Oxford Economic Papers, 2022, 1–27
https://doi.org/10.1093/oep/gpac024

On the use of current and forward-looking data in monetary policy: a behavioural macroeconomic approach

Paul De Grauwe[a,*] **and Yuemei Ji**[b]

[a]London School of Economics and Political Science, London, WC2A 2AE, UK
[b]University College London, London, WC1E 6BT, UK

*Corresponding author: p.c.de-grauwe@lse.ac.uk

Abstract

We analyse the question of whether the use of forward-looking data in monetary policy is to be preferred over the use of current data. We use a behavioural macroeconomic model that generates periods of tranquillity alternating with crisis periods characterized by fat tails in the distribution of output gap. We find that in a strict inflation targeting (SIT) regime, the use of forward-looking data leads to a lower quality of monetary policymaking than in a dual mandate monetary policy regime, because the first regime creates more extreme movements in output and inflation than the second one. We also find that nowcasting tends to improve the quality of monetary policy, especially in a SIT regime. Finally, we provide a case study of monetary policies in the USA and the eurozone during 2000–20.

JEL classifications: E30, E50, E70

1. Introduction

Modern macroeconomics has given central stage to forward -looking agents. This means that agents are assumed to make decisions based on forecasts of the variables that matter. Consumers, for example, are supposed to base their decision to consume on what they expect their future income to be. Similarly, policymakers in a rational expectations (REs) setting are assumed to make decisions based on forecasts of the variables they wish to influence. In this logic, central bankers should set the interest rate based on their expectations (forecasts) of future inflation and output gap (or growth rate, see Svensson, 1997; Batini and Haldane, 1999; Clarida *et al.*, 2000).

The question that arises here is whether this is a sensible decision rule when the future is highly uncertain. We illustrate the problem with Figs 1 and 2. These show the actual inflation rates and the inflation rates as forecasted a year earlier by professional forecasters in

Fig. 1. US inflation.
Source: US Federal Reserve (Fed).

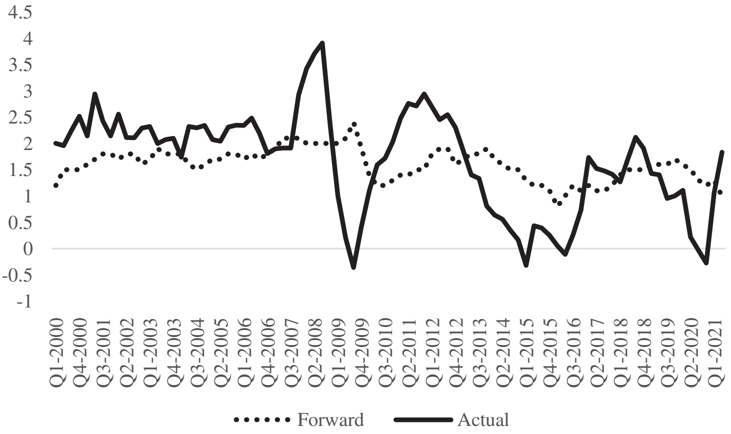

Fig. 2. Eurozone Inflation.
Source: European Central Bank (ECB).

the USA and the eurozone during 2000–21. We observe not only that the forecast errors (measured by the distance between the two lines) are large, but more importantly that a systematic bias seems to occur. During periods of increasing inflation forecasters underestimate actual inflation and during periods of declining inflation they overestimate actual inflation. These biases often last for several years. For example, during the 2013–7 period when both in the USA and in the eurozone deflation set in and the zero-lower bound was hit, forecasters continued to expect positive inflation rates exceeding 1% for several years.

From the preceding it will be clear that when central banks rely on forecasts to make their decisions they are likely to often make significant policy mistakes. The question then is whether they can improve the quality of their policy decisions by not relying on forecasts, but instead by relying on currently observed variables. This is the question we wish to analyse in this article.

There is empirical evidence that central banks understand the implications of radical uncertainty for policymaking, and as a result often rely on currently observed values of inflation and output when they have to make decisions about monetary policies. Taylor and Williams (2010) survey the recent literature and they find evidence that the Taylor rule works well when current observations of inflation and output gap (or growth rates) are used. This indicates that central banks base their decisions on currently observed variables. The empirical evidence, however, is mixed suggesting that central banks use both forward-looking and currently observed variables in their policymaking (see Orphanides, 2001; Gorter *et al.*, 2008 ; Blattner and Margaritov, 2010; Belke and Klose, 2011).

In this article, we explore the question of how the use of currently observed data of output and inflation affects the quality of monetary policymaking as compared to the use of forward-looking data (market forecasts of output and inflation). The novelty of our article is to use a behavioural macroeconomic model to analyse these questions.

The behavioural model is characterized by the assumption that agents experience cognitive limitations by preventing them from having REs. 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. This heuristic switching model produces endogenous waves of optimism and pessimism (animal spirits) that drive the business cycle in a self-fulfilling way, that is, optimism (pessimism) leads to an increase (decline) in output, and the increase (decline) in output in term intensifies optimism (pessimism). See Brock and Hommes, 1997; Branch and McGough, 2010; De Grauwe, 2012; De Grauwe and Ji, 2019; Hommes and Lustenhouwer, 2019, and many others.

We will show that the answer to the question of whether the use of forward -looking data is to be preferred to the use of current data in conducting monetary policies very much depends on the monetary policy regime. We will contrast two regimes, one is the strict inflation targeting (SIT) regime and the other the dual mandate (DM) regime. We will show that the SIT regime produces more extreme values of animal spirits and thus more booms and busts. This then, in turn, increases forecasting errors and as a result tends to decrease the quality of monetary policies that rely on forward -looking data. This is less the case in a DM regime.

We will also conduct a case study of the monetary policies of the Fed and the ECB during periods of great volatility of output growth. It will be shown that central banks have learned that during periods of turmoil they should focus on currently observed values of growth and inflation, and not on their forecasts. We will show that the Fed did this during the recessions of 2001 and 2008–9 and that both the Fed and the ECB followed this approach during the pandemic. When the central bank fails to do so, like the ECB in 2008 when it raised the interest rate in the midst of a recession and again in 2011 in similar circumstances, it is likely to make big policy mistakes. We will document that in the case of the ECB this appears to have been due to the fixation of the ECB on inflation forecasts that stubbornly pointed to future inflation.

Our analysis will also allow us to focus on the use of ‘nowcasting’, that is, a technology that allows central bank to reduce the noise in the observations of current output and inflation. It will be shown that nowcasting improves the quality of monetary policymaking and that this improvement is more pronounced in the SIT regime than in the DM regime.

The organization of the article is as follows. Sections and 3 describe the model and the two Taylor rules. Section 4 discusses the calibration and the stability conditions of the model. Section 5 presents the basic results of the model. Section 6 compares the performance of the two Taylor rules under the two different monetary policy regimes. Section 7 provides sensitivity analysis on how different factors affect the performance of the two Taylor rules. It discusses the attractiveness of nowcasting. Section 8 provides a case study of monetary policies in the USA and the eurozone during 2000–20. We conclude in Section 9.

2. The model

The basic model consists of an aggregate demand equation, an aggregate supply equation, and a Taylor rule (see also De Grauwe, 2011).

The aggregate demand equation can be expressed in the following way:

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

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 $\tilde{\mathrm{E}}_t \pi_{t+1}$ and $\tilde{\mathrm{E}}_t y_{t+1}$. The tilde above E refers to the fact that expectations are not formed rationally. How exactly these expectations are formed will be specified subsequently.

The aggregate supply equation is represented in Equation (2). This New Keynesian Philips curve includes a forward-looking component, $\tilde{\mathrm{E}}_t \pi_{t+1}$ 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.

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

Equations (1) and (2) can be derived from expected utility maximization of consumers and expected profit maximization of firms (see Hommes and Lustenhouwer, 2019; De Grauwe and Ji, 2020).

We will use two versions of the Taylor rule. Both versions follow the idea that interest rate policies respond to both inflation and output gap. The central bank can use two types of data to obtain information about output gap and inflation. These data can be current information (such as manufacturing purchasing managers' index, industrial production, factory orders, retail sales, and consumer spending) or forward-looking information (such as business sentiment, consumer confidence, and professional forecasts).

In the first version of the Taylor rule the central bank has access to data about the current state of the economy (e.g., output gap and inflation). They then use these currently observed data to set the interest rate. We will call this a 'current-looking Taylor rule'. This behaviour can be described as follows:

$$r_t = (1 - c_3)[c_1((\pi_t + \varepsilon_t) - \pi^*) + c_2(y_t + \theta_t)] + c_3 r_{t-1} + u_t \tag{3a}$$

where π^* is the target rate of inflation. The central bank is assumed to raise the interest when the observed inflation rate increases relative to the announced inflation target. The intensity with which it does this is measured by the coefficient c_1. Similarly, when the output gap increases the central bank is assumed to raise the interest rate. The intensity with which it does this is measured by c_2 which indicates the ambitions the central bank has to stabilize output. A central bank that does not care about output stabilization sets $c_2 = 0$. We say that this central bank applies SIT. The central bank wants to smoothen interest rate changes (see Levin *et al.*,1999; Woodford, 1999). This is shown by including a lagged interest rate assuming $0 < c_3 < 1$.

We assume that the current inflation and output gap are not observed perfectly. There is some noise that arises from the fact that at time t the current inflation and output gap are not yet observed. This noise is represented by, respectively, ε_t and θ_t. For example, industrial production, factory orders, retail sales, and consumer spending have a significant delay (sometimes more than 1 month) in its release. The central bank can increase the precision with which it observes π_t and y_t at time t by 'nowcasting', that is, by using high frequency and large data sets providing quick information about current variables like output and inflation (Giannone *et al.*, 2008). However, even then some noise will persist. Nowcasting can then be seen as an information technology that reduces the noise ε_t and θ_t.

In the second version of the Taylor rule, the central bank has access to forward-looking data which include the surveys of business and consumer confidence, that is, forecasts about output and consumption in the near future. In this second version of the Taylor rule the central bank uses this information set in setting interest rates. We can therefore call this behaviour to be *forward looking* described in Equation (3b).

$$r_t = (1 - c_3)\left[c_1\left(\tilde{\mathrm{E}}_t\pi_{t+1} - \pi^*\right) + c_2\tilde{\mathrm{E}}_t y_{t+1}\right] + c_3 r_{t-1} + u_t \tag{3b}$$

In this formulation of the Taylor rule, the central bank uses market forecasts of inflation and output gap. We do not include noise terms in the forward-looking Taylor rule. This is because market forecasts data are less subject to time delay compared to current output and inflation. With the help of big data nowadays, most central banks have good quality data on market forecasts. According to the forward-looking Taylor rule, the central bank then raises (reduces) the interest rate when the market forecasts of inflation exceed (are below) the target and when the forecasted output gap is positive (negative).

Equations (1)–(3a/b) also include different shocks that can hit the economy. There are demand shocks v_t, supply shocks η_t, and interest rate shocks u_t. These shocks are normally distributed with mean zero and a constant standard deviation.

3. Expectation formation and animal spirits

We analyse how the forecast of output gap $\tilde{\mathrm{E}}_t y_{t+1}$ and inflation $\tilde{\mathrm{E}}_t\pi_{t+1}$ are formed in the model. The REs 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 agents have cognitive limitations that 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 and Zakelj, 2014).

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 an 'extrapolator' 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 Kryvtsov and Petersen, 2013; Assenza *et al.*, 2014; Pfajfar and Zakelj, 2014). The fundamentalist and extrapolator rules for output gap are specified as follows:

$$\tilde{E}_t^f y_{t+1} = 0 \tag{4}$$

$$\tilde{E}_t^e y_{t+1} = y_{t-1} \tag{5}$$

This kind of simple heuristic has often been used in the behavioural macroeconomics and finance literature (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 behaviour. In De Grauwe (2012), more complex rules are used.

The market forecast can be obtained as a weighted average of these two forecasts:

$$\tilde{E}_t y_{t+1} = \alpha_{f,t}\tilde{E}_t^f y_{t+1} + \alpha_{e,t}\tilde{E}_t^e y_{t+1} \tag{6}$$

$$\alpha_{f,t} + \alpha_{e,t} = 1 \tag{7}$$

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

Agents in our model are willing to learn, that is, they continuously evaluate their forecast performance. We specify a switching mechanism of how agents adopt specific rule. As shown in the Supplementary Appendix, we follow the discrete choice theory (see Anderson *et al.*, 1992; Brock and 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 $U_{e,t}$ are the past forecast performance (utility) of using the fundamentalist and the extrapolator 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 forecast inflation. Similar heuristics rules as in the case of output forecasting can be used. We assume that the fundamentalists use the announced inflation target as the fundamental value to which inflation will return. They are thus trusting the central bank. The extrapolators distrust the central bank and extrapolate the past inflation into the future. More detail can be found in De Grauwe and Ji (2019). This simple heuristics allows us to use the switching mechanism similar to the ones specified in Equations (8) and (9).

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. It is obtained from the fraction of extrapolators ($\alpha_{e,t}$) and fundamentalists ($\alpha_{f,t}$) as follows:

$$S_t = \begin{cases} \alpha_{e,t} - \alpha_{f,t} & if\ y_{t-1} > 0 \\ -\alpha_{e,t} + \alpha_{f,t} & if\ y_{t-1} < 0 \end{cases} \tag{10}$$

This index of animal spirits S_t can change between −1 and +1. As extrapolators and fundamentalists make different directions of forecasts[1] (i.e., one optimistic and the other pessimistic), the difference of the fractions $\alpha_{e,t}$ and $\alpha_{f,t}$ determines whether market sentiments (animal spirits) S_t are optimistic or pessimistic. When the fraction of pessimists (optimists) exceeds the fraction of optimists (pessimists), S_t becomes negative (positive).

4. Calibration and stability condition

The standard procedure to solve the model can be found in De Grauwe and Ji (2019). As our model has strong non-linear features, we use numerical methods to analyse the dynamics created by the model. We calibrate the model based on numerical values from the literature for the parameters of the model (in Table 1).

The model is simulated over 10,000 periods. We analyse the conditions under which the model produces stable outcomes and the results are shown in Tables 2 and 3. Fixing $c_3 = 0.5$, we allow the parameters c_1 (inflation parameter) and c_2 (output gap parameter) in the Taylor rule to vary.

Table 1. Parameter values of the calibrated model

$a_1 = 0.5$	Coefficient of expected output in output equation (Smets and Wouters, 2003)
$a_2 = -0.2$	Interest elasticity of output demand (McCallum and Nelson, 1999).
$b_1 = 0.5$	Coefficient of expected inflation in inflation equation (Smets and Wouters, 2003)
$b_2 = 0.05$	Coefficient of output in inflation equation.
$\pi^* = 0$	Inflation target level
$c_1 = 1.5$	Coefficient of inflation in Taylor equation (Blattner and Margaritov, 2010)
$c_2 = 0.5$	Coefficient of output in Taylor equation assuming a DM Central Bank (Blattner and Margaritov, 2010)
$c_2 = 0.1$	Coefficient of output in Taylor equation assuming a SIT Central Bank. The size of c_2 see discussion in Belke and Klose (2011)
$c_3 = 0.5$	Interest smoothing parameter in Taylor equation (Blattner and Margaritov, 2010)
$\gamma = 2$	Intensity of choice parameter, see Kukacka *et al.* (2018)
$\sigma_v = 0.5$	Standard deviation shocks output
$\sigma_\eta = 0.5$	Standard deviation shocks inflation
$\sigma_u = 0.5$	Standard deviation shocks Taylor
σ_ε and σ_θ	We choose low (0,0) and high value (1,0) to analyse efficiency of nowcasting
$\rho = 0.5$	Memory parameter (see footnote 3 in the Supplementary Appendix)

---

[1] When $y_{t-1} > 0$, extrapolators forecast a positive output gap. Fundamentalists, however, then make a pessimistic forecast since they expect the positive output gap to decline towards the equilibrium value of 0. When $y_{t-1} < 0$, extrapolators forecast a negative output gap. Fundamentalists make an optimistic forecast since they expect the negative output gap to increase towards the equilibrium value of 0.

Table 2. Stability analysis, current Taylor rule ($\sigma_\varepsilon, \sigma_\theta = 0$), no noise

	Output parameter c_2									
Inflation parameter c_1	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	S	S	S	S	S	S	S	S	S	S
1,6	S	S	S	S	S	S	S	S	S	S
1,9	S	S	S	S	S	S	S	S	S	S
2,2	S	S	S	S	S	S	S	S	S	S
2,5	S	S	S	S	S	S	S	S	S	S

Source: Authors' calculations.

Table 3. Stability analysis, forward Taylor rule

	Output parameter c_2									
Inflation parameter c_1	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	S	S	S	S	S	S	S	S	S
1,3	U	S	S	S	S	S	S	S	S	S
1,6	U	S	S	S	S	S	S	S	S	S
1,9	U	S	S	S	S	S	S	S	S	S
2,2	U	S	S	S	S	S	S	S	S	S
2,5	U	S	S	S	S	S	S	S	S	S

Source: Authors' calculations.

We find in both Taylor regimes the crucial role of c_1 in maintaining stability of the model. The parameter $c_1 \geq 1$ to ensure stability in both Taylor rule regimes. This so-called Taylor principle is found in most macroeconomic models. The parameter c_2 that expresses the central bank's preference for output stabilization also matters. A general discussion on the stability conditions of behavioural models can be found in De Grauwe and Ji (2020) and Hommes and Lustenhouwer (2019).

In Tables 2 and 3, we present the stability condition of the two Taylor rules (unstable indicated as '*u*' and stable as '*s*'). There is a contrast here between the two Taylor rule regimes. Under the current Taylor rule regime (without noise), the model produces stable solutions for all values of $c_1 \geq 1$ and $c_2 \geq 0$. Under the forward-looking Taylor rule regime, a value of $c_2 = 0$ leads to instability. Thus, the forward-looking Taylor regime produces more problems of instability and high volatility than the current Taylor regime. Note that we have assumed that the central bank observes current variables and current market forecasts without noise. Later we will also analyse what happens when there is noise in the observation of current variables.

The previous diagnostic stability analysis suggests that it will be useful to distinguish two types of central banks. The first one is a 'Strict Inflation Targeting' central bank (SIT) whose sole objective is to stabilize inflation. This is a central bank that sets c_2 close to zero. Assume it sets $c_2 = 0.1$. The second central bank can be called as 'Dual Mandate' (DM) central bank. This is a central bank that sets c_2 high enough to reflect its desire to stabilize the output gap. Assume it sets $c_2 = 0.5$.

5. Results of the model

Before analysing the different characteristics of the results obtained under the two monetary regimes (SIT and DM), we present some general results of the model that allow us to better understand the working of this behavioural model. We use the parameter values presented in Table 1 (including setting $c_2 = 0.5$, thus implicitly assuming a DM central bank). At a later stage, we will perform Monte-Carlo experiments to check the robustness of the results. We analyse the model for both the current and the forward Taylor rules.

The results obtained using the current Taylor rule (without noise) are presented in Fig. 3, 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.

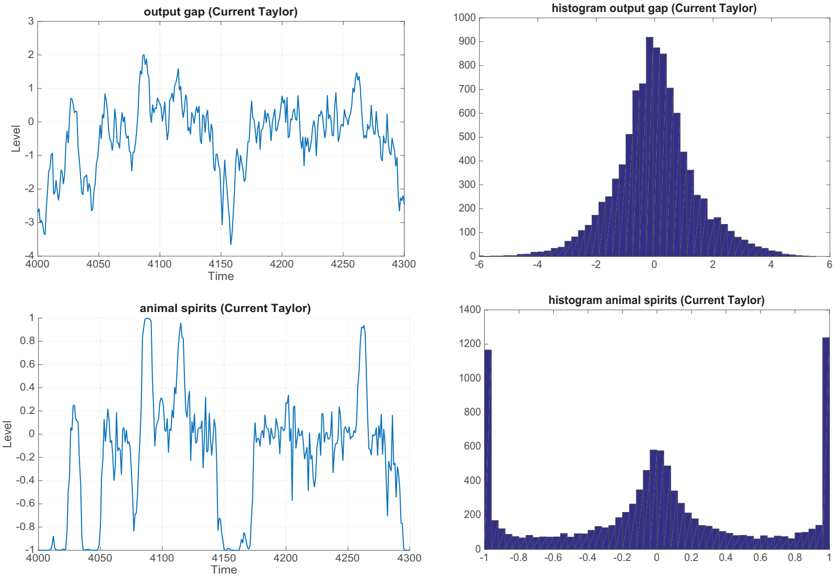

Fig. 3. Output and animal spirits, Current Taylor ($c_2 = 0.5$).

The model produces waves of optimism and pessimism that can lead to situations where everybody becomes optimist ($S_t = 1$) or pessimist ($S_t = -1$). These waves of optimism and pessimism are generated endogenously, that is, 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. 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 distributions 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) or +1 (extreme optimism). These extreme values of animal spirits explain the fat tails observed in the distribution of the output gap. These fat tails episodes are usually associated with crisis situations.

When comparing these results obtained under the current Taylor rule regime with those obtained under the forward Taylor rule regime, we find that they are similar. This is shown in Fig. 4.

The results discussed up to now use the point estimates of the parameters of the model as given in Table 1. It will be interesting to know how sensitive these results are to the choice of these numerical values. To do so we perform a Monte-Carlo experiment in which the parameters in Table 1 vary within a certain range. We set this range as + and −50% of the point estimates and assumed a uniform distribution (e.g., a_1 varies uniformly between 0.25 and 0.75). We then performed 1,000 simulations of 10,000 periods where for each simulation we choose the parameter values randomly within that range. We show the frequency distributions obtained from this exercise in Fig. 5. We observe that the results are very similar to those obtained in Figs 3 and 4.

6. Performance of central bank: two regimes

Nowadays through big data and nowcasting technologies, central banks have perfect knowledge about the current output gap and inflation and they also have perfect knowledge on the market forecasts of output gap and inflation. In Section 7, we will study how relaxing these assumptions affect the results. The question we ask in this section is how the information set affects the performance of the Taylor rules. Our analysis will very much depend on the regimes of central bank policy.

We will perform similar Monte-Carlo exercises, that is, we allow the parameter values to be chosen randomly within the ranges as specified in the previous section. In this way,

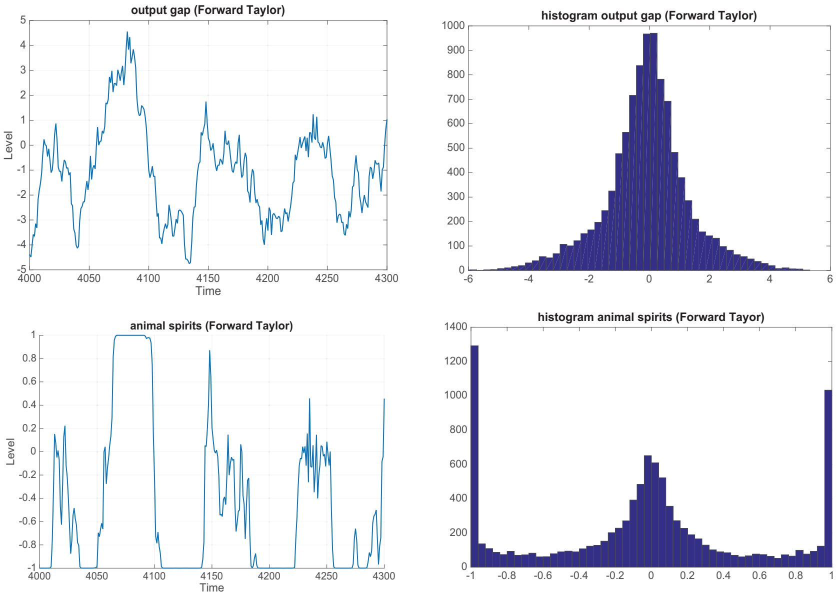

Fig. 4. Output and animal spirits, Forward Taylor ($c_2 = 0.5$).

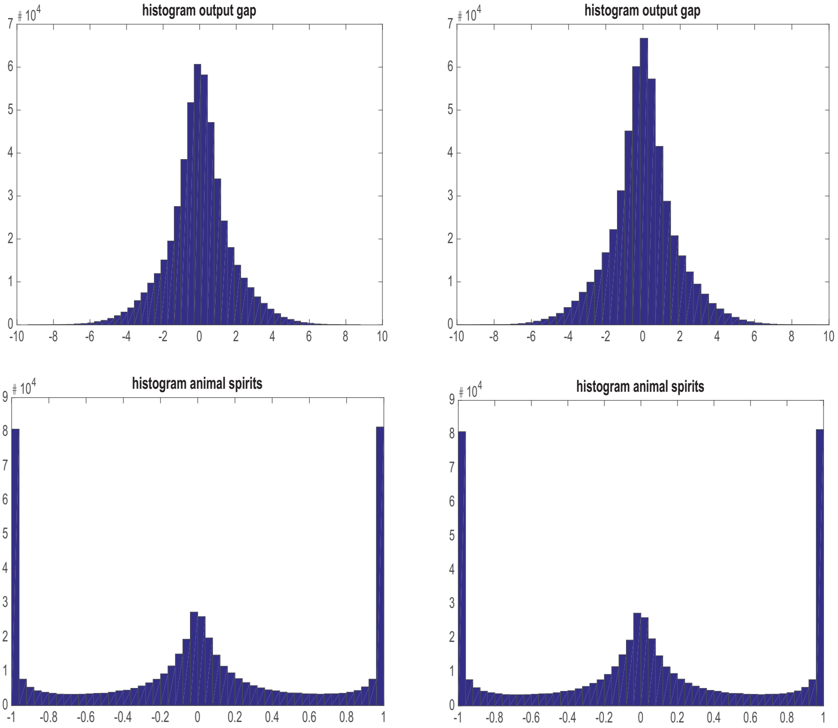

Fig. 5. Frequency distribution output and animal spirits.

we obtain results that are more robust as they are not dependent on the point estimates in Table 1.

6.1 SIT central bank

Turning to the model in a regime of SIT ($c_2 = 0.1$), we show the results in Table 4. We find that 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.

6.2 DM central bank

Next, we analyse the model assuming a ‘dual mandate’ central bank, that is, $c_2 = 0.5$. We analyse the model for both the current and the forward-looking Taylor rules. In Table 5, we present indicators of variability obtained under the two Taylor rules. The first striking difference between Tables 4 and 5 is that the variability of output gap and inflation is significantly lower in the DM regime than in the SIT regime. We will come back to this result and give it an interpretation. Secondly, we find that in the DM regime the two Taylor rules produce similar levels of variability of output and inflation. 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).

How can the previous results be explained? First, when the central bank puts too little weight on output stabilization (a small c_2) as it does in the SIT central bank, 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 and inflation. As a result, the volatility of both output gap and inflation will tend to be higher in the SIT regime than in the DM regime. This is what we observe when comparing Tables 4 and 5. Secondly, when this boom–bust feature is strong, as it is in the SIT regime, the forward-looking Taylor rule exacerbates this feature. The reason is that when booms and busts occur, that is, 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, an SIT and forward-looking central bank will make many policy moves that turn out to be wrong. 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-looking Taylor rule is used the quality of policymaking declines, leading to greater variability of the output gap.

Table 4. Output gap and inflation volatilities ($c_2 = 0.1$)

	std (y)	std(π)	Min(y)	Max(y)	Min (π)	Max(π)
Current Taylor	3.62	2.67	−20.04	20.38	−20.90	21.64
Forward Taylor	4.53	3.36	−28.81	23.31	−27.56	25.28

(sigma 4 and 5 = 0; sigma 1 and 2 = 0.5)

Source: these estimates of volatilities are obtained from 1,000 time-domain simulations allowing for randomly chosen parameter values within specified range.

Table 5. Output gap and inflation volatilities ($c_2 = 0.5$)

	std (y)	std(π)	Min(y)	Max(y)	Min (π)	Max(π)
Current Taylor	1.62	1.81	−9.48	10.82	−10.60	12.35
Forward Taylor	1.72	1.91	−9.81	10.38	−9.81	11.16

(sigma 4 and 5 = 0; sigma 1 and 2 = 0.5).

Source: these estimates of volatilities are obtained from 1000 time domain simulations allowing for randomly chosen parameter values within specified range.

We checked for this interpretation by calculating the forecast errors made by agents (and by the SIT central bank) under the current- and forward-looking Taylor rules in Figs 6 and 7. We plot the squared forecast errors of output gap (Fig. 6) and inflation (Fig. 7) 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.

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 strict inflation central bank to use currently observed output and inflation to set the interest rate. Given the extreme volatility of these variables when animal spirits are intense, the central bank that uses market expectations will make many policy errors that have to be corrected afterwards.

From the previous analysis, we conclude that in a DM central bank regime the difference between current and forward-looking Taylor rules is insignificant. In contrast in an SIT regime a forward Taylor rule produces significantly higher volatility of the output gap.

7. Performance of Taylor rules: sensitivity analysis

7.1 The importance of output stabilizer c_2

To make the previous conclusions more precise, we computed the sensitivity of output volatility with respect to changes in the c_2 parameter in the Taylor rule. For the sake of completeness, we repeat the exercise for inflation volatility.

As before, we apply a Monte-Carlo technique in our simulation. We vary c_2 between 0.05 and 1 with increments of 0.001. With each new value of c_2 we select the parameters of the model randomly within the range specified earlier (+ and −50% from point estimate in Table 1).

We computed the standard deviations in output gap and inflation for different values of c_2 and we show the results in Figs 8 and 9. The parameter c_2 is shown on the horizontal axis and the standard deviations of the output gap and inflation, on the vertical axis. We find that when c_2 is large enough the differences in the performance of the current and forward Taylor rules become very small. Only when c_2 is close to zero (SIT) does the current Taylor rule perform significantly better than the forward Taylor rule in keeping output and inflation volatility low.

We also performed *t*-tests to investigate the difference between the mean volatilities produced by the forward and current rules. When $c_2 \leq 0.5$, the mean volatilities of the forward

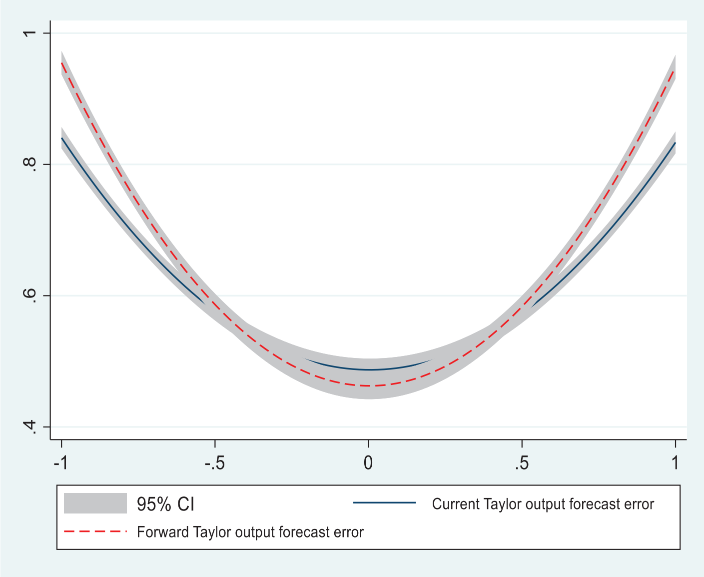

Fig. 6. Squared forecast errors output gap and animal spirits.
Source: Authors' calculations.

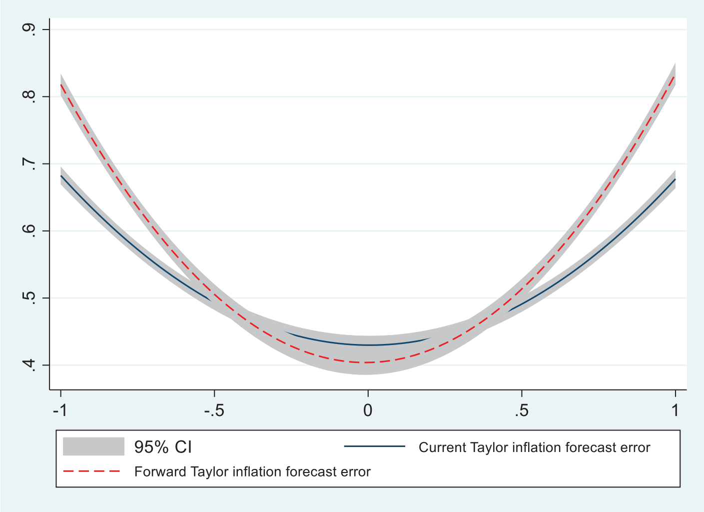

Fig. 7. Squared forecast errors inflation and animal spirits.
Source: Authors' calculations.

Taylor rule are significantly larger than the mean of the current Taylor rule (2.82 versus 2.41); when $c_2 > 0.5$, the mean volatility of the forward Taylor rule is significantly larger than the mean volatility of the current Taylor rule (1.42 versus 1.35) but this difference is so small to be economically unimportant. Thus, when central banks care about output stabilization as measured by c_2 the current and forward Taylor rules perform (almost) equally well in stabilizing output and inflation.

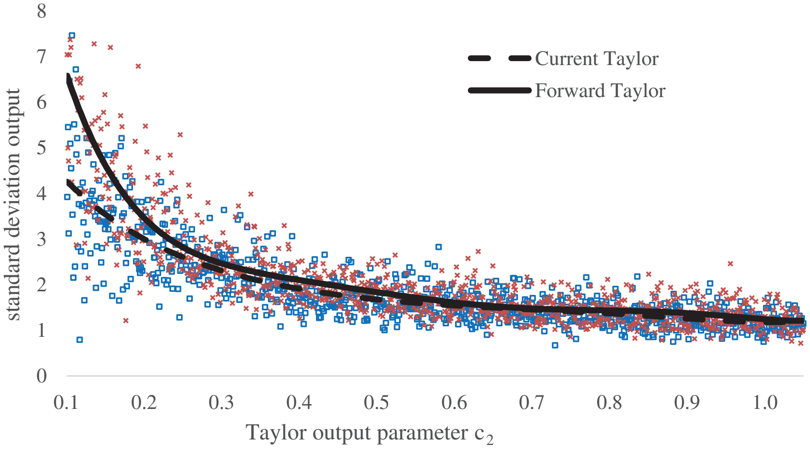

Fig. 8. Standard deviation output and c_2.

Note: (i) c_2 varies between 0.05 and 1 with increments of 0.001. With each new value of c_2 we select the parameters of the model randomly within the specified range. We obtain a range of standard deviations and compute the best fit. (ii) when $c_2 \leq 0.5$, mean(forward) = 2.82 and mean(current) = 2.41; test of hypothesis that difference between means of forward and current >0: *t*-test = 7.7025 and P-value = 0; when $c_2 > 0.5$, mean(forward) = 1.41 and mean(current) = 1.35, test of hypothesis that difference between means of forward and current >0: *t*-test = 3.7 and P-value = 0.0001.

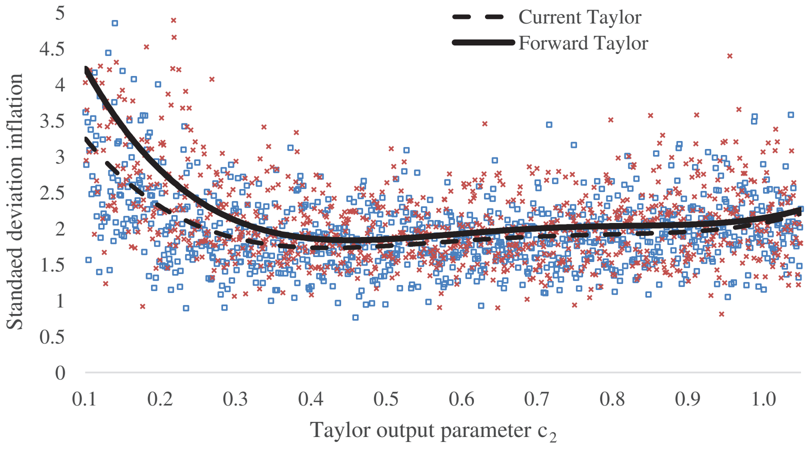

Fig. 9. Standard deviation inflation and c_2.

Note: (i) c2 varies between 0.05 and 1 with increments of 0.001. With each new value of c_2, we select the parameters of the model randomly within the specified range. We obtain a range of standard deviations and compute the best fit. (ii) when $c_2 \leq 0.5$, mean(forward) = 2.38 and mean(current) = 2.06, test of hypothesis that difference between means of forward and current >0: t test = 6.2419 and P-value = 0; when $c_2 > 0.5$, mean(forward) = 2.02 and mean(current) = 1.94, test of hypothesis that difference between means of forward and current >0: t test = 3.13 and P-value = 0.0009.

Another feature of the results of Figs 8 and 9 is the following. We observe that starting from the lowest level of c_2, increases in this parameter have the effect of reducing both the volatility of output gap and inflation. The former is not a surprise since a greater output stabilization effort from the central bank is likely to lead to less output volatility. The surprise is in the fact that this increase in output stabilization efforts by the central bank also reduces inflation volatility. Where does this come from? The answer is that when c_2 is very low the model produces intense booms and busts characterized by the occurrence of fat tails. In such boom–bust situations both output and inflation are extremely volatile. By increasing c_2 the central bank reduces the occurrence of boom–bust scenarios and thus also the extreme volatility of both output and inflation. However, at some point when c_2 is large enough (approximately 0.5) inflation volatility starts increasing with increases of c_2. Thus, from that point on, the central bank's increased attempts at stabilizing output come at a price of more inflation volatility. This then creates the standard trade-off between output and inflation volatility.

7.2 The response to exogenous shocks

In a second sensitivity exercise, we simulated the model for different standard deviations of demand and supply shocks. As before, we did this for the two policy regimes, DM and SIT. We show the results in Figs 10 and 11. These figures present the standard deviations of the output gap for different values of the standard deviations of the aggregate demand and supply shocks, σ_v and σ_η in Equations (1) and (2). The results have the following interpretation. In the DM regime ($c_2 = 0.5$) the impact of the different Taylor rules on the volatility of output is not much affected by the size of the demand and supply shocks, that is, as the latter increase the volatility of output and inflation increases in the same proportion in the two Taylor rules. We find that the mean of the forward rule is significantly larger than the mean of the current rule ; however, the difference (0.76 versus 0.73 when shock ≤ 0.5 and 6.04 versus 5.73 when shock > 0.5) is so small as to be economically unimportant (see Fig. 10, note (2)). This contrasts with the SIT regime (Fig. 11: $c_2 = 0.1$). In this regime, we observe that as the size of the demand and supply shocks increases the forward-looking Taylor rule becomes increasingly less attractive, that is, it leads to increases in the volatility of output in comparison with the current Taylor rule. For example, when the shock > 0.5, the difference in the mean volatility of the forward and current rules is both statistically significant and economically meaningful (16.26 versus 12.85).

These results suggest that when the central bank is giving enough emphasis to output stabilization, the nature of the data it uses to pursue its policies does not matter much. It is only when, due to a lack of sufficient output stabilization in the SIT regime, the economy regularly gets embroiled in boom–busts dynamics that the nature of the data matters. We then find that the use of forward-looking data in the Taylor rule leads to inferior stabilization results as compared to the use of current data. Put differently, in the SIT regime the exogenous shocks lead to more volatility of output when the central bank is forward-looking than when it uses current data.

7.3 The importance of nowcasting

During the last few decades, central banks have made efforts at increasing the precision with which they observe current output and inflation. The lack of precision in observing these variables comes from the fact that there is a lag between their realization and their observation. 'Nowcasting' has provided for a new technology in increasing this precision. Here we ask the question of how increased precision provided by nowcasting helps the central bank in reducing the volatility of output and inflation. We show the answer in Fig. 12

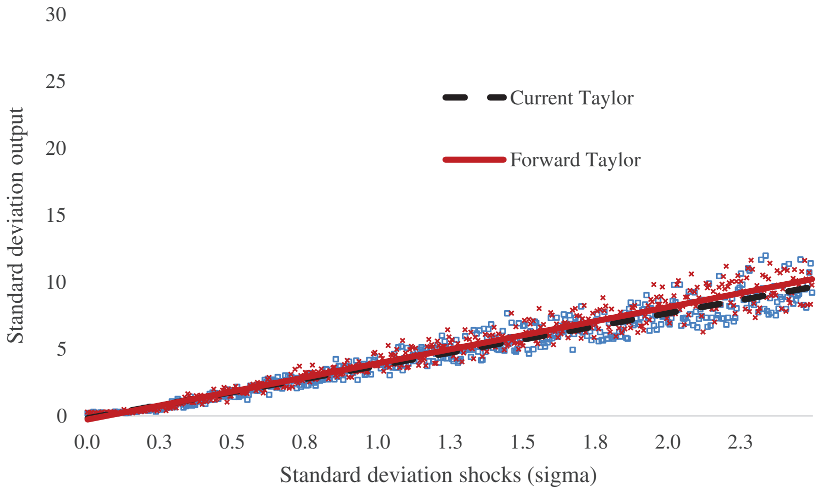

Fig. 10. Standard deviation output and shocks DM ($c_2 = 0.5$).

Note: (i) std of shocks varies between 0.0 and 2.5 with increments of 0.002. With each new value of shocks we select the parameters of the model randomly within the specified range.

(2) when std of shocks sigma ≤ 0.5, mean(forward) $= 0.76$ and mean(current) $= 0.73$, hypothesis that difference between means of forward and current >0: *t*-test $= 1.0017$ and P-value $= 0.1595$; when sigma >0.5, mean(forward) $= 6.04$ and mean(current) $= 5.73$, hypothesis that difference between means of forward and current >0: *t*-test $= 5.5640$ and P-value $= 0$.

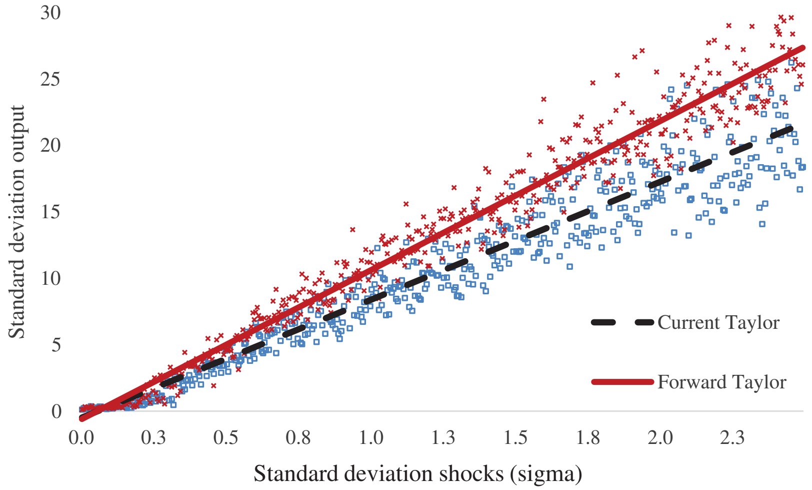

Fig. 11. Standard deviation output and shocks SIT ($c_2 = 0.1$).

Note: (i) std of shocks varies between 0.0 and 2.5 with increments of 0.002. With each new value of shocks we select the parameters of the model randomly within the specified range. (ii) when std of shocks sigma ≤ 0.2, mean(forward) $= 0.34$ and mean(current) $= 0.34$, hypothesis that difference between means of forward and current >0: *t*-test $= 0.0867$ and P-value $= 0.4657$; when $0.2 < \text{sigma} \leq 0.5$, mean(forward) $= 2.85$ and mean(current) $= 2.14$, hypothesis that difference between means of forward and current >0: *t*-test $= 6.3572$ and P-value $= 0$; when sigma >0.5, mean(forward) $= 16.26$ and mean(-current) $= 12.85$, hypothesis that difference between means of forward and current >0: *t*-test $= 23.4403$ and P-value $= 0$.

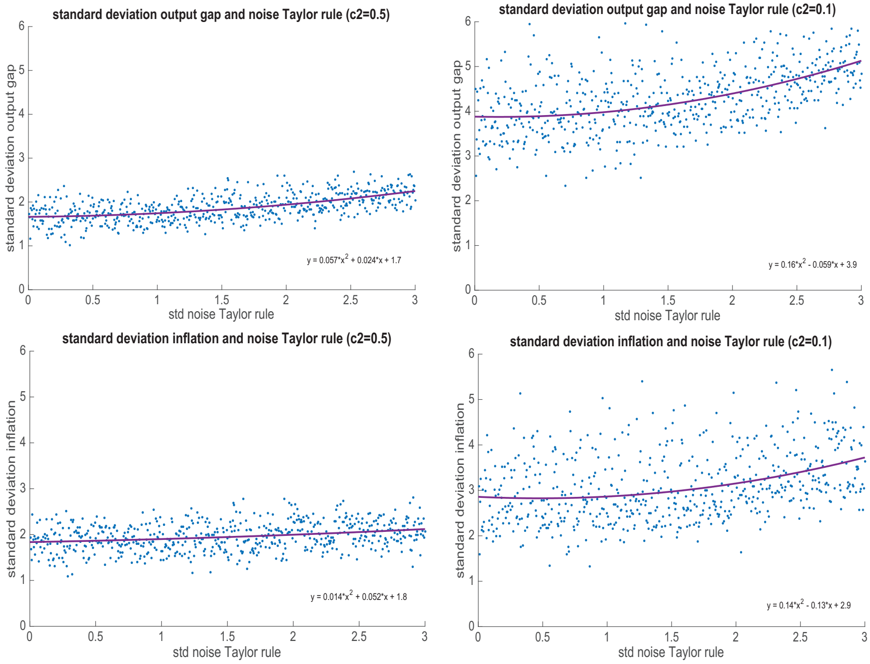

Fig. 12. Standard deviation output gap and inflation with different noise in observing current variables.

for the two regimes, that is, Dual-Mandate central bank and SIT central banks. On the horizontal axis, we set out the noise in observing current output and inflation. This is measured by σ_ε and σ_θ. On the vertical axis we show the standard deviations of the output gap and inflation, respectively. We observe that in both regimes a decline in the noise leads to a decline in the variability of the output gap and inflation. However, this decline is more pronounced and more non-linear in the SIT central bank. Thus, nowcasting improves the quality of monetary policymaking and this improvement is the strongest in a regime where the central bank pursues a SIT.

Note that Fig. 12 confirms our results obtained from Tables 4 and 5. This is that the DM regime produces lower volatilities than the SIT regime of both output and inflation for whatever Taylor rule is used.

Although typically information about market forecasts is obtained quicker than about current variables there is also noise surrounding market forecasts. Thus, we ask the same question of how innovations in nowcasting that reduce the noise around forecasts improve the quality of monetary policymaking. The answer is given in Fig. 13 which is very similar to Fig. 12. The reduction of noise around the collection of market forecasts reduces the volatility of inflation and output gap and this reduction is stronger in the SIT regime than in the DM regime.

Note of Figs 12 and 13: Standard deviation of shocks varies between 0.0 and 3 with increments of 0.002. With each new value of shocks, we select the parameters of the model randomly within the specified range. We obtain a range of standard deviations and compute the best fit.

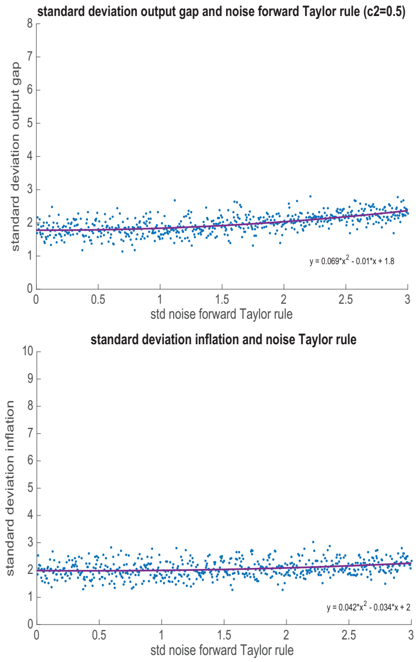

Fig. 13. Standard deviation output gap and inflation with different noise in observing market forecast.

8. Monetary policies in the USA and the eurozone

In this section, we provide a case study of monetary policies in the USA and the eurozone during 2000–20. This was a period of extraordinary turbulence in the business cycles. It can give us some insights into the conduct of monetary policies and will allow us to apply some of the theoretical results developed in the previous sections.

The main results of our model are, first that forward -looking rules perform increasingly badly relative to current -looking rules when volatility (and thus uncertainty) increases. This holds whether this volatility is produced by a lack of output stabilization or by external shocks. Secondly, the use of nowcasting improves the trade-off between inflation and output volatility.

We start from Fig. 14, and this shows the standard deviation of output growth[2] on the vertical axis and of inflation on the horizontal axis in the eurozone and the USA. We show two sets of points, those relating to the whole period (in round) and those relating to the post-2008 period (in square). We observe that in the eurozone the volatility of output growth has been higher than in the USA in both the full period and the post-2008 period. The reverse is true for inflation volatility with higher volatility in the USA than in the eurozone. Thus, it appears that policymakers in the eurozone have exhibited a relative preference for low inflation volatility and the USA for low output growth volatility. This is made visible by connecting the eurozone and the US points. We obtain 'trade-offs' that visualize

[2] We use output growth rather than output gap because data of the former are obtained with greater frequency and are more reliable than data on output gap. The latter also are subject to large revisions.

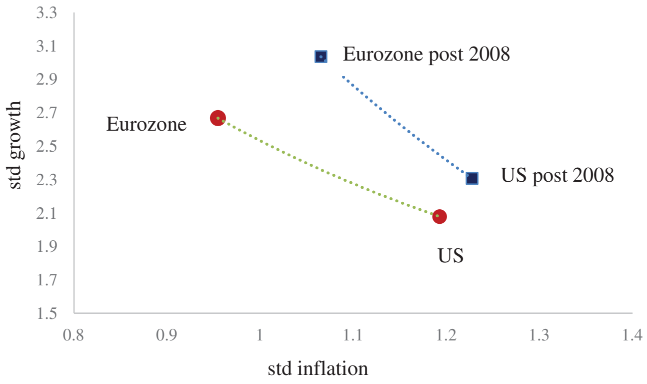

Fig. 14. Eurozone and US volatility (2000 infla).
Source: European Central Bank and US Federal Reserve.

these different preferences. We obtain one trade-off for the whole period and one for the post-2008 period, which includes both the financial crisis years and the pandemic year of 2020. Not surprisingly, this has led to an upward and rightward shift in the trade-off. The interesting feature of this result is that it has kept the ranking of the eurozone and the USA unchanged, that is, the ECB exhibiting a relative preference towards inflation stabilization and the US Fed towards output stabilization.

How do these two countries compare as far as the reliability of inflation and growth forecasting is concerned? We show the evidence in Tables 6 and 7. Table 6 shows the mean squared errors (MSEs) of the forecasts of inflation and output growth made by the ECB and the Fed during 2000–19 and 2008–19. We observe that inflation forecasting is more precise in the eurozone than in the USA. The reverse holds true for output growth forecasting. Table 7 shows the ratios of these MSEs for both the ECB and the US Fed. These can be interpreted as the forecasting performance of output growth relative to inflation forecasting performance. We observe that the ECB's mean errors in forecasting output growth is more than twice (2.2) the level of inflation forecasting errors. In the USA, the ratio is 1.5. Thus, while the ECB does a relatively good job in forecasting inflation, its performance in output forecasting is considerably poorer than that obtained by the US Fed.

Having established the differences in preferences and forecasting performance of the ECB versus the US Fed, we now proceed towards a more detailed analysis of monetary policymaking in the eurozone and the USA. We concentrate on how these central banks have attempted to stabilize output (business cycle).

We first show the quarterly observations of GDP growth in the eurozone and the USA in Figs 15 and 16, together with the forecasts made 1 year earlier (called 'forward'). It is striking to find how poor these forecasts were. In particular, the three recessions were completely missed by the forecasters. In the case of the pandemic of 2020, this is certainly understandable. It is less so for the recessions of 2001–2 and the very deep one of 2008–9.

Central banks could not rely on these forecasts to make monetary policy decisions. If they had the policy mistakes would have been very large. In fact, they did not, or only partially. This can be seen by comparing Figs 15 and 16 with Fig. 17. The latter shows the evolution of the policy rates applied by the ECB and the US Fed and the exact timing of the

Table 6. MSE forecasts of inflation and growth

	2000–19	2008–19
Inflation		
ECB	0.87	1.01
Fed	1.21	1.35
GDP growth		
ECB	1.90	2.22
Fed	1.78	1.98

Source: ECB and US Federal Reserve.

Table 7. Ratio MSE of forecasts of inflation and growth

	2000–19	2008–19
ECB	2.2	2.2
Fed	1.5	1.5

Source: ECB and US Federal Reserve.

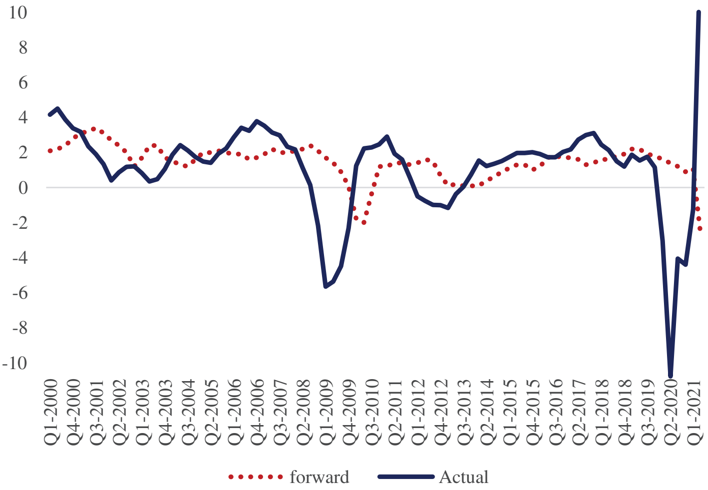

Fig. 15. GDP growth rate eurozone.
Source: US Federal Reserve.

changes in these interest rates. We analyse consecutively the recessions of 2001–2, 2008–9, and 2020.

8.1 The recession of 2001–2

The dot-com bubble reached its peak in March 2000. From then on it would go down swiftly setting in motion recessionary forces that typically are engendered by a stock market crash. The downturn in economic activity started during the second quarter of 2000. Forecasters were caught wrong-footed. Forecasts for economic growth continued to be

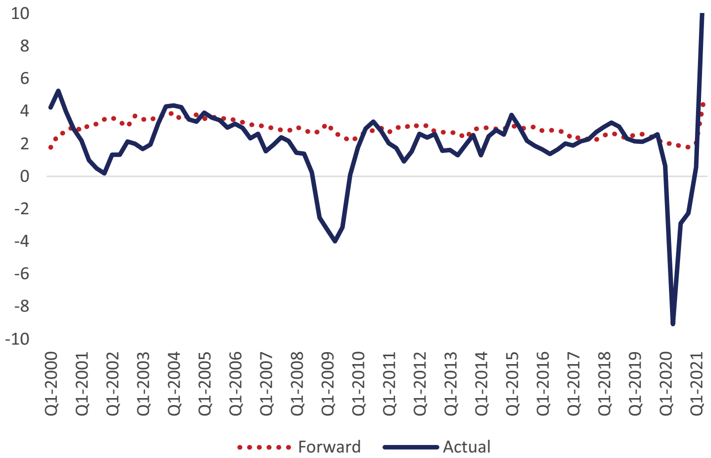

Fig. 16. Growth of GDP in USA.
Source: Eurostat.

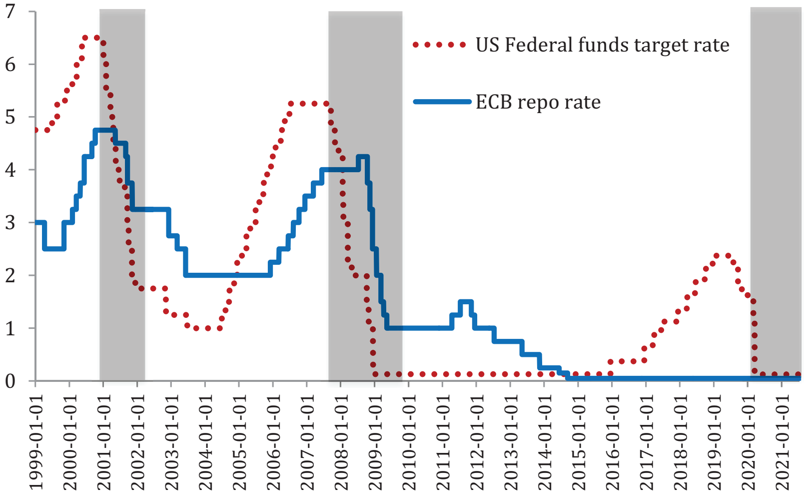

Fig. 17. Policy rate of US Fed and ECB, 2000–20.
Source: US Federal Reserve and ECB.

favourable exceeding 2% (on a yearly basis). The Federal Reserve was the first to react. It lowered its interest rate in January 2001 at the time when forecasters actually became more optimistic. The Federal Reserve disregarded these forecasts and looked at current observations of economic growth (and output gap). These were turning down. This is confirmed by the Press Release of the Federal Reserve of 3 January 2001 announcing a reduction of 0.25% in the discount rate: ‘These actions were taken in light of further weakening of sales and production, and in the context of lower consumer confidence, tight conditions in some segments of financial markets, and high energy prices sapping household and business purchasing power’ (Board of Governors of the Federal Reserve System. 2001).

It took the ECB longer to react. That institution reduced the interest rate in August 2001 only. In addition, the ECB reacted much more cautiously than the US Fed. The latter lowered the interest rate from 6.5% to less than 2% throughout 2001. The ECB lowered its interest rate from 4.74% to 3.25% over the course of the same year, illustrating from the start of its existence that it would not be willing to be too active in stabilizing the business cycle.

8.2 The recession of 2008–9

A similar pattern is observed during the much more intense recession of 2008–9 which followed the crash in the subprime housing market in the USA. That recession started at the end of 2007 (last quarter). In October 2007, the US Fed started a series of interest rate cuts which reached 0.1% in February 2009. In contrast to the swift action of the Fed the ECB waited until October 2008, a full year after the US Fed had started to relax its monetary policies. What is worse, before the ECB lowered its rate in October 2008 it actually raised the interest rate in September from 4% to 4.25%.

It appears that the Fed was following the current observations about growth and output gap more closely than the ECB did when it decided relatively quickly to fight the recession. This is confirmed by the following quote of a press release of the Fed in December 2007: ‘Incoming information suggests that economic growth is slowing, reflecting the intensification of the housing correction and some softening in business and consumer spending’ (Board of Governors of the Federal Reserve System, 2007).

The long delay and timid response of the ECB were probably motivated by the fact that in July 2008 the eurozone rate of inflation had reached about 4.1% (as it had in the USA). Inflation forecasters were still forecasting inflation rates of 2% or more (see Figs 1 and 2). The ECB took these forecasts seriously leading to a historic policy mistake of raising the interest rate in the midst of the then worst recession of the post-war period. The focus of the ECB on inflation forecasts is confirmed by the following statement of Jean-Claude Trichet, the then President of the ECB, during the press conference of 3 July 2008: ‘On the basis of our regular economic and monetary analyses, we decided at today’s meeting to increase the key ECB interest rates by 25 basis points. This decision was taken to prevent broadly based second-round effects and to counteract the increasing upside risks to price stability over the medium term. The Harmonised Index of Consumer Prices (HICP) inflation rates have continued to rise significantly since the autumn of last year. They are expected to remain well above the level consistent with price stability for a more protracted period than previously thought’ (ECB, 2008).

The ECB repeated the same mistake during the double-dip recession that the eurozone experienced in 2010–11 (see Fig. 15 and the negative output gap in that period). During 2011 the ECB raised the interest rate twice from 1% to 1.25% in June and from 1.25% to 1.5% in September. It appears that this was motivated by the upward movements in inflation and inflation forecasts in the same period. This is confirmed by the statement issued by the ECB following the interest rate increase of September 2011: ‘Looking ahead, inflation rates are likely to stay clearly above 2% over the coming months. (.). It remains of paramount importance that the rise in HICP inflation does not translate into second-round effects in price and wage-setting behaviour and lead to broad-based inflationary pressures. Inflation expectations must remain firmly anchored in line with the Governing Council’s aim of maintaining inflation rates below, but close to, 2% over the medium term’. (Reuters, 2011).

These forecasts would turn out to be wrong. The ECB recognized its policy error when it lowered the interest rate again in December 2011.

8.3 The recession of 2020

This recession, which was the deepest of the post-war period, was different in nature of the previous two in that it was the result of a true exogenous shock. In contrast, the 2001–2 and the 2008–9 recessions were the result of a boom –bust dynamics that is at the core of our behavioural macro model.

When comparing the US Fed reactions to the ECB, we find one difference. As the Fed had reacted to the 2016–8 boom in economic activity by raising the interest rate it had some leeway in 2020 to lower the interest rate as a response to the pandemic. Both central bankers reacted quickly and forcefully using the other tool of monetary policy, that is, quantitative easing . They increased liquidity (money base) massively to counter the recessionary forces. They were guided not by forecasts (which were way off the mark as can be seen from Figs 15 and 16) but by the observations in real time of the collapse of economic activity during the first half of 2020. In doing so (and with the additional help of massive fiscal expansion), they managed to quickly pull the economy out of the doldrums. This can certainly be called a successful policy episode.

We can summarize our case study of monetary policies conducted by the Fed and the ECB during periods of turmoil as follows. When the economy is hit by large shocks (either because of a lack of output stabilization or because of a massive exogenous shock), central banks have learned that they should focus on currently observed values of growth and inflation, and not on their forecasts. This is what the Fed did during the recessions of 2001 and 2008–9 and what both the Fed and the ECB did during the pandemic. When the central bank fails to do so, like the ECB in 2008 when it raised the interest rate in the midst of a recession and again in 2011 in similar circumstances, it is likely to make big policy mistakes. We have documented that in the case of the ECB this appears to have been due to the fixation of the ECB on inflation forecasts that stubbornly pointed to future inflation.

Central banks have also learned to develop new instruments of monetary policies to deal with the great uncertainties surrounding forecasts. First, through the use of nowcasting they have obtained a more precise source of information about current developments in inflation and growth. We have indicated in our theoretical analysis that this improves policymaking. Secondly, they have also instituted policies of ‘forward guidance’. These are announcements of future policy intentions (e.g., about the interest rate). If credible, these announcements can create more certainty about the future when forecasts lack credibility. The key here is credibility. In the absence of credibility, forward guidance will have little impact on the quality of policymaking (Hubert, 2014; Darvas, 2018; Goy *et al.*, 2020).

9. Conclusion

Should a central bank use current- or forward-looking data when setting its interest rate? This question has been analysed in the macroeconomic literature. In the context of theoretical REs models, the answer is generally found to be positive. However, the empirical evidence suggests that central banks do not always take a forward-looking attitude. This evidence also suggests that the benefits of using forward-looking Taylor rule are ambiguous.

We contributed to this literature by comparing Taylor rules with current- and forward-looking data using a behavioural macroeconomic model. We showed that in a world where agents have limited cognitive abilities and, as a result, are prevented from having REs the use of forward-looking data by the central bank leads to inferior outcomes in particular monetary policy 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. However, when the economy is in a regime of booms and bust produced by extreme values of animal spirits (crisis periods), 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. Given the extreme volatility of these variables when animal spirits are extreme, the central bank that uses forward -looking data will make many policy errors that have to be corrected afterwards. Thus, when the forward Taylor rule is used in an environment of strong volatility, the quality of policymaking declines, leading to even greater variability of the output gap and inflation.

We also found that the difference between the use of current- and forward-looking data tends to disappear when the central bank does a degree of output stabilization that reduces the occurrences of extreme values of output gap and inflation. The reason is that in such a monetary policy regime the absence of extreme booms and busts makes the forward-looking data more reliable.

In response to exogenous shock, we also found that in the SIT regime, the forward-looking Taylor rule becomes increasingly less attractive, that is, it leads to increases in the volatility of output in comparison with the current Taylor rules.

Finally, we showed that the use of nowcasting can significantly improve the quality of monetary policy. In fact, we found that this improvement is more pronounced in the monetary policy regime based on SIT than in the DM monetary policy regime.

Our short historical case study of the USA and the eurozone during 2000–20 seems to confirm these theoretical insights. During the three recessions of this period, these central banks tended to focus on current observations of output and inflation rather than on forecasted values and took better decisions. The exception is the ECB that raised the interest rate during the recession of 2008–9. The ECB repeated this policy mistake during the double-dip recession of 2010–2011. Clearly more empirical research should be undertaken to confirm these insights.

Supplementary material

Supplementary material is available on the OUP website. These are the data and replication files (Matlab code) and the online Appendix.

Funding

No funding was received for the research reported in this article.

Acknowledgements

We are grateful to Raoul Minetti and an anonymous referee for very useful comments.

References

Anderson, S.P., De Palma, A., and Thisse, J.F. (1992) *Discrete Choice Theory of Product Differentiation*, MIT Press, Cambridge, MA.

Assenza, T., Bao, T., Hommes, C., and Massaro, D. (2014) Experiments on expectations in macroeconomics and finance, in J. Duffy (ed) *Experiments in Macroeconomics*, Emerald Group Publishing Limited, Bingley.

Batini, N. and Haldane, A. (1999) *Forward-Looking Rules for Monetary Policy. In Monetary Policy Rules*, University of Chicago Press,Chicago, IL, pp. 157–202.

Belke, A. and Klose, J. (2011) Does the ECB rely on a Taylor rule during the financial crisis? Comparing ex-post and real time data with real time forecasts, *Economic Analysis and Policy*, **41**, 147–71.

Blattner, T.S. and Margaritov, E. (2010) *Towards a robust monetary policy rule for the euro area. ECB Working Paper Series*, June, 41. Frankfurt.

Board of Governors, Federal Reserve System. (2001) *Press release*. https://www.federalreserve.gov/boarddocs/press/general/2001/20010103/ (date last accessed 3 January 2001).

Board of Governors, Federal Reserve System. (2007) *Press release*. https://www.federalreserve.gov/newsevents/pressreleases/monetary20071211a.htm (date last accessed 3 January 2001).

Branch, W.A. (2004) The theory of rationally heterogeneous expectations: evidence from survey data on inflation expectations, *The Economic Journal*, **114**, 592–621.

Branch, W.A. and Evans, G.W. (2006) Intrinsic heterogeneity in expectation formation, *Journal of Economic Theory*, **127**, 264–95.

Branch, W.A. and McGough, B. (2010) Dynamic predictor selection in a new Keynesian model with heterogeneous expectations, *Journal of Economic Dynamics and Control*, **34**, 1492–508.

Brazier, A., Harrison, R., King, M., and Yates, T. (2008) The danger of inflating expectations of macroeconomic stability: Heuristic switching in an overlapping-generations monetary model, *International Journal of Central Banking*, **4**, 219–54.

Brock, W. and Hommes, C. (1997) A rational route to randomness, *Econometrica*, **65**, 1059–95.

Clarida, R., Gali, J., and Gertler, M. (2000) Monetary policy rules and macroeconomic stability: Evidence and some theory, *Quarterly Journal of Economics*, **115**, 147–80.

Carroll, C.D. (2003) Macroeconomic expectations of households and professional forecasters, *The Quarterly Journal of Economics*, **118**, 269–98.

Darvas, Z. 2018. Forecast errors and monetary policy normalisation in the euro area. *Policy Contributions* 28816, Bruegel, Brussels.

De Grauwe, P. (2011) Animal spirits and monetary policy, *Economic Theory*, **47**, 423–57.

De Grauwe, P. 2012. *Lectures on Behavioral Macroeconomics*, Princeton University Press, Princeton, NJ, p. 136.

De Grauwe, P. and Grimaldi, M. (2006) Exchange rate puzzles: a tale of switching attractors, *European Economic Review*, **50**, 1–33.

De Grauwe, P. and Ji, Y. (2019) Behavioural macroeconomics. *Theory and Policy*, Oxford University Press, Oxford

De Grauwe, P. and Ji, Y. (2020) Structural reforms, animal spirits, and monetary policies, *European Economic Review*, **124**, 103395.

European Central Bank. (2008) *Introductory statement, jean-claude trichet, president of the ECB*. https://www.ecb.europa.eu/press/pressconf/2008/html/is080703.en.html (date last accessed 3 January 2001).

Giannone, D., Reichlin, L., and Small, D. (2008) Nowcasting: the real-time informational content of macroeconomic data, *Journal of Monetary Economics*, **55**, 665–76.

Gorter, J., Jacobs, J., and De Haan, J. (2008) Taylor rules for the ECB using expectations data, *Scandinavian Journal of Economics*, **110**, 473–88.

Goy, G., Hommes, C., and Mavromatis, K. (2020) Forward guidance, the role of central bank credibility under heterogeneous beliefs, *Journal of Economic Behavior Organization*, doi: 10.1016/j.jebo.2020.06.025.

Hommes, C.H. and Lustenhouwer, J. (2019) Inflation targeting and liquidity traps under endogenous credibility, *Journal of Monetary Economics*, **107**, 48–62.

Hubert, P. (2014) FOMC forecasts as a focal point for private expectations, *Journal of Money, Credit and Banking*, **46**, 1381–420.

Kryvtsov, O. and Petersen, L. (2013) *Expectations and Monetary Policy: Experimental Evidence (No. 2013–44)*, Bank of Canada, Ottawa, ON.

Kukacka, J., Jang, T.-S., and Sacht, S. (2018) On the estimation of behavioral macroeconomic models via simulated maximum likelihood. Christian-Albrechts-University of Kiel, Department of Economics, Economics Working Papers 2018–11.

Levin, A.T., Wieland, V., and Williams, J.C. (1999) Robustness of simple monetary policy rules under model uncertainty, in Taylor J.B. (ed) *Monetary Policy Rules*, Chicago University Press, Chicago, IL, pp. 263–299.

Orphanides, A. (2001) Monetary policy rules based on real-time data, *American Economic Review*, **91**, 964–85.

Pfajfar, D. and Žakelj, B. (2014) Experimental evidence on inflation expectation formation, *Journal of Economic Dynamics and Control*, **44**, 147–68.

Reuters (2011), ECB raises interest rates. https://www.reuters.com/article/us-ecb-rates-text-idUSTRE7662WZ20110707 (date last accessed 3 January 2001).

Smets, F. and Wouters, R. (2003) An estimated dynamic stochastic general equilibrium model, *Journal of the European Economic Association*, **1**, 1123–75.

Svensson, L.E. (1997) Inflation forecast targeting: Implementing and monitoring inflation targets, *European Economic Review*, **41**, 1111–46.

Taylor, J.B. and Williams, J.C. 2010. *Simple and Robust Rules for Monetary Policy. In Handbook of Monetary Economics*, vol. 3, Elsevier, Amsterdam, Netherlands, 829–859.

Woodford, M. (1999) Optimal monetary policy inertia, *Manchester School*, **67**, 1–35. Supplement.