the two Taylor rule regimes

When central banks set the optimal interest rate they are generally concerned to avoid sudden and large interest rate changes so as to not create too much volatility in the financial markets. They will do interest rate smoothing. The degree of interest rate smoothing is measured by the parameter c3 in the Taylor rule. In this section we examine how much scope there is for interest rate smoothing in the two Taylor rule regimes.

We have already established in section 3 (Table 5) that the constraint on interest rate smoothing is tighter in a forward-looking Taylor rule than in the current Taylor rule regime. This has to do with the fact that in the forward-looking regime the model becomes unstable for values of c3 that are lower than in the current-looking regime. Here we pursue the matter further and we compute the volatility of output gap and inflation. We do this for two values of c3, a low value of 0.5 and a high value of 0.85. We show the results in Tables 6 and 7. We observe that with a low value of c3 both Taylor rule regimes produce similar volatilities of output and inflation. However, when we allow for a larger value of c3 the forward looking regime has significantly larger volatilities.

Table 6: Output gap and inflation volatilities (c3=0.5)

	std (y)	std(π)	Min(y)	Max(y)	Min (π)	Max(π)
Current Taylor	1.71	1.76	-7.37	6.00	-7.01	8.33
Forward Taylor	1.65	1.86	-5.54	7.86	-9.07	6.43

Table 7: Output gap and inflation volatilities (c3=0.85)

	std (y)	std(π)	Min(y)	Max(y)	Min (π)	Max(π)
Current Taylor	4.16	3.59	-16.57	15.31	-12.03	12.82
Forward Taylor	5.95	4.65	-20.55	18.60	-16.13	16.50

We can interpret the previous results as follows. When the central bank is forward looking its capacity for smoothing interest rate changes is reduced compared to the regime in which it is looking at current values of output and inflation. This has to do with the fact that in the current Taylor rule regime the central bank's interest rate smoothing actually helps to smoothen the forecasts made by private agents, which are dominated by extrapolative behavior. This does not happen in a forward-looking Taylor rule regime where, as we have seen earlier, the forward-looking regime creates larger forecast errors of output and inflation.

6. Policy choices

In this section we analyze the choices the central bank faces between output and inflation volatility. We do this by deriving a monetary policy tradeoff that measures how increasing the intensity with which the central bank stabilizes the output gap affects its choice between inflation and output volatility. We do this by varying the parameter c_2 in the Taylor rule and compute the standard deviations of output gap and inflation for increasing values of c_2. We repeat this exercise for the current and forward looking Taylor rules. This exercise was already performed in section 4 (see Figures 6 and 7).

Let us concentrate on Figure 6 first. We find negatively sloped curves for both the current and forward looking Taylor rules. As c_2 increases the curves become flatter. We noted earlier that for small values of c2 the forward looking Taylor rule produces a higher volatility of the output gap than the current Taylor rule.

Figure 7 shows the relationship between the output stabilization parameter c_2 and inflation volatility in the two Taylor rule regime. Here we find another type of non-linearity. When c_2 increases (starting from 0) the effect is to reduce inflation volatility in both regimes. This goes on up to a point. When this point is reached, further attempts at output stabilization lead to increases in inflation variability. We note again that for very small values of c2 the forward Taylor rule produces more volatility (of inflation) than the current Taylor rule.

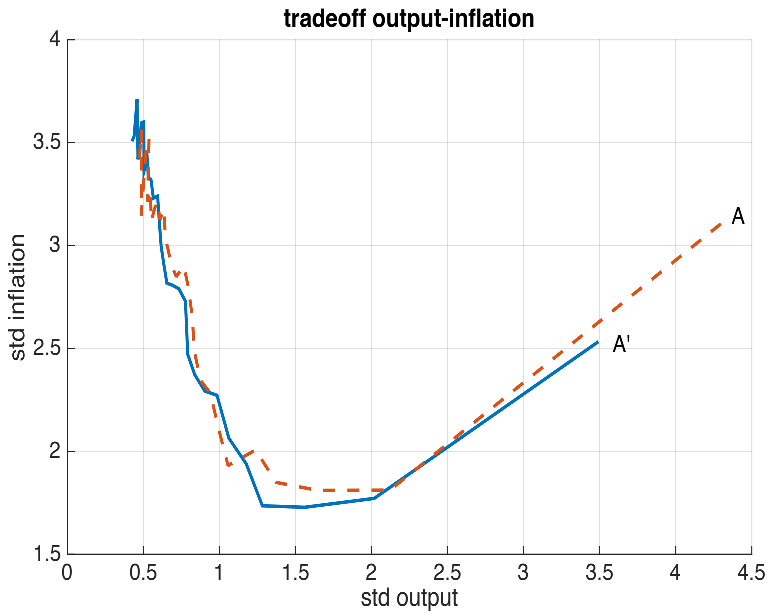
Combining Figures 6 and 7 allows us to derive the trade-offs. These are shown in Figure 12. We observe that there is an upward sloping part of the trade-offs. In order to understand this it is useful to start from A on the uppermost trade-off (corresponding to the forward Taylor rule), or from A' (corresponding to the current Taylor rule). These are the points obtained when the central bank does not stabilize output, i.e. $c_2 = 0$. When c_2 increases (i.e. the central bank increases its output stabilization effort) we move down along these curves. This leads to a "win-win" situation: by increasing its output stabilization the central bank reduces the volatility of output and inflation. When this is the case the central bank does not have to make a choice: more output stabilization can be achieved without cost in terms of more inflation volatility. At some point, however, when the central bank continues to increase its stabilization effort it reaches the negatively sloped part of the trade-offs, implying that it has to make a choice between output and inflation stabilization.

The reason why we obtain this result is that in it is initial stage output stabilization has the effect of reducing the fat tails in the distribution of the output gap (the booms and busts). Put differently, it reduces the power of animal spirits. As long as these are intense, output stabilization reduces both the volatility of inflation and output. When these fat tails are sufficiently lowered, the standard result of a negative trade-off reappears.

We can now contrast the results obtained in the two Taylor rule regimes. We observe from Figure 12 that point A is located above and to the right of A'. This means that in the forward looking Taylor regime the volatility of output and inflation is higher when the central bank does not do much output stabilization (low c2). This was also visible from Figures 6 and 7. Thus when the central bank does not do much output stabilization the forward looking Taylor rule produces significantly more macroeconomic volatility. This is related to what we observed earlier. When c2 is low the model produces a lot of extreme values of animal spirits, output and inflation. This also creates an environment of very high forecast errors. The central bank is also subjected to these high forecast errors. As a result, when the central bank uses a rule based on forecasting output and inflation it will make large policy errors. The latter are less pronounced when the central bank uses a rule based on currently observed values of output and inflation.

Note that as c2 increases and we reach the negatively sloped part of the tradeoffs this difference between the two Taylor rule regimes disappears. The reason is that as c2 increases the frequency with which the models creates extreme values (fat tails) declines, and so the do the forecast errors. Thus, in tranquil periods, both Taylor rule regimes create very similar policy tradeoffs.

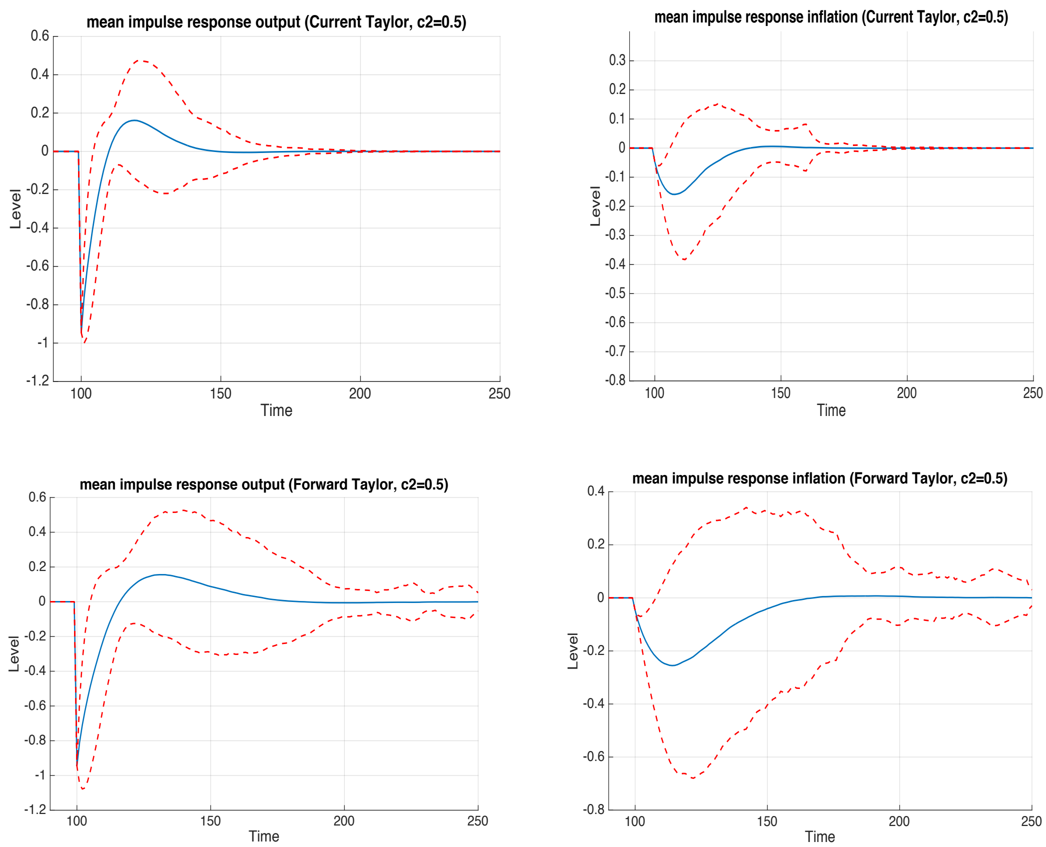
Figure 12



7. Impulse responses

It is useful to also compare how the system reacts to shocks under the two Taylor rule regimes. That is what we do in this section. We first present the impulse responses to a negative demand shock in the two regimes using the standard parameter values (c1=1.5, c2=0.5, c3=0.5). We show the results in Figure 13. We find strikingly that in the forward Taylor rule regime the impact of the same demand shock on inflation is significantly larger than in the current Taylor rule regime. In addition, in the forward Taylor rule regime the variance of the impulse responses (dotted lanes) around the mean response (blue line is larger) than in the current Taylor rule regime and this variance lasts much longer in the former than in the latter. This suggests that after a demand shock the responses of output and inflation are more difficult to predict when the central bank is forward looking than when it only takes the current observed values of output and inflation into account. This is quite paradoxical, as one might have expected that in a forward-looking regime less uncertainty about the transmission of shocks would be the rule. The reason we have this result is related to what we observed earlier. In a forward looking regime the central bank will make large forecast errors and thus will also make large policy errors that have to be corrects afterwards. This is less the case in a regime where the central bank only looks at currently observed variables.

Figure 13



We also produce the impulse responses for the same demand shock but assuming a low c1=0.1. This is a value that produces strong fat tails and boom bust dynamics. We present the results in appendix 5. We again find significant differences between the two Taylor rule regimes. In general the same demand shock produces stronger effects on output and inflation and longer lasting cyclical movements in the impulse responses. This suggests that in an environment of frequent booms and busts the forward looking Taylor rule leads the central bank to induce stronger impacts and more volatile impacts of the same demand shocks. We obtain similar results for other types of shocks, e.g. supply shocks.

8. Conclusion

Should a central bank be forward looking when setting its optimal interest rate? This question has been analyzed in great detail in the macroeconomic literature. When this question is analyzed in the context of theoretical Rational Expectations models with utility maximizing agents, the answer is generally found to be positive. However, the empirical evidence suggests that central banks do not always take a forward looking attitude. Moreover, this evidence also suggest that the benefits of using forward-looking Taylor rule are ambiguous.

We have shown in this paper that in a world where agents have limited cognitive abilities and, as a result, are prevented from having rational expectations a forward looking attitude of the central bank leads to inferior outcomes in particular regimes. We found that in "tranquil periods" when market sentiments (animal spirits) are neutral a forward-looking Taylor rule produces similar results as current-looking Taylor rule in terms. However, when the economy is in a regime of booms and bust produced by extreme values of animal spirits a central bank that bases its interest rate decisions on forecasted values of output and inflation introduces more variability in these variables. We interpreted this result as follows. Extreme moods of optimism and pessimism are the result of the fact that all agents tend to extrapolate what they observe today: a boom in the optimistic case, a decline in the pessimistic case. It is then better for the central bank to use currently observed output and inflation to set the interest rate, rather than to try to outwit these agents by making forecasts of output and inflation. Given the extreme volatility of these variables when animal spirits are extreme, the forward-looking central bank will make many policy errors that have to be corrected afterwards. Thus when the forward Taylor rule is used the quality of policy-making declines, leading to greater variability of the output gap.

We also found that when central banks are forward looking their capacity of applying interest rate smoothing is reduced; exogenous shocks then also tend to produce stronger and more uncertain effects on output and inflation; and the policy tradeoffs they face are generally less attractive than when they set the interest rate using currently observed values of output and inflation. All this leads to the conclusion that in a world in which agents have cognitive limitations preventing them from having rational expectations it is generally a better idea for the central bank to use current values of output and inflation to set the interest rate.

In a way our results generalize an intuition we have when the economy experiences great and uncertain volatility. The recent Corona-crisis is an example. This crisis is characterized by historically large and uncertain disturbances. Under these conditions, no rational central bank would base its monetary policy decisions on a forecast of future output and inflation. The future is too uncertain to do this. When uncertainty is extreme, prudent central banks will be guided by what they observe, and not by what they expect to happen in the future. In this paper we have analyzed this problem in a more systematic way in the context of a behavioural models that regularly but unpredictably produces large variations in output and inflation. The uncertainty this creates is akin to the uncertainty in the sense of Knight. When such an uncertainty regularly but unpredictably pops up, central banks should not look into the future but to the present when setting monetary policies. There is empirical evidence that central banks actually do this and are often not forward-looking (Taylor and Williams(2010)). Our model provides the theoretical justification for this.

APPENDIX 1: Selecting the forecasting rules in output forecasting

We define the forecast performance (utility) of a using particular rule as follows[4].

$$U_{f,t} = -\sum_{k=0}^{\infty} \omega_k \left[y_{t-k-1} - \tilde{E}_{f,t-k-2} y_{t-k-1}\right]^2 \qquad (10)$$

$$U_{e,t} = -\sum_{k=0}^{\infty} \omega_k \left[y_{t-k-1} - \tilde{E}_{e,t-k-2} y_{t-k-1}\right]^2 \qquad (11)$$

where $U_{f,t}$ and $U_{e,t}$ are the utilities of the fundamentalist and naïve rules, respectively. These are defined as the negative of the mean squared forecasting errors (MSFEs) of the forecasting rules; ω_k are geometrically declining weights. We make these weights declining because we assume that agents tend to forget. Put differently, they give a lower weight to errors made far in the past as compared to errors made recently. The degree of forgetting turns out to play a major role in our model. This was analyzed in De Grauwe(2012).

Agents evaluate these utilities in each period. We apply discrete choice theory (see Anderson, de Palma, and Thisse, (1992) and Brock & Hommes(1997)) in specifying the procedure agents follow in this evaluation process. If agents were purely rational they would just compare $U_{f,t}$ and $U_{e,t}$ in (10) and (11) and choose the rule that produces the highest value. Thus under pure rationality, agents would choose the fundamentalist rule if $U_{f,t} > U_{e,t}$, and vice versa. However, psychologists have stressed that when we have to choose among alternatives we are also influenced by our state of mind (see Kahneman(2002)). The latter can be influenced by many unpredictable things. One way to formalize this is that the utilities of the two alternatives have a deterministic component (these are $U_{f,t}$ and $U_{e,t}$) and a random component $\xi_{f,t}$ and $\xi_{e,t}$ The probability of choosing the fundamentalist rule is then given by

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[4] (10) and (11) can be derived from the following equation:

$$U_t = \rho U_{t-1} + (1-\rho)[y_{t-1} - \tilde{E}_{t-2} y_{t-1}]^2 \quad (10')$$

where ρ can be interpreted as a memory parameter. When $\rho = 0$ only the last period's forecast error is remembered; when $\rho = 1$ all past periods get the same weight and agents have infinite memory. We will generally assume that $0 < \rho < 1$. Using (9') we can write

$$U_{t-1} = \rho U_{t-2} + (1-\rho)[y_{t-2} - \tilde{E}_{t-3} y_{t-2}]^2 (10'')$$

Substituting (10") into (10') and repeating such substitutions ad infinitum yields the expression (10) where

$$\omega_k = (1-\rho)\rho^k$$

$$\alpha_{f,t} = P\left[(U_{f,t} + \xi_{f,t}) > (U_{e,t} + \xi_{e,t})\right] \tag{12}$$

In words, this means that the probability of selecting the fundamentalist rule is equal to the probability that the stochastic utility associated with using the fundamentalist rule exceeds the stochastic utility of using the naïve rule. In order to derive a more precise expression one has to specify the distribution of the random variables $\xi_{f,t}$ and $\xi_{e,t}$. It is customary in the discrete choice literature to assume that these random variables are logistically distributed. One then can obtain the probabilities specified in (8) and (9).

The parameter γ measures the "intensity of choice". It is related to the variance of the random components. Defining $\xi_t = \xi_{f,t} - \xi_{e,t}$ we can write (see Anderson, Palma and Thisse(1992)):

$$\gamma = \frac{1}{\sqrt{var(\xi_t)}}$$

When var(ξ_t) goes to infinity, γ approaches *0.* In that case agents' utility is completely overwhelmed by random events making it impossible for them to choose rationally between the two rules. As a result, they decide to be fundamentalist or extrapolator by tossing a coin and the probability to be fundamentalist (or extrapolator) is exactly 0.5. When $\gamma = \infty$ the variance of the random components is zero (utility is then fully deterministic) and the probability of using a fundamentalist rule is either 1 or 0.

APPENDIX 2: *forecasting inflation*

Agents also have to forecast inflation. A similar simple heuristics is used as in the case of output gap forecasting, with one rule that could be called a fundamentalist rule and the other a naïve rule. (See Brazier et al. (2008) for a similar setup). We assume an institutional set-up in which the central bank announces an explicit inflation target. The fundamentalist rule then is based on this announced inflation target, i.e. agents using this rule have confidence in the credibility of this rule and use it to forecast inflation. Agents who do not trust the announced inflation target use the naïve rule, which consists in extrapolating inflation from the past into the future.

The fundamentalist rule will be called an "inflation targeting" rule. It consists in using the central bank's inflation target to forecast future inflation, i.e.

$$\tilde{E}_t^f \pi_{t+1} = \pi^* \tag{13}$$

where the inflation target is π^*. The "naive" rule is defined by

$$\tilde{E}_t^e \pi_{t+1} = \pi_{t-1} \tag{14}$$

The market forecast is a weighted average of these two forecasts, i.e.

$$\tilde{E}_t \pi_{t+1} = \beta_{f,t} \tilde{E}_t^f \pi_{t+1} + \beta_{e,t} \tilde{E}_t^e \pi_{t+1} \tag{15}$$

$$\beta_{f,t} + \beta_{e,t} = 1 \tag{16}$$

The same selection mechanism is used as in the case of output forecasting to determine the probabilities of agents trusting the inflation target and those who do not trust it and revert to extrapolation of past inflation, yielding equations similar to (8) and (9).

This inflation forecasting heuristics can be interpreted as a procedure of agents to find out how credible the central bank's inflation targeting is. If this is very credible, using the announced inflation target will produce good forecasts and as a result, the probability that agents will rely on the inflation target will be high. If on the other hand the inflation target does not produce good forecasts (compared to a simple extrapolation rule) the probability that agents will use it will be small.

Appendix 3 Solving the model

The solution of the model is found by first substituting (3) into (1) and rewriting in matrix notation. This yields:

$$\begin{bmatrix} 1 & -b_2 \\ -a_2c_1 & 1-a_2c_2 \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t \end{bmatrix}$$
$$= \begin{bmatrix} b_1 & 0 \\ -a_2 & a_1 \end{bmatrix} \begin{bmatrix} \widetilde{\mathrm{E}}_{\mathrm{t}}\pi_{t+1} \\ \widetilde{\mathrm{E}}_{\mathrm{t}}y_{t+1} \end{bmatrix} + \begin{bmatrix} 1-b_1 & 0 \\ 0 & 1-a_1 \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ a_2c_3 \end{bmatrix} r_{t-1}$$
$$+ \begin{bmatrix} \eta_t \\ a_2u_t + \varepsilon_t \end{bmatrix}$$

i.e.

$$\boldsymbol{AZ_t} = \boldsymbol{B\widetilde{E_t}\,Z_{t+1}} + \boldsymbol{CZ_{t-1}} + \boldsymbol{b}r_{t-1} + \boldsymbol{v_t} \tag{17}$$

where bold characters refer to matrices and vectors. The solution for $\boldsymbol{Z_t}$ is given by

$$\boldsymbol{Z_t} = \boldsymbol{A^{-1}}\left[\boldsymbol{B\widetilde{E_t}\,Z_{t+1}} + \boldsymbol{CZ_{t-1}} + \boldsymbol{b}r_{t-1} + \boldsymbol{v_t}\right] \tag{18}$$

The solution exists if the matrix $\boldsymbol{A}$ is non-singular, i.e. $(1-a_2c_2)-a_2b_2c_1 \neq 0.$ The system (18) describes the solutions for y_t and π_t given the forecasts of y_t and π_t discussed in equations (6) and (15). The solution for r_t is found by substituting y_t and π_t obtained from (18) into (3).

In Table 1 the parameters used in the calibration exercise are presented. The values of the parameters are based on what we found in the literature. We indicate the sources from which these numerical values were obtained. The model was calibrated in such a way that the time units can be considered to be quarters. The three shocks (demand shocks, supply shocks and interest rate shocks) are independently and identically distributed (i.i.d.) with standard deviations of 0.5%. These shocks produce standard deviations of the output gap and inflation that mimic the standard deviations found in the empirical data using quarterly observations for the US and the Eurozone. The way we did this is be described in more detail in De Grauwe and Ji(2020). Finally, it should be mentioned that the parameter values in Table 1 ensure local stability of the steady state.

Table 1: Parameter values of the calibrated model

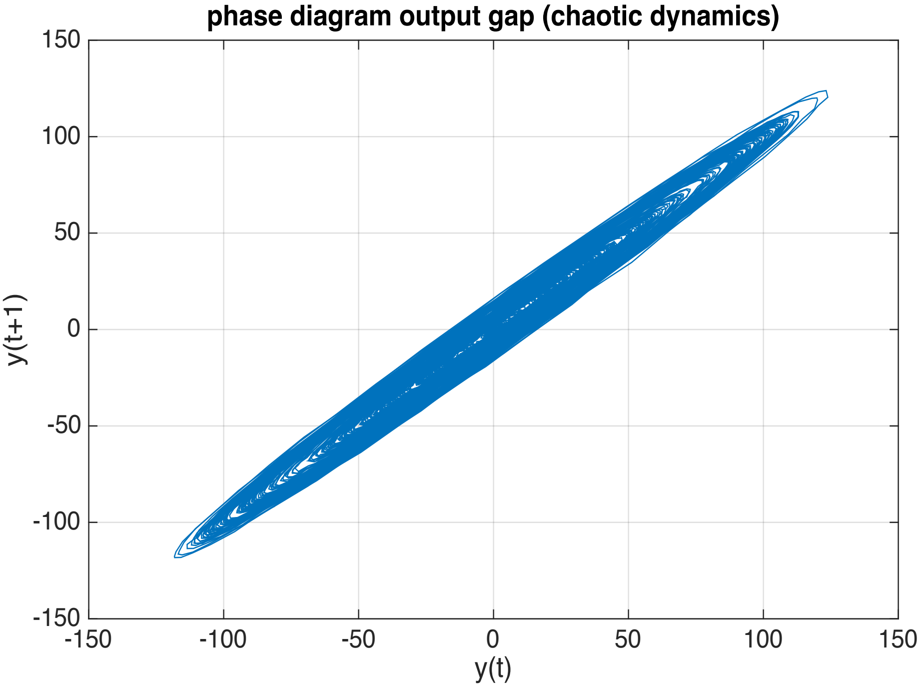
a1 = 0.5	coefficient of expected output in output equation (Smets and Wouters(2003))
a2 = -0.2	interest elasticity of output demand (McCallum and Nelson (1999)).
b1 = 0.5	coefficient of expected inflation in inflation equation (Smets and Wouters (2003))
b2 = 0.05	coefficient of output in inflation equation,
π^*=0	inflation target level
c1 = 1.5	coefficient of inflation in Taylor equation (Blattner and Margaritov(2010))
c2 = 0.5	coefficient of output in Taylor equation (Blattner and Margaritov(2010))
c3 = 0.5	interest smoothing parameter in Taylor equation (Blattner and Margaritov(2010))
γ = 2	intensity of choice parameter (Kukacka,et al.(2018))
σ_v = 0.5	standard deviation shocks output
σ_η = 0.5	standard deviation shocks inflation
σ_u = 0.5	standard deviation shocks Taylor
ρ = 0.5	memory parameter (see footnote 3)

Notes:

1. Kukacka, Jang and Sacht (2018) used the US and Eurozone data and applied the simulated maximum likelihood method to estimate the same model we use here with satisfying results. The estimated values of some of the parameters are in the same range as the ones we have used in our simulations. For example, these authors find that the rigidity coefficient b_2 of the Eurozone is very close to zero and the switching parameter γ is around 7. For the US data, the value of b_2 is significantly higher varying between 0.23-0.64 and γ is in the range of 0.53-0.95. Our parameters are in line with these estimation results.
2. c_1 and c_2 satisfy the stability condition outlined in section 3.

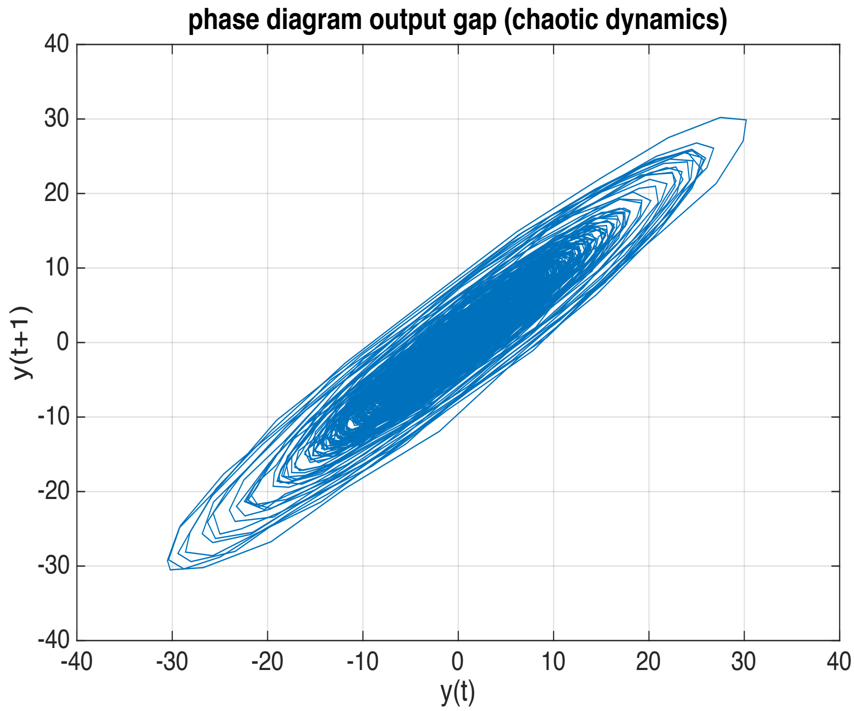
APPENDIX 4

Figure A1



Note: this phase diagram is obtained for c1=1.4, c2=0, c3=0.5 (current Taylor)

Figure A2



Note: This phase diagram was obtained for c1=1.5, c2=0.5, c3=0.88 (forward Taylor)

Appendix 5. Defining animal spirits

The forecasts made by extrapolators and fundamentalists play an important role. In order to highlight this role we define an index of market sentiments S_t, called "animal spirits". It reflects how optimistic or pessimistic these forecasts are.

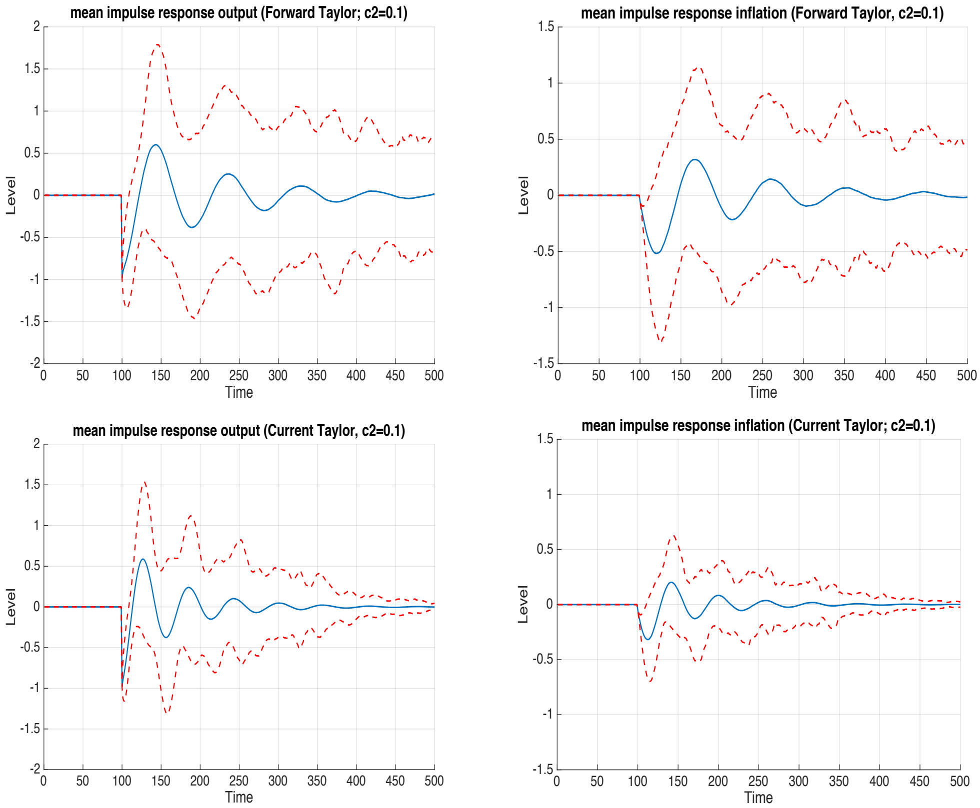
$$S_t = \begin{cases} \alpha_{e,t} - \alpha_{f,t} & \text{if } y_{t-1} > 0 \\ -\alpha_{e,t} + \alpha_{f,t} & \text{if } y_{t-1} < 0 \end{cases} \tag{19}$$

where S_t is the index of animal spirits. This can change between -1 and +1. There are two possibilities:

- When $y_{t-1} > 0$, extrapolators forecast a positive output gap. The fraction of agents who make such a positive forecasts is $\alpha_{e,t}$. Fundamentalists, however, then make a pessimistic forecast since they expect the positive output gap to decline towards the equilibrium value of 0. The fraction of agents who make such a forecast is $\alpha_{f,t}$. We subtract this fraction of pessimistic forecasts from the fraction $\alpha_{e,t}$ who make a positive forecast. When these two fractions are equal to each other (both are then 0.5) market sentiments (animal spirits) are neutral, i.e. optimists and pessimists cancel out and $S_t = 0$. When the fraction of optimists $\alpha_{e,t}$ exceeds the fraction of pessimists $\alpha_{f,t}$, S_t becomes positive. As we will see, the model allows for the possibility that $\alpha_{e,t}$ moves to 1. In that case there are only optimists and $S_t = 1$.
- When $y_{t-1} < 0$, extrapolators forecast a negative output gap. The fraction of agents who make such a negative forecasts is $\alpha_{e,t}$. We give this fraction a negative sign. Fundamentalists, however, then make an optimistic forecast since they expect the negative output gap to increase towards the equilibrium value of 0. The fraction of agents who make such a forecast is $\alpha_{f,t}$. We give this fraction of optimistic forecasts a positive sign. When these two fractions are equal to each other (both are then 0.5) market sentiments (animal spirits) are neutral, i.e. optimists and pessimists cancel out and $S_t = 0$. When the fraction of pessimists $\alpha_{e,t}$ exceeds the fraction of optimists $\alpha_{f,t}$ S_t becomes negative. The fraction of pessimists, $\alpha_{e,t}$, can move to 1. In that case there are only pessimists and $S_t = -1$.

Appendix 5: Impulse responses to negative demand shock

Figure 14



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