

## STOCK PRICES AND MONETARY POLICY

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**Paul De Grauwe**

The question of whether central banks should target stock prices so as to prevent bubbles and crashes from occurring has been hotly debated. We analyse this question using a behavioural macroeconomic model. This model generates bubbles and crashes. We analyse how 'leaning against the wind' strategies, which aim to reduce the volatility of stock prices, can help in reducing volatility of output and inflation. We find that such policies can be effective in reducing macroeconomic volatility, thereby improving the trade-off between output and inflation variability. The strength of this result, however, depends on the degree of credibility of the inflation-targeting regime. In the absence of such credibility, policies aiming at stabilising stock prices do not stabilise output and inflation.

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PAUL DE GRAUWE\*

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### 1. Introduction

The question of whether central banks should react to stock price developments has been hotly debated. It is fair to state that there are two schools of thought on this issue. The first one, which is well represented by Bernanke & Gertler (2001), Schwartz (2002), and Greenspan (2007), argues that central banks should not use the interest rate to influence stock prices. The main arguments advanced by this school of thought are, first, that it is difficult to identify bubbles *ex ante*, (and it only makes sense to intervene if stock prices are on a bubble path, i.e. if they clearly deviate from underlying fundamentals).<sup>1</sup> The second argument is that even if a bubble can be identified *ex ante*, using the interest rate is ineffective to burst a bubble. All the central bank can do is to limit the damage once the bubble bursts. This school of thought also stresses that by keeping the rate of inflation low, the central bank contributes to creating an environment of sustainable growth in which bubbles are less likely to emerge.

The second school of thought takes the opposite view (see Smets, 1997, Ceccetti et al., 2002, Borio & White, 2004, Bordo & Jeanne, 2002 and Roubini, 2006). Stock prices are often subject to bubbles and crashes. These can have strong pro-cyclical effects and can also affect the stability of financial markets. Since central banks are responsible for financial stability they should monitor asset prices and try to prevent the emergence of bubbles (that invariably lead to crashes). In this view the use of the interest rate is seen as effective in preventing bubbles from emerging.<sup>2</sup> Few economists from this school will argue that the central bank should target a particular value of the stock price (in the same way as it targets an inflation rate). Instead many will argue that a strategy of ‘leaning against the wind’ may be useful to reduce too strong movements in stock prices.

In this paper we analyze the question of whether central banks should try to influence stock prices using their interest rate policy. We will do this in the context of a behavioural macroeconomic model as developed in De Grauwe (2008). (For similar models see Branch & Evans (2006) and Brazier, et al. (2006)). Thus we depart from rational expectations and their implementation in the currently fashionable DSGE-models. The reason why we depart from this modelling approach is double. First, DSGE-models make extremely strong informational assumptions, i.e. agents are assumed to understand the structure of the underlying model. This follows directly from the rational expectations assumption which requires agents to use the underlying model structure to make forecasts. The scientific evidence from other sciences

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<sup>1</sup> An extreme version of this school of thought denies the existence of bubbles altogether. In this view financial markets are efficient and thus stock prices always reflect the best available information. Since central banks do not possess better information than markets, it makes no sense for them to try to influence stock prices.

<sup>2</sup> Note that both schools of thought accept that the central bank has other instruments to maintain financial stability, e.g. supervision and regulation

(psychology, brain sciences) casts doubts about the plausibility of this assumption. It is no exaggeration to say that there is now strong evidence that individual agents suffer from deep cognitive problems limiting their capacity to understand and to process the complexity of the information they receive. Many anomalies that challenge the rational expectations assumption were discovered (see Thaler, 1994, for spirited discussions of these anomalies; see also Camerer & Lovo, 1999, Read & van Leeuwen, 1998, and Della Vigna, 2007).

The second reason why we depart from DSGE-modelling is that in these models there is no room for bubbles and crashes. Markets are always efficient, so that asset prices reflect underlying fundamentals. Thus central banks cannot improve welfare by guiding asset prices to other values than those produced by efficient markets. In a way it can be said that DSGE-models are not the appropriate tools to study the issue of whether central banks should try to prick asset bubbles, as such bubbles cannot occur in these models.

In our modelling approach we will take the view that agents face cognitive problems in understanding and processing information. As a result, they use simple rules ('heuristics') to guide their behaviour (see Gabaix et al., 2006). They do this not because they are irrational, but rather because the complexity of the world is overwhelming. In a way it can be said that using heuristics is a rational response of agents who are aware of their limited capacity to understand the world. The challenge when we try to model heuristics will be to introduce discipline in the selection of rules so as to avoid that 'everything becomes possible'.

In this paper we develop a parsimonious model capable of generating endogenous and self-fulfilling waves of optimism and pessimism leading to bubbles and crashes in asset markets. We look for parsimony because we wish to find out what is the simplest possible model needed to generate such cycles.

## 2. A behavioural macroeconomic model

In this section we describe our modelling strategy. We do this by presenting a standard aggregate-demand-aggregate supply model augmented with a Taylor rule. The model has two novel features. The first on is that agents use simple rules, heuristics, to forecast the future. These rules are subjected to a selection mechanism. Put differently, agents will endogenously select the forecasting rules that have delivered the highest fitness in the past. This selection mechanism acts as a disciplining device on the kind of rules that are acceptable. Since agents use different heuristics we also obtain heterogeneity.

The second novelty is to introduce asset prices (stock prices) in this behavioural model. Our purpose is to analyze how a departure from rational expectations affects our view of the need for monetary authorities to intervene in the stock markets. In the standard rational expectations models (including the DSGE-model), there is no need for them to monitor asset prices and to attempt to influence these prices because fully informed agents in these models ensure that bubbles and crashes in asset prices do not occur. Put differently, in these models financial markets are efficient and asset prices are uniquely determined by underlying fundamentals. It would be quite counterproductive for the monetary authorities to try to influence these asset prices.<sup>3</sup>

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<sup>3</sup> There is a strand of literature using rational expectations models that allow for bubbles and crashes in the asset prices. Bubbles and crashes arise as a result of multiple equilibria (sunspot equilibria) that are embedded in rational expectations models. Examples are Azariadis (1981), Benhabib & Farmer (1996) and Farmer (2006). The conventional DSGE-models however exclude this possibility by ruling out bubble solutions from the analysis.

## 2.1 The basic model

We first present the model without asset prices. It consists of an aggregate demand equation, an aggregate supply equation and a Taylor rule.

The aggregate demand equation can be derived from dynamic utility maximisation. This produces an Euler equation in the same vein as in DSGE-models (see Gali, 2008). We obtain

$$y_t = a_1 \tilde{E}_t y_{t+1} + (1 - a_1) y_{t-1} + a_2 (r_t - \tilde{E}_t \pi_{t+1}) + \varepsilon_t \quad (1)$$

where  $y_t$  is the output gap in period  $t$ ,  $r_t$  is the nominal interest rate,  $\pi_t$  is the rate of inflation, and  $\varepsilon_t$  is a white noise disturbance term.  $\tilde{E}_t$  is the expectations operator where the tilde above  $E$  refers to expectations that are not formed rationally. We will specify this process subsequently. We follow the procedure introduced in DSGE-models of adding a lagged output in the demand equation. This is usually justified by invoking habit formation.

The aggregate supply equation can be derived from profit maximisation of individual producers. We assume as in DSGE-models a Calvo pricing rule, which leads to a lagged inflation variable in the equation.<sup>4</sup> The supply curve can also be interpreted as a New Keynesian Philips curve. We obtain:

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

Finally the Taylor rule describes the behaviour of the central bank

$$r_t = c_1 (\pi_t - \pi_t^*) + c_2 y_t + c_3 r_{t-1} + u_t \quad (3)$$

where  $\pi_t^*$  is the inflation target which for the sake of convenience will be set equal to 0. Note that we assume, as is commonly done, that the central bank smoothes the interest rate. This smoothing behaviour is represented by the lagged interest rate in equation (3). Ideally, the Taylor rule should be formulated using a forward looking inflation variable, i.e. central banks set the interest rate on the basis of their forecasts about the rate of inflation. We have not done so here in order to maintain simplicity in the model.

## 2.2 Introducing asset prices

Next we describe how asset prices enter the model. These asset prices will be assumed to be stock prices. We allow the stock prices to affect aggregate demand and supply. The way we do this is by allowing changes in stock prices to affect the cost of credit of firms. An increase in the

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<sup>4</sup> It is now standard in DSGE-models to use a pricing equation in which marginal costs enter on the right hand side. Such an equation is derived from profit maximisation in a world of imperfect competition. It allows introducing more detail into the model and makes it possible to specify productivity shocks better. It also allows for analysing how shocks in markups affect the economy. We have not tried to introduce this feature here (see Gali, 2008 and Smets & Wouters, 2003).

stock price of the firm increases its net equity. As a result, credit becomes more easily available for the firm, stimulating investment demand. This is the aggregate demand effect of an increase in the stock price. It is akin to the credit multiplier analysis made popular by Bernanke & Gertler (1995). The same increase in the firm's equity also reduces its credit costs on its outstanding debt. This lowers the marginal costs of the firm. This is the supply side effect.

These demand and supply side effects can also be labelled balance sheet effects of stock price changes. An increase in stock prices improves the balance sheet of the firm allowing it to increase its spending for investment at a lower cost and to run its operations at a lower (credit) cost. As it is a balance sheet effect we will introduce a lag in its operation, i.e. an increase in the stock price in period  $t$  improves the published balance sheet at the end of period  $t$ , allowing the firm to profit from the improved balance sheet in the next period.

Clearly, a decline in the stock price has the reverse effect on the balance sheets of firms, leading to a negative effect on investment spending and on the credit costs.

We use the discounted dividend model (Gordon model) to compute stock prices, i.e.

$$S_t = \frac{E_t(D_{t+1})}{R_t} \quad (4)$$

where  $E_t(D_{t+1})$  is the expected future dividend, which is assumed to be constant from  $t+1$  onwards;  $R_t$  is the discount rate used to compute the present value of future dividends. It consists of the interest rate  $r_t$  and the equity premium (which we will assume to be constant). Thus we assume that each period agents make a forecast of the future dividends that they assume will then be constant for the indefinite future. They re-evaluate this forecast every period.

Dividends are a fraction,  $\alpha$ , of nominal GDP. Thus the forecasts of future dividends are tightly linked to the forecasts of output and inflation that we discuss in the next section.

We now specify the aggregate demand curve as follows

$$y_t = a_1 \tilde{E}_t y_{t+1} + (1 - a_1) y_{t-1} + a_2 (r_t - \tilde{E}_t \pi_{t+1}) + a_3 \Delta s_{t-1} + \varepsilon_t \quad (5)$$

where  $\Delta s_{t-1}$  is the change in the log of  $S_{t-1}$  and  $a_3 \geq 0$ .

The aggregate supply (New Keynesian Phillips curve) is specified as follows

$$\pi_t = b_1 \tilde{E}_t \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 y_t + b_3 \Delta s_{t-1} + \eta_t \quad (6)$$

where  $b_3 \leq 0$ , i.e. an increase in the stock prices lowers marginal costs and thus has a negative effect on inflation.

Finally we will allow the central bank to react to changes in the stock prices. Thus the Taylor rule becomes

$$r_t = c_1 (\pi_t - \pi_t^*) + c_2 y_t + c_3 r_{t-1} + c_4 \Delta s_{t-1} + u_t \quad (7)$$

Note that we specify the way the central bank reacts to stock prices in a different way than the way it reacts to inflation and output. In the latter case, the central bank has a target for inflation and output and wishes to reduce deviations from that target.<sup>5</sup> In the case of stock prices, the

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<sup>5</sup> This may not be obvious for the output gap. The output gap is the difference between observed output and capacity (natural) output. Thus implicit in the Taylor rule is the idea that the central banks wants to minimise the deviation of observed output from capacity output (the target).

central bank has no target for stock prices. Instead, it follows a ‘leaning against the wind’ strategy. This is the way proponents of central banks’ involvement in the stock market usually formulate the central bank’s strategy.

### 2.3 Expectations formation: forecasting output

We take the view that agents experience cognitive problems in understanding how the world functions. Thus, in contrast to what is assumed in rational expectations models in which agents understand the full model structure and the objective distribution of the shocks, we assume that agents use simple rules (heuristics) to forecast future output. The way we proceed is as follows. We start with a very simple heuristics for forecasting and apply it to the forecasting rules of future output. We assume that because agents do not fully understand how the output gap is determined, their forecasts are biased. We assume that some agents are optimistic and systematically bias the output gap upwards, others are pessimistic and systematically bias the output gap downwards.

The optimists are defined by  $\tilde{E}_t^{opt} y_{t+1} = g$  (8)

The pessimists are defined by  $\tilde{E}_t^{pes} y_{t+1} = -g$  (9)

where  $g > 0$  expresses the degree of bias in estimating the output gap. We will interpret  $2g$  to express the divergence in beliefs among agents about the output gap.

Note that we do not consider this assumption of a simple bias to be a realistic representation of the how agents forecast. Rather is it a very parsimonious representation of a world where agents do not know the ‘truth’ (i.e. the underlying model) and have a biased view about this truth.

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

$$\tilde{E}_t y_{t+1} = \alpha_{opt,t} \tilde{E}_t^{opt} y_{t+1} + \alpha_{pes,t} \tilde{E}_t^{pes} y_{t+1} \quad (10)$$

$$\tilde{E}_t y_{t+1} = \alpha_{opt,t} g - \alpha_{pes,t} g \quad (11)$$

$$\text{and } \alpha_{opt,t} + \alpha_{pes,t} = 1 \quad (12)$$

where  $\alpha_{opt,t}$  and  $\alpha_{pes,t}$  are the weights of optimists, respectively, pessimists in the market.

A methodological issue arises here. The forecasting rules (heuristics) introduced here are not derived at the micro level and then aggregated. Instead, they are imposed ex post, once the demand and supply equations are derived. This has also been the approach in the learning literature pioneered by Evans & Honkapohja (2001). Ideally one would like to derive the heuristics from the micro-level in an environment in which agents experience cognitive

problems. Our knowledge about how to model this behaviour at the micro level<sup>6</sup> and how to aggregate it is too sketchy, however, and we have not tried to do so.

As indicated earlier, agents are rational in the sense that they continuously evaluate their forecast performance. We follow Brock & Hommes (1997) in specifying the procedure agents follow in this evaluation process. Recently, Branch & Evans (2006) introduced this selection mechanism in a macroeconomic model.

Agents compute the forecast performance of the different heuristics as follows:

$$U_{opt,t} = -\sum_{k=1}^{\infty} \omega_k \left[ y_{t-k} - \tilde{E}_{opt,t-k-1} y_{t-k} \right]^2 \quad (13)$$

$$U_{pes,t} = -\sum_{k=1}^{\infty} \omega_k \left[ y_{t-k} - \tilde{E}_{pes,t-k-1} y_{t-k} \right]^2 \quad (14)$$

where  $U_{opt,t}$  and  $U_{pes,t}$  are the forecast performances of the optimists and pessimists, respectively. These are defined as the mean squared forecasting errors (MSFEs) of the optimistic and pessimistic forecasting rules;  $\omega_k$  are geometrically declining weights.

The proportion of agents using the optimistic and the pessimistic forecasting rules is then determined in the following way (Brock & Hommes, 1997).<sup>7</sup>

$$\alpha_{opt,t} = \frac{\exp(\gamma U_{opt,t})}{\exp(\gamma U_{opt,t}) + \exp(\gamma U_{pes,t})} \quad (15)$$

$$\alpha_{pes,t} = \frac{\exp(\gamma U_{pes,t})}{\exp(\gamma U_{opt,t}) + \exp(\gamma U_{pes,t})} = 1 - \alpha_{opt,t} \quad (16)$$

Equation (15) says that as the past forecast performance of the optimists improves relative to that of the pessimists more agents will select the optimistic belief about the output gap for their future forecasts. As a result the proportion of agents using the optimistic rule increases. Equation (16) has a similar interpretation. The parameter  $\gamma$  measures the ‘intensity of choice’, i.e. the intensity with which agents allow their choice for a particular heuristic to depend on past forecast performance. In the limit when  $\gamma = \infty$  only one, the best performing heuristic, will be selected.

Note that this selection mechanism is the disciplining device introduced in this model on the kind of rules of behaviour that are acceptable. Only those rules that pass the fitness test remain in place. The others are weeded out. In contrast with the disciplining device implicit in rational

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<sup>6</sup> Psychologists and brain scientists struggle to understand how our brain processes information. There is as yet no generally accepted model we could use to model the micro-foundations of information processing.

<sup>7</sup> Such a specification is often used in discrete choice theory. See Anderson et al., (1992).



expectations models which implies that agents have superior cognitive capacities, we do not have to make such an assumption here.

It is also useful to point out that the selection mechanism used here can be interpreted as an evolutionary mechanism that allows high forecasting performance to spread throughout the economy through replication.

## 2.4 Expectations formation: forecasting inflation

Agents also make forecasts of inflation in this model. We specify the inflation expectations formation in an environment in which the central bank has announced an inflation target, which agents may or may not find credible.

We follow Brazier et al. (2006) in allowing for two inflation forecasting rules. One rule is based on the announced inflation target; the other rule extrapolates inflation from the past into the future. This is a different pair of heuristics than in the case of output forecasting. The difference between inflation forecasting and output forecasting is that in the former case there is a central bank that announces a particular inflation target. This target works as an anchor for the forecasts of agents. Such an anchor is absent in the case of output forecasting.

The ‘inflation targeters’ use the central bank’s inflation target to forecast future inflation, i.e.

$$\tilde{E}_t^{tar} = \pi_t^* \quad (17)$$

where for the sake of convenience we set the inflation target  $\pi_t^* = 0$

The ‘extrapolators’ are defined by  $E_t^{ext} = \pi_{t-1}$  (18)

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

$$\tilde{E}_t \pi_{t+1} = \beta_{tar,t} \tilde{E}_t^{tar} \pi_{t+1} + \beta_{ext,t} \tilde{E}_t^{ext} \pi_{t+1} \quad (19)$$

or

$$E_t \pi_{t+1} = \beta_{tar,t} \pi_t^* + \beta_{ext,t} \pi_{t-1} \quad (20)$$

and  $\beta_{tar,t} + \beta_{ext,t} = 1$  (21)

We use the same selection mechanism as in the previous section based on the mean squared forecasting errors produced by the two rules to determine the proportions of agents trusting the inflation target and those who do not trust it and revert to extrapolation of past inflation, i.e.

$$\beta_{tar,t} = \frac{\exp(\gamma U_{tar,t})}{\exp(\gamma U_{tar,t}) + \exp(\gamma U_{ext,t})} \quad (22)$$

$$\beta_{ext,t} = \frac{\exp(\gamma U_{ext,t})}{\exp(\gamma U_{tar,t}) + \exp(\gamma U_{ext,t})} \quad (23)$$

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 proportion of agents relying 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) it will not be used much and therefore the proportion of agents using it will be small.

Finally, the stock price  $S_t$  is determined by the forecasts of future dividends. We assume these to be a constant fraction of GDP. Thus the change in the stock price  $\Delta s_t$  is determined by the forecast of future inflation and output gap. We will use the same expectations formation process as the one spelled out in the previous paragraphs.

## 2.5 Calibrating the model

We proceed by calibrating the model. In appendix A we present the parameters used in the calibration exercise. We have calibrated the model in such a way that the time units can be considered to be months.

We show the results of a simulation exercise in which the three shocks (demand shocks, supply shocks and interest rate shocks) are i.i.d. with standard deviations of 0.5%. In the first set of simulations we assume that the central bank does not attempt to influence the stock prices, i.e.  $c_4 = 0$ . We will analyze the implications of allowing the central bank to react to changes in the stock price in section 3.

We first present a simulation in the time domain. Figure 1 shows the time pattern of output, stock prices and inflation produced by the model. We observe a strong cyclical movement in the output gap. The source of these cyclical movements is seen to be the weight of optimists and pessimists in the market (see second panel of Figure 1). The model in fact generates endogenous waves of optimism and pessimism. During some periods pessimists dominate and this translates into below average output growth. These pessimistic periods are followed by optimistic ones when optimistic forecasts tend to dominate and the growth rate of output is above average. These waves of optimism and pessimism are essentially unpredictable. Other realisations of the shocks produce different cycles with the same general characteristics.

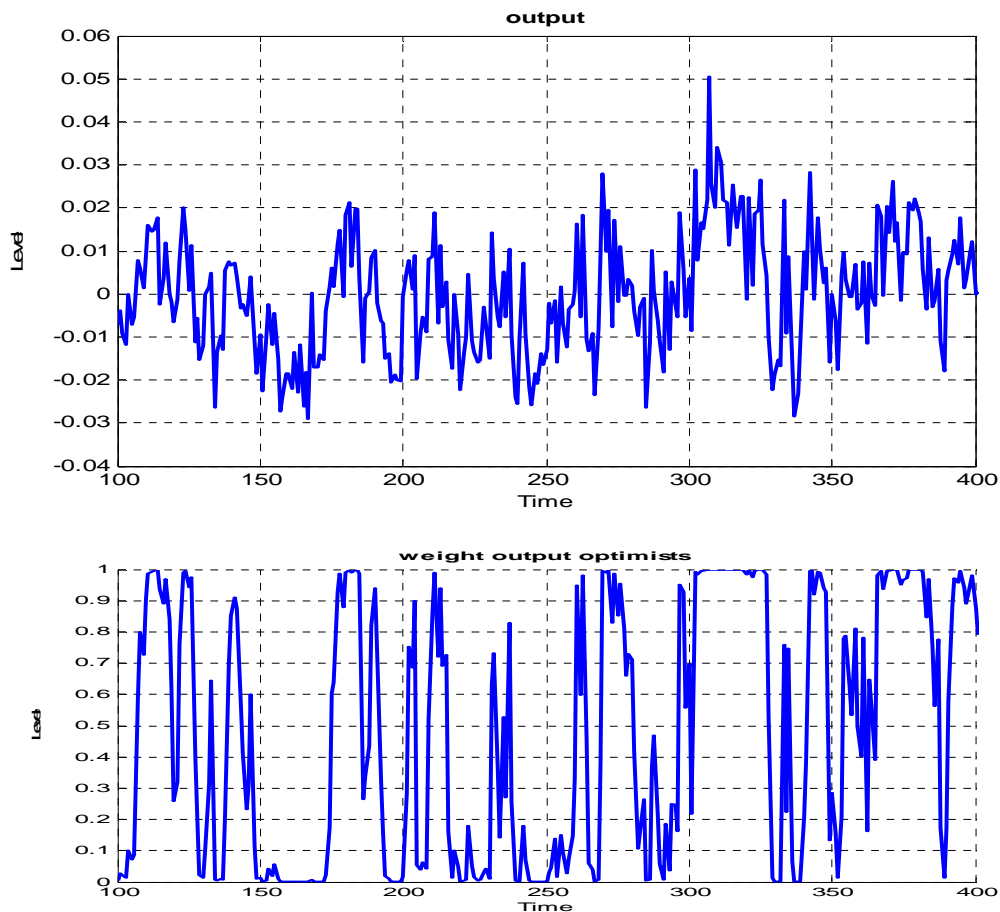
The third panel of Figure 1 shows the evolution of the stock prices in the time domain. The model creates periods of bullish and bearish behaviour of the stock prices that are associated with the same waves of optimism and pessimism (second panel). The model is also capable of creating what appears to be a bubble and a crash (around period 300). This feature is regularly found in the simulations of the stock prices in the time domain.

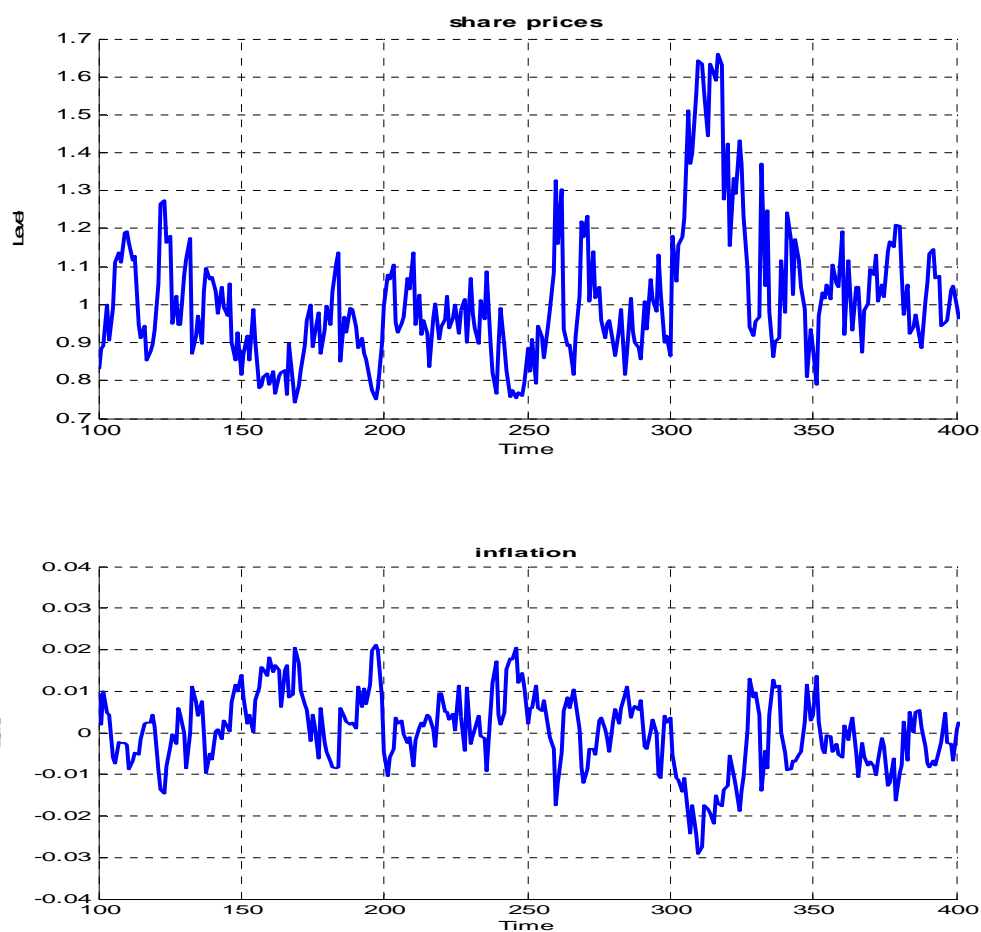
These endogenously generated cycles in output and stock prices are made possible by a self-fulfilling mechanism that can be described as follows. A series of random shocks creates the possibility that one of the two forecasting rules, say the optimistic one, delivers a higher payoff, i.e. a lower mean squared forecast error (MSFE). This attracts agents that were using the

pessimistic rule. The ‘contagion-effect’ leads to an increasing use of the optimistic belief to forecast the output-gap, which in turn stimulates aggregate demand and leads to a bull stock market. Optimism is therefore self-fulfilling. A boom is created. At some point, negative stochastic shocks make a dent in the MSFE of the optimistic forecasts. The pessimistic belief becomes attractive and therefore fashionable again. The stock market and the economy turn around.

The last panel of Figure 1 shows the simulated inflation. Inflation is kept within a relatively narrow band around the target (0%) most of the time. Occasionally, it goes beyond this band. This feature is found repeatedly in different simulations of the model. It has to do with the fact that occasionally the extrapolators in forecasting inflation tend to dominate the market. As a result, the credibility of inflation targeting is reduced allowing the inflation rate to drift away from its target. We will come back to this problem and analyse under what conditions the credibility of the inflation targeting regime can be enhanced.

Figure 1. Output gap, inflation and stock prices



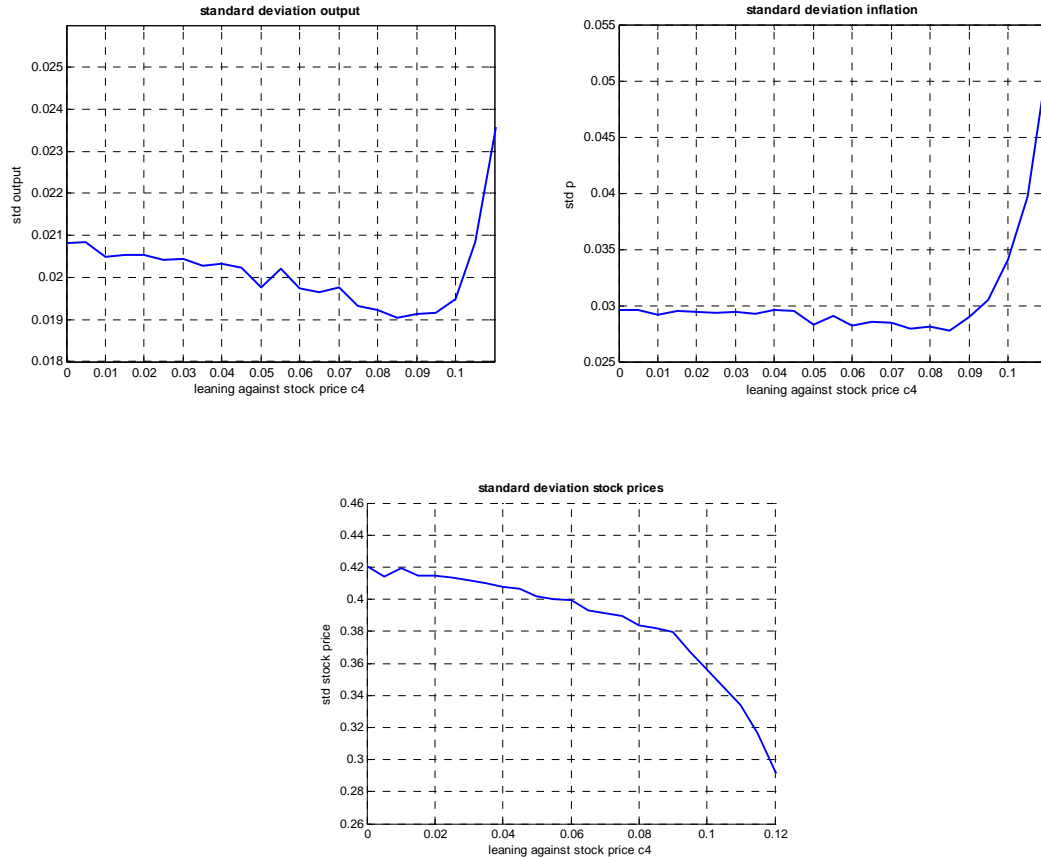


### 3. 'Leaning against the wind' in the stock markets

In this section we analyse the issue of the effectiveness of a 'leaning against the wind' strategy used by the central bank to limit the fluctuations in the stock prices. We will ask the question of whether this strategy improves the central bank's capacity of stabilising output and inflation. Thus, we take the view that attempts to reduce stock price fluctuations should be gauged by the success they have in reducing inflation and output volatility.

The way we attempt to answer this question is as follows. We simulated the model under different assumptions about the intensity of the 'leaning against the wind' strategy in the stock market as measured by the coefficient  $c_4$  in the Taylor rule equation. We selected values of  $c_4$  ranging from 0 to 0.12. For each of these parameter values we simulated the model over 1000 periods and computed the standard deviations of output, inflation and stock prices. We repeated this exercise 100 times and computed the mean standard deviations obtained for each value of  $c_4$ . We show the results in Figure 2. We observe the following. As  $c_4$  increases the standard deviations of output, inflation and stock prices decline. At some point, i.e. when  $c_4$  comes close to 0.1 the standard deviations of output and inflation increase dramatically, while the standard deviation of the stock prices declines significantly. Thus, as long as the 'leaning against the wind' strategy is moderate, this strategy pays off and reduces the volatility of inflation, output and stock prices. When this strategy becomes too active (too large a value of  $c_4$ ), it creates additional volatility in inflation and output. We conclude that mild forms of interventions in the stock markets can be effective in reducing macroeconomic volatility.

Figure 2. Macroeconomic volatility and ‘leaning against the wind’



#### 4. Inflation targeting and macroeconomic stability

Our previous analysis was conducted in an environment of inflation targeting in which, however, agents maintained their scepticism about the credibility of the inflation targeting regime. As a result, as we have seen, the inflation rate occasionally departs from its target in a substantial way. Thus we modelled a regime of imperfect credibility of the inflation target.

In this section we analyze two extreme cases concerning the credibility of the inflation target. One is to assume that it is 100% credibility; the other assumption is that there is no credibility at all. We take these two extremes, not because these are particularly realistic, but rather to focus on how different degrees of credibility affect macroeconomic stability and the capacity of the monetary authorities to enhance stability by leaning against the wind strategies in the stock markets.

The way we model these two extremes is as follows. In the perfect credibility regime we assume that all agents perceive the central bank’s announced inflation target  $\pi_t^*$  to be fully credible.

They use this value as their forecast of future inflation, i.e.  $\tilde{E}_t \pi_{t+1} = \pi_t^*$ . Since all agents believe this, they do not switch to the alternative forecasting rule of extrapolating the past inflation rate.

The other extreme case, i.e. zero credibility of the inflation target, is modelled symmetrically. Now no agent attaches any credibility to the announced inflation target, and therefore each of them is an ‘extrapolator’. As before, this is defined by  $E_t^{ext} = \pi_{t-1}$ . In this case there is also no switching to the alternative forecasting rule.

We show the results of these two exercises in figures 3 and 4. Let us concentrate on Figure 3 first, showing the degree of macroeconomic volatility in a regime of 100% credibility of the inflation target. A first thing to note is that in a regime of full credibility of the inflation target the volatility of the output, inflation and stock prices is significantly lower as compared to the regime of imperfectly credible inflation target. The difference is quite high. Comparing Figure 3 with Figure 2 shows that in a fully credible inflation targeting regime the standard deviation of output, inflation and stock prices are about half as large as in the case of imperfect credibility. Thus, credibility is extremely valuable. It allows reducing the volatility of all three macroeconomic variables, at no apparent cost.

A second conclusion from a comparison of Figures 3 and 2 is that mild forms of ‘leaning against the wind’ in the stock market have a much stronger effect in reducing volatility of output, inflation and stock prices. Thus, credibility of the inflation target makes ‘leaning against the wind’ in the stock markets more effective in reducing macroeconomic volatility. (Note again that this only holds for relatively low levels of  $c_4$ )

The importance of credibility as a means to achieving macroeconomic stability and as a way to make ‘leaning against the wind’ in the stock market an effective stabilisation tool is reinforced by the results of Figure 4. These show that when there is total absence of credibility in the inflation target, the volatility of output, inflation and stock prices is higher for all values of  $c_4$ . In addition, ‘leaning against the wind’ in the stock market, now has almost no stabilising properties for output and inflation (compare Figure 4 with Figure 2).

Figure 3. Macroeconomic volatility when inflation target is 100% credible

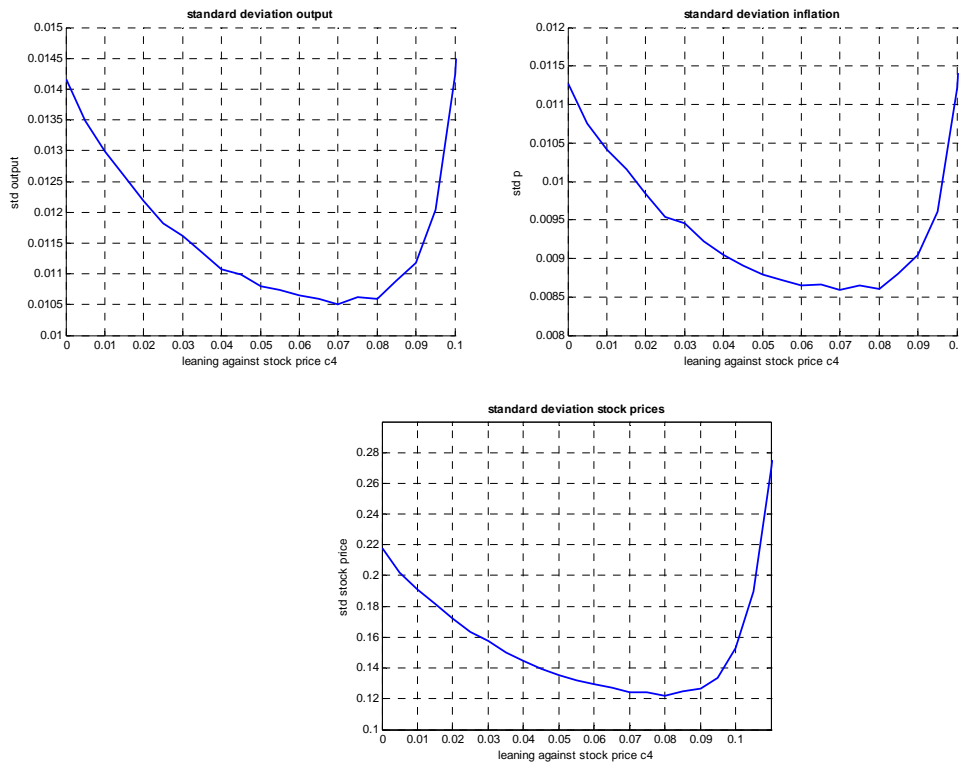
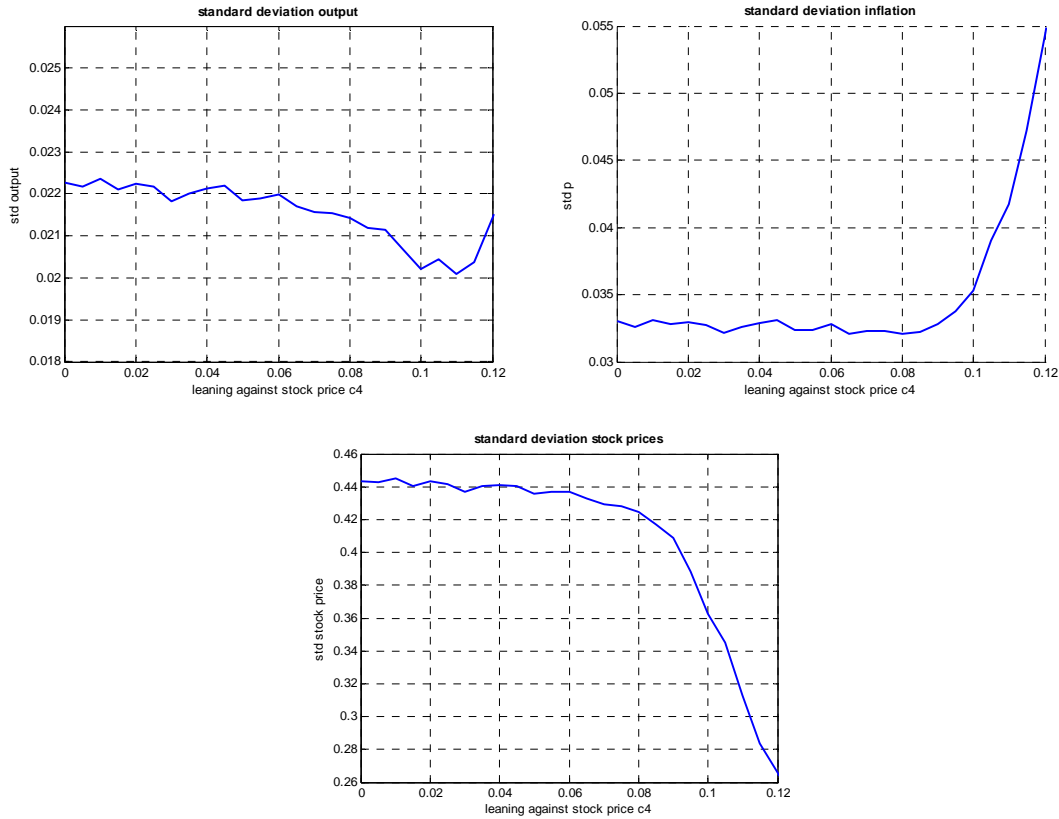


Figure 4. Macroeconomic volatility when inflation target is 0% credible



### 5. The trade-off between output and inflation variability

Another way to evaluate ‘leaning against the wind’ strategies in the stock markets is to analyze how they affect the trade-off between output and inflation variability. We will proceed as follows. We return to the regime of imperfectly credible inflation target. We assume several values of  $c_4$  from 0 to 0.05 (the ‘leaning against the wind’ parameter in the stock market). We then compute the tradeoffs between output and inflation variability in the usual way.<sup>8</sup> We plot the results in Figure 5.

A first important finding concerns the shape of these trade-offs. We find that these trade-offs are non-linear, i.e. there is a positively and a negatively sloped segment. The interpretation is the following. When the central bank does not care about output stabilisation ( $c_2=0$ ) we are located in the upper right points of the tradeoffs. An increase in the willingness to stabilise output ( $c_2$  increases) leads to a downward movement along the trade-off. This means that when the central bank increases its output stabilisation effort it reduces both the variability of output and

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<sup>8</sup> That is, we allow the output stabilisation parameter ( $c_2$ ) in the Taylor rule to increase from 0 to 1 and compute the standard deviations of output and inflation for each value of  $c_2$ . Note that the output stabilisation coefficient has much larger values than the stock price coefficient ( $c_4$ ). This has to do with the fact that the variations in stock prices per unit of time are a multiple of the variations in the output gap.

inflation. At some point, however, applying more stabilisation ( $c_2$  increases further) brings us in the upward sloping part. From then on more stabilisation leads to the traditional trade-off: more output stability is bought by more inflation variability. This is the standard result obtained in rational expectations models. In these models any attempt to stabilise output leads to more inflation variability. In our behavioural model this is not necessarily the case. Mild forms of output stabilisation (low  $c_2$ ) have the effect of reducing both output and inflation variability. When however the ambition to stabilise output is too strong, we return to the traditional negatively sloped trade-off and the gain in output stabilisation leads to more inflation variability. Thus, in our model some output stabilisation is always better than no stabilisation at all. This result comes from the structure of our model. When the central bank applies modest output stabilisation it also reduces the waves of optimism and pessimism. The latter affect not only output variability but also inflation variability. Thus by reducing these ‘animal spirits’ the central bank achieves both lower output and inflation variability. It can do this because it profits from a credibility bonus. Too much activism, however, destroys this credibility bonus, leading to the normal negatively sloped tradeoffs.

A second finding from Figure 5 relates to the effect of ‘leaning against the wind’ in the stock market. We find that a more intense ‘leaning against the wind’ in the stock market improves the tradeoffs, i.e. shifts them downwards. Thus ‘leaning against the wind’ reduces both output and inflation variability. Note, however, that this result only holds in the positively sloped segment of the tradeoffs. In the negatively sloped part, there is no clear effect of leaning against the wind strategies. This suggests that ‘leaning against the wind’ strategies are effective in reducing both output and inflation variability for the same reason as output stabilisation does. These strategies tend to reduce the scope for waves of optimism and pessimism and thus stabilise the macroeconomy as a whole. A too aggressive use of these strategies, however, will tend to create an inflationary bias, which then re-establishes the negative trade-off between output and inflation variability.

As in the previous section we analyzed the importance of the credibility of inflation. We do this by assuming the same two extreme regimes, perfect credibility and zero credibility. The perfect credibility case is shown in Figure 6. It confirms some of the results obtained earlier. For example, the tradeoffs under perfect credibility are located much lower than those obtained under imperfect credibility (compare Figure 5 with Figure 4). Thus, credibility dramatically improves the tradeoffs, leading to less variability of both output and inflation. We also find that ‘leaning against the wind’ strategies improves these tradeoffs significantly, thus lowering both output and inflation variability.

The case of zero credibility of inflation target is shown in Figure 7. The contrast with the previous figures is striking. The tradeoffs are located higher than in the previous two cases, and the positive segments of the tradeoffs have practically disappeared. This has to do with the fact that the absence of any credibility in the inflation target is quickly punished by agents who will extrapolate the higher inflation that results from active stabilisation policies. We also conclude from Figure 7 that ‘leaning against the wind’ strategies have no visible impact on the tradeoffs. Thus policies aiming at reducing the volatility of asset prices by manipulating the interest rates do not improve macroeconomic stability when inflation targeting has no credibility.



Figure 5. Trade-off output and inflation variability: Imperfect credibility

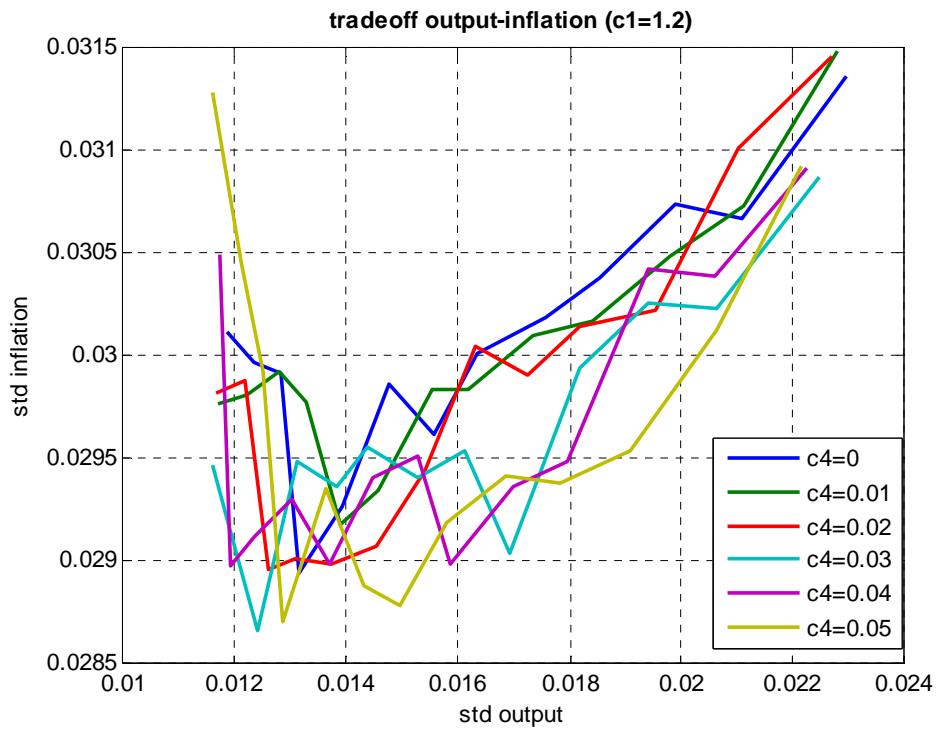


Figure 6. Trade-off output and inflation variability: perfect credibility

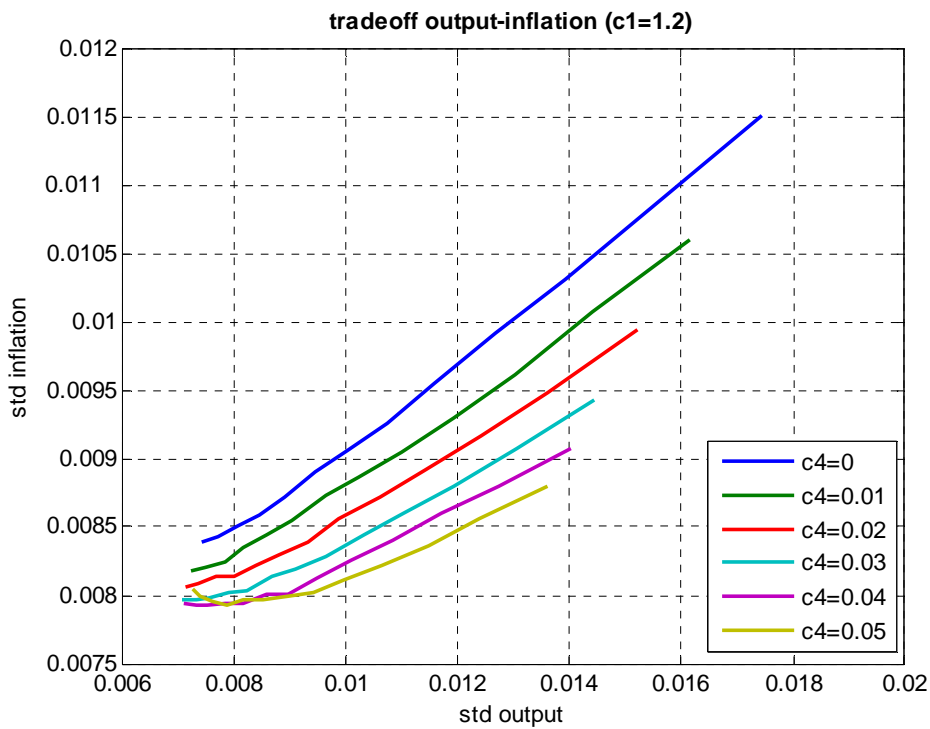
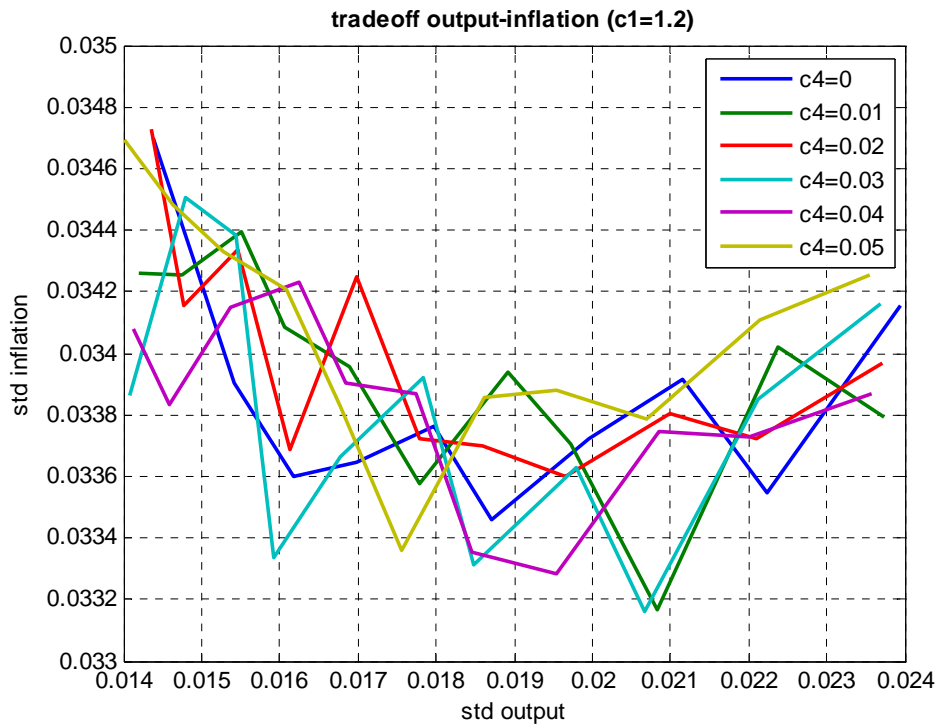


Figure 7. Trade-off output and inflation variability: zero credibility



## 6. Conclusion

Should central banks use their interest rate instrument to influence the asset prices and to prevent bubbles from emerging? This question has been hotly debated by economists. It has become topical again since the credit crisis erupted in August 2007. We analysed this question using a behavioural macroeconomic model. This model produces booms and busts that arise from the fact that beliefs about the future become correlated. It is the appropriate one to study this question.

Our main results are the following. Yes, central banks can influence stock prices, and by following ‘leaning against the wind’ strategies in the stock market, they can improve the trade-off between output and inflation, i.e. they can reduce the volatility of both output and inflation. This result, however, only holds in an environment of credible inflation targeting. If the inflation target has a high degree of credibility we find that these ‘leaning against the wind’ strategies significantly improve macroeconomic stability (output and inflation stability). However, these policies aiming at reducing the volatility of asset prices by manipulating the interest rates do not improve macroeconomic stability when inflation targeting has no credibility.

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## Appendix A

### Parameter values of the calibrated model

```
pstar = 0;           % the central bank's inflation target
a1 = 0.5;           % coefficient of expected output in output equation
a2 = -0.2;         % a is the interest elasticity of output demand
a3 = 0.05;         % a3 is the elasticity of demand with respect to share prices
b1 = 0.5;           % b1 is coefficient of expected inflation in inflation equation
b2 = 0.05;         % b2 is coefficient of output in inflation equation
b3 = 0.02;         % b3 is the elasticity of supply with respect to share prices
c1 = 1.5;          % c1 is coefficient of inflation in Taylor equation
c2 = 0.5;          % c2 is coefficient of output in Taylor equation
c3 = 0.5;          % interest smoothing parameter in Taylor equation
c4 = 0.0;          % stock price smoothing parameter in Taylor equation
beta = 0.01;       % fixed divergence in beliefs
gamma = 10000;     % switching parameter gamma in Brock Hommes
sigma1 = 0.005;    % standard deviation shocks output
sigma2 = 0.005;    % standard deviation shocks inflation
sigma3 = 0.005;    % standard deviation shocks Taylor
rho=0.5;           % rho measures the speed of declining weights omega in mean squares errors
```

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