Open-Economy Inflation-Forecast Targeting*

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Abstract

This paper extends previous research on simple inflation-forecast targeting by considering its effect in the open economy. It discusses the effect of the forecast-targeting horizon on interest rates and the exchange rate, and moreover what role it plays in determining the rational expectations equilibrium. Inflation-forecast targeting may not comply with the Taylor principle, as a sufficiently long horizon may not provide a adequately strong interest rate response to the determinants of future inflation. A long horizon causes the short-term real interest rate and the exchange rate to fluctuate persistently, producing inflation and especially traded sector output volatility.

Keywords: Inflation targeting, forecast targeting, monetary policy, small open economy.

JEL codes: E52, E47, E43.

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1. Introduction

A large number of countries have either formally or more informally adopted inflation targeting as a framework for monetary policy throughout the 1990s. Following the idea that inflation targeting implies using all available information efficiently in minimizing the variance of inflation around a target level[1] (possibly by stabilizing other variables as well), the implementation is left to the discretion of the analysts and policymakers in the respective central banks. Due to the traditional arguments of lags in the monetary policy transmission mechanism, e.g. as modeled in the influential article by Svensson (1997), the inflation forecast plays an important role in the conduct of monetary policy. The argument is that since the monetary policymaker's instrument has its strongest impact on its goal variables several quarters ahead, optimal monetary policy is forward looking and the instrument should respond to the determinants of future inflation (i.e. the forecast) and possibly other target variables. Since in most models, nominal inertia implies a trade-off between nominal and real variability, the inflation targeting central bank should aim to bring inflation in line with target over time. Short-sightedness should be avoided, since such a policy could produce high output and interest rate volatility. In the open economy, the exchange rate channel opens the possibility of stabilizing inflation at a very short horizon, leading to high real variability (Svensson, 2000).

This paper extends previous research on the implications of a simple inflation-forecast targeting strategy where the central bank sets an interest rate level which, if kept constant throughout the forecast-targeting horizon, produces a conditional inflation forecast equal to the inflation target level.[2] This rule has seemingly strong intuitive appeal: the monetary policy stance is set in such a way that if the economy evolves as expected, policy is in line with achieving the inflation target at some horizon. Rudebusch and Svensson (1999) discuss this strategy within a backward-looking, closed-economy model of the US economy. This paper extends the analysis of the properties of inflation-forecast targeting by considering its open-economy implications. Particular emphasis is put on describing how the forecast targeting horizon effects the traded and non-traded sectors through implied exchange-rate and interest rate dynamics and what role the choice of horizon plays in determining the rational expectations equilibrium. Moreover, the paper also discusses what role the inflation target plays in pinning down long-run inflation expectations under inflation-forecast targeting.

[1] Lars Svensson has suggested this definition of inflation targeting in several papers, for instance (Svensson, 1999b, 2000).

[2] This policy should be contrasted to *optimal* inflation-forecast targeting, explored in Svensson and Woodford (1999) and Svensson (2001), where the forecasts of the target variables satisfy the first-order conditions of optimal inflation targeting, i.e. a situation in which the policymaker minimizes a quadratic loss function.

Inflation-forecast targeting requires strong movements in the interest rate when the forecast-targeting horizon is relatively short. If a shock hits the economy, the policymaker needs to stabilize the inflationary impulses quickly which requires strong interest rate responses to the factors determining future inflation. With a longer forecast-targeting horizon, there is less need for strong interest rate responses since the policy multiplier increases with the forecast-targeting horizon. In models that respect the *long-run superneutrality* of monetary policy, an equilibrium rate of inflation is achieved without monetary policy following a state-contingent rule, but rather satisfies conditions for having the equilibrium inflation rate equal to target. Extending the forecast-targeting horizon brings it closer to the time it takes for the nominal inertia to have worked itself out and the equilibrium rate of inflation achieved. Hence, a longer forecast-targeting horizon implies a greater degree of interest rate stabilization around its equilibrium rate.

In order to address the open-economy implications, we develop a New Keynesian, small open-economy macroeconomic model similar to the one-sector model developed by Batini and Haldane (1999) and used as a policy model at the Bank of England.[3] Our model is, however, extended in several respects. Recently, Ball (2000) has argued that analysis should be carried out within multi-sector models in order to shed light on the role and sectoral influence of the exchange rate in monetary policymaking. In this respect, we add a competitive, traded sector to the model in order to refine the view of how monetary policy influences the real economy. We show that the nominal interest rate stabilization implied by a long forecast-targeting horizon implies that inflation will fluctuate more, causing the short *real* interest rate and the real exchange rate to fluctuate persistently. As the real exchange rate affects the traded sector relatively more than it does the non-traded sector, we show that if the inflation-forecast targeting central bank chooses a long forecast-targeting horizon, the traded sector will be relatively more exposed to fluctuations than the non-traded sector. Thus, merely extending the forecast-targeting horizon does not necessarily provide more real stability. Inflation variability will, however, increase.

The paper is organized as follows. Section 2 starts by defining what we mean by inflation-forecast targeting in this context and discusses the simple intuition behind it. In the final part of Section 2, we derive the policy rule implied by inflation-forecast targeting and discuss some model-independent features of such a rule. Section 3 introduces open-economy elements by considering a model in the New Keynesian, open-economy model. Section 4 first discusses issues of rational expectations determinacy and the so-called Taylor principle with respect to inflation-forecast targeting within the model and then goes on to discuss its stabilizing properties. Finally,

[3] See Bank of England (1999).

Section 5 concludes.

2. Inflation-forecast targeting

Goodhart (1999) suggests that the instrument should be adjusted so as to stabilize the forecast of inflation at some appropriate horizon at the target level. Formally, such a policy target can be denoted by

$$\bar{\pi}_{t+h|t} = \pi^*, \tag{1}$$

where h is the inflation-forecast targeting horizon; $\bar{\pi}_{t+h|t}$ is the central bank's forecast of the four-quarter inflation rate at time $t+h$ made at time t; and π^* is the inflation target level. If h is set equal to the shortest lag at which the instrument of the central bank affects inflation (the *inflation control lag*), (1) is equivalent to strict inflation targeting, in Svensson's terminology, as this policy would imply a use of the instrument that would minimize the variance of inflation (and inflation only) around the target level. If, however, h is a number greater than the length of the inflation control lag, equation (1) does not fully determine policy. There is then an infinity of instrument paths that are consistent with this formulation. For concreteness, assume that the forecast-targeting horizon is three periods and the inflation control lag is two, and that the prevailing inflation rate is above target. The policymaker can now either choose to follow a lax policy in the first period and a more contractionary policy in the second period or do this in the reverse order; in either case the target can be reached at the specified horizon.

In order to pin down policy, we need to place additional restrictions on policy. One common restriction is that the interest rate is constant within the forecast-targeting horizon. Let a policy of setting the instrument so as to have the constant-interest-rate forecast of inflation at a given horizon on target be denoted by

$$\bar{\pi}_{t+h|t}(\bar{i}) = \pi^*, \tag{2}$$

where policy is well-defined in a mathematical sense. The interest rate is now set at the rate which, on the assumption that it is kept constant throughout the forecast-targeting horizon, will ensure that the inflation forecast is on target. If the forecast of inflation at the forecast-targeting horizon is not on target given the prevailing interest rate level, the interest rate is exactly adjusted to correct for this.[4] This is the definition of inflation-forecast targeting used in this paper.[5]

[4] Smets (2000) discusses a similar targeting procedure, where the central bank minimizes a loss function subject to inflation being back on target within a specified time.

[5] Our definition of (simple) inflation-forecast targeting is distinct from optimal inflation-forecast targeting, as pointed out in footnote 3. Simple and optimal inflation-forecast targeting will, however, coincide when the forecast-targeting horizon is equal to the inflation control lag and inflation is the only argument in the loss

Several central banks provide constant-interest-rate projections of inflation in their inflation reports and discuss their policy stance in relation to these projections. The reason is that these projections show the most likely outcome of inflation if the policy stance is kept unchanged, thereby providing a helpful benchmark to guide the policy assessment (See, e.g. Bank of England, 2001, p.58). Some researchers have even claimed that inflation-forecast targeting comes very close to describing the actual policy procedure at some central banks.[6] Considering the intuitive and simple appeal of inflation-forecast targeting, together with the claimed empricial relevance, make it altogether an interesting strategy to analyze.

2.1. Time inconsistency, inflation dynamics and credibility

It is important to note that forecast targeting does not necessarily imply that inflation will be back on target at the end of the h-period forecast-targeting horizon, if h is a number greater than the shortest lag at which the monetary policy instrument affects inflation. Under forecast targeting, the chosen interest rate will attain the inflation target (in expectations) provided that the interest rate is kept constant within the forecast-targeting horizon. If the central bank, however, follows inflation-forecast targeting also in subsequent periods, the condition of interest rate constancy will in general not be valid. The reason for this is that as time passes, the end of the forecast-targeting horizon moves forward and the relevant forecast changes which may necessitate a change in the interest rate. For these reasons inflation-forecast targeting is time inconsistent. This time inconsistency will, however, disappear if the forecast-targeting horizon exceeds the inflation control lag. Time inconsistency implies that the forecast-targeting horizon is not equal to the expected time at which inflation will have returned to its target level.[7]

This form of time inconsistency may not be as harmless as it may seem at first sight. As a constant-interest-rate inflation forecast potentially deviates considerably from the rational expectations path, it may contain limited information for agents who strive to base their nominal contracts on the most likely future development of inflation. For agents who do not understand the time-inconsistency implications of inflation-forecast targeting, the updating of policy each period which creates the "postponement" of the time at which inflation should attain its target

function.

[6]Goodhart (2000), former member of the UK Monetary Policy Committee, states: "When I was a member of the MPC I thought that I was trying, at each forecast round, to set the level of interest rates, on each occasion, so that without the need for future rate changes prospective inflation would on average equal the target at the policy horizon. That was, I thought, what the exercise was supposed to be." Svensson (2001) asks whether "[it is] possible to provide more optimal, but still operational, targeting rules than the Bank of Englands and the Riksbanks 'the constant-interest-rate inflation forecast about two years ahead should equal the inflation target?' ".

[7]It should be noted that the forecast-targeting horizon, as defined in this paper, is distinct from the forecast-*feedback* horizon, as discussed in Batini and Nelson (2001). The latter concept refers to the forecast-lead of inflation when used as an argument in an interest rate reaction function.

level, may be interpreted as the central bank not being fully committed to its stated inflation target. Such beliefs would possibly induce a loss of credibility for the central bank and be a problem for reasons outlined in Svensson (1999a). If private agents do not believe inflation will quickly stabilize around the announced inflation target, the informational content of the target is reduced and agents will undertake the costs of forming expectations based upon other indicators with larger informational content. This may reduce the central bank's ability to stabilize inflation without causing large output movements, i.e., increase the sacrifice ratio.

In order to understand what inflation dynamics inflation-forecast targeting may induce, it is useful to study some stylized examples. Figure 1 shows three possible developments of inflation under two-period inflation-forecast targeting within different model settings where the interest rate affects inflation with a one-period lag. The solid line in each panel shows the expected evolution of the inflation rate after a shock to inflation. The dashed lines show the constant-interest-rate forecasts made in each period for two and three periods ahead. Note that the two-period forecasts are on target, while the three-period forecasts in general deviate from the target value. The constant-interest-rate forecasts coincide with the expected development during the first period, but then deviate as policy is updated to conform to the new forecast horizon.

Panel A illustrates a state of the economy and a model in which the three-period inflation forecast undershoots the target level. As time passes, and assuming no new information arrives, the previous three-period forecast becomes the two-period forecast at the prevailing interest rate, and due to the undershooting, the interest rate is lowered accordingly. In this situation, forecast-targeting induces a monotonic convergence of inflation toward the target level. In the situation illustrated by Panel B, the three-period inflation forecast overshoots the target level. As time passes, the overshooting requires a tightening of monetary policy and the interest rate is raised accordingly, causing a further decline in the inflation rate. Inflation converges non-monotonically toward the target level, but monetary policy does cause inflation to deviate persistently from the target level. Panel C shows that forecast-targeting may induce oscillations in the inflation process. If the model implies that the assumption of a constant interest rate induces the two-period and three-period forecasts to move in the opposite directions, inflation-forecast targeting may produce erratic movements in the interest rate and hence possibly in the inflation rate.

Although the intuition behind forecast targeting may be quite seductive, these simple examples show that time-inconsistency makes this intuition somewhat deceptive. This intensifies the need for analyzing inflation-forecast targeting in models we have confidence in, as most of

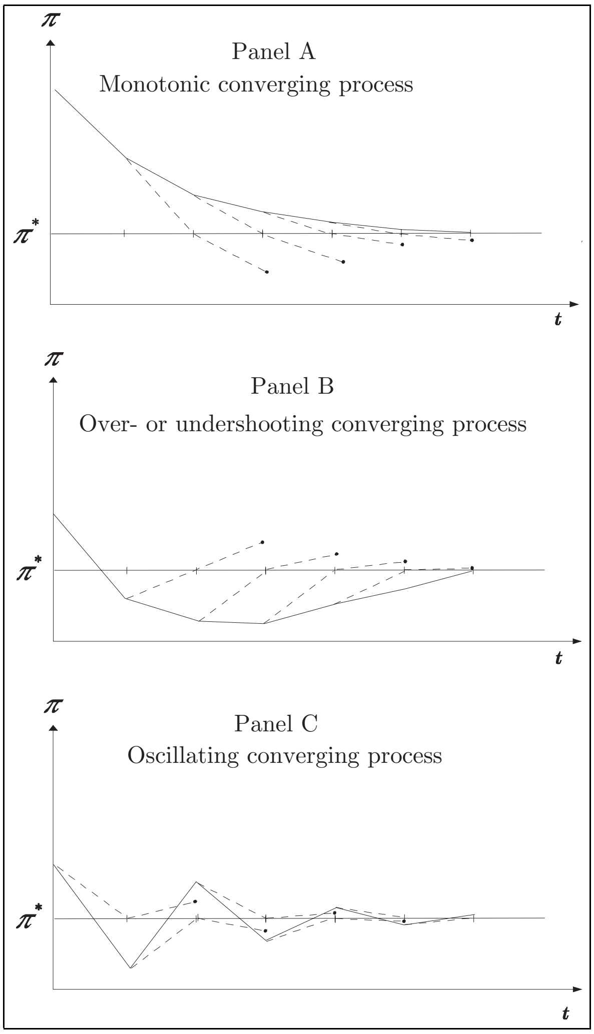

Figure 1
Constant-interest-rate forecast targeting illustration.

its properties are likely to be highly model dependent.

2.2. Deriving the policy implications

An inflation-forecast targeting central bank is concerned with choosing an interest rate each period that minimizes its loss function given by

$$L_t = \frac{1}{2}\left[\theta\left(\bar{\pi}_{t+h|t}\left(\bar{i}\right) - \pi^*\right)^2 + (1-\theta)\left(y_{t+h|t}(\bar{i}) - y^*\right)^2\right], \tag{3}$$

where $\bar{\pi}_{t+h|t}\left(\bar{i}\right)$ and $y_{t+h|t}(\bar{i})$ are the constant-interest-rate forecasts of four-quarter inflation and output respectively, and y^* is the output target, assumed to be equal to the natural rate. For the remainder of the paper, the inflation target (π^*) and the natural rate (y^*) are both normalized to zero. According to (3), the central bank is concerned about both having the forecast of inflation close to its target and the forecast of output not deviating too far from its natural rate. $\theta \in [.5, 1]$ is a parameter reflecting the central bank preference for inflation forecast stabilization relative to output stabilization.[8] A lower value reflects a central bank that is relatively more concerned about stabilizing the output forecast, denoted a *flexible* inflation-forecast targeter. The first order condition of (3) is

$$\theta \frac{\partial \bar{\pi}_{t+h|t}\left(\bar{i}\right)}{\partial i} \bar{\pi}_{t+h|t}\left(\bar{i}\right) + (1-\theta) \frac{\partial y_{t+h|t}(\bar{i})}{\partial i} y_{t+h|t}(\bar{i}) = 0. \tag{4}$$

According to (4), the central bank targets a weighted average of the inflation and output forecasts. The weights are partly determined by the preferences of the central bank, but also by the policy multipliers, i.e. the effect a change in the interest rate has on the respective forecasts. An inflation-forecast targeting central bank with preferences for output forecast targeting, i.e. $\theta < 1$, accepts over- or undershooting of the target in accordance with the distance of the forecast of output from the natural rate. This can easily be seen by rearranging (4) as

$$\bar{\pi}_{t+h|t}\left(\bar{i}\right) = -\frac{(1-\theta)}{\theta} \frac{\frac{\partial y_{t+h|t}(\bar{i})}{\partial i}}{\frac{\partial \bar{\pi}_{t+h|t}\left(\bar{i}\right)}{\partial i}} y_{t+h|t}(\bar{i}), \tag{5}$$

which implies a conditional inflation target. If the output forecast is well below the natural rate, the inflation target rises above its normal rate, e.g. to the upper level of the target band. Equation (2) is equivalent to equation (5) when $\theta = 1$, that is, under strict inflation-forecast targeting.

In order to derive the policy implications, i.e. the interest rate reaction function, under this procedure, consider a general backward-looking model in state space form

$$X_{t+1} = AX_t + Bi_t + \epsilon_{t+1}, \tag{6}$$

where X is a vector of state variables; i is the policy instrument, i.e. the short nominal interest rate within this framework, and ϵ is a vector of disturbance terms with zero expectations and finite variance. A is the transition matrix of the model and B is the vector of parameters describing the direct effects of the interest rate. By subsequent substitutions, the h-period-

[8] It seems appropriate to restrict θ downwards to a value of .5, as a smaller number would be more in line with output-forecast targeting than inflation-forecast targeting.

ahead forecast is written as

$$X_{t+h|t} = A^h X_t + \sum_{j=0}^{h-1} A^j B i_{t+h-1-j|t}, \tag{7}$$

where the forecast of the state variables is a function of the state of the economy at the time of the forecast, the policy assumptions in the forecast period and the economic model being analyzed. Under the assumption that the interest rate is kept constant in the forecast period, $i_{t+j|t}(\bar{\imath}) = i_t$ for $h > j \geq 0$, we can write the constant-interest-rate forecast of the state variables as

$$X_{t+h|t}(\bar{\imath}) = A^h X_t + \sum_{j=0}^{h-1} A^j B i_t. \tag{8}$$

We may also write the target variables as functions of the state variables

$$\begin{aligned} \bar{\pi}_t &= K_\pi X_t, \\ y_t &= K_y X_t, \end{aligned}$$

where K_π and K_y are vectors that relate inflation and output to the state vector.

Correspondingly, the constant-interest-rate forecasts of the target variables are then given by $\bar{\pi}_{t+h|t}\left(\bar{\imath}\right) = K_\pi X_{t+h|t}(\bar{\imath})$ and $y_{t+h|t}(\bar{\imath}) = K_y X_{t+h|t}(\bar{\imath})$. Using (2.5) we can write these forecasts as functions of the interest rate and the current state,

$$\begin{aligned} \bar{\pi}_{t+h|t}\left(\bar{\imath}\right) &= K_\pi A^h X_t + K_\pi \sum_{j=0}^{h-1} A^j B i_t, \\ y_{t+h|t}(\bar{\imath}) &= K_y A^h X_t + K_y \sum_{j=0}^{h-1} A^j B i_t, \end{aligned}$$

where the policy multipliers associated with the inflation and output forecasts are

$$\begin{aligned} \frac{\partial \bar{\pi}_{t+h|t}\left(\bar{\imath}\right)}{\partial i} &= K_\pi \sum_{j=0}^{h-1} A^j B, \\ \frac{\partial y_{t+h|t}(\bar{\imath})}{\partial i} &= K_y \sum_{j=0}^{h-1} A^j B. \end{aligned}$$

Substituting the expressions for the forecasts and the policy multipliers into (4) gives

$$\theta K_\pi \sum_{j=0}^{h-1} A^j B \left[K_\pi A^h X_t + K_\pi \sum_{j=0}^{h-1} A^j B i_t \right] + (1-\theta) K_y \sum_{j=0}^{h-1} A^j B \left[K_y A^h X_t + K_y \sum_{j=0}^{h-1} A^j B i_t \right] = 0,$$

which may be expressed in terms of the interest rate as

$$\begin{aligned} i_t &= \frac{\Omega}{\Omega \sum_{j=0}^{h-1} A^j B} A^h X_t, \\ &= F_{cir} X_t, \end{aligned} \tag{9}$$

where $\Omega = \left(-\theta K_\pi \sum_{j=0}^{h-1} A^j B K_\pi + (1-\theta) K_y \sum_{j=0}^{h-1} A^j B K_y \right)$. Equation (9) denotes the CIR targeting central bank's reaction function and yields the following proposition.

Proposition 1

Given that A is positive semi-definite and has eigenvalues within the unit circle, extending the length of the forecast-targeting horizon reduces the absolute value of the coefficients in the reaction function (9).

There are two independent effects that produce this outcome. The first, which refers to $\sum_{j=0}^{h-1} A^j B$ in the denominator of (9), is the effect of the interest rate level on the forecast when extending the inflation-forecast targeting horizon. A given constant interest rate level is more effective in influencing the determinants of the forecasts if it remains in place for a longer period of time. Thus, the reaction to the underlying determinants does not have to be as strong as under a shorter forecast-targeting horizon. The second effect refers to the inherent properties of the forecasting model and its transition matrix, A. If A is 'stable', that is, has all eigenvalues within the unit circle,[9] the state variables in the model will approach their equilibrium values even without any response from policy since $A^h \to 0$ as $h \to \infty$. In the case of a long forecast-targeting horizon, the inflation targeting central bank will exploit these effects to a greater degree than a central bank with a shorter horizon. The result is less need for monetary policy to respond to disequilibrium conditions, but rather instead satisfy the equilibrium conditions for having inflation equal the target level.

[9]For an important class of models, this conditions will fail to hold. If the backward-looking model includes an accellerationist Phillips curve, there is a unit root in the A matrix, and the model is not self-stabilizing with respect to the inflation rate. The first effect will still ensure that a long forecast-targeting horizon will imply more interest rate stability.

Proposition 1 is not directly applicable to a model with forward-looking behaviour. However, there is reason to believe that a longer forecast-targeting horizon increases interest rate stabilization around the equilibrium rate also in models with forward-looking behaviour. The constant-interest-rate forecast of the target variables conditions on the state of the economy and the level of the forward-looking variables at the time the forecast is being made and, as before, lengthening the horizon implies that the instrument is expected to remain in place for a longer period of time and therefore will have a stronger effect on the relevant forecast. Thus, forward-looking behaviour does not lead us to expect a change in this result of increased interest rate stabilization with a longer forecast-targeting horizon in any fundamental way.

3. A New Keynesian, open-economy policy model

In order to study the implications of inflation-forecast targeting in a small open economy, we use a rational expectations, forward-looking model with a traded and a non-traded sector. The model is in the New Keynesian tradition, building upon, among others, Taylor (1979), Calvo (1983), Fuhrer and Moore (1995), Roberts (1995), Blanchard and Kiyotaki (1987), Woodford and Rotemberg (1997), Rudebusch (2002, 2000) and McCallum and Nelson (1999b,a). There is monopolistic competition in the non-traded sector. Production in this sector is hence restricted by demand. Monetary policy influences demand through the short real interest rate and expectations about its future development. The traded sector operates in a perfectly competitive market and takes prices as given. Nominal rigidities are introduced through overlapping wage contracts in the spirit of Fuhrer and Moore (1995) and Fuhrer (1997), creating a role for monetary policy influencing real variables in the short run. A model that will be used for evaluating a forecast-based rule quite naturally needs to be able to track data in a reasonable manner. The model is calibrated to match UK data, and most parameters are taken from Batini and Haldane (1999) who set parameters "in line with prior empirical estimates on quarterly data [...] and to ensure a plausible dynamic profile from impulse responses."

All variables, except the interest rate, are measured as log deviations from their (possibly time-varying) long-run equilibrium values which are assumed to be independent of monetary policy.[10] To make notation easier to read, we generally write $x_{t+s|t} \equiv E_t x_{t+s}$. The model is

[10] For some interesting views on how the choice of monetary policy strategy may influence the long-run equilibrium of real variables, see Bratsiotis and Martin (1999) for the closed economy and Holden (1998) for the open economy.

summarized by the following equations:

$$y^T_{t+1} = \rho_T y^T_t + \beta \sum_{s=0}^{\infty} \delta^s (p^T_{t+1+s|t} - w_{t+1+s|t}) + u^T_{t+1} \tag{10}$$

$$y^N_{t+1} = \rho_N y^N_t - \alpha(\omega R_t + (1-\omega) r_t) + \kappa(p^T_t - p_t) + u^N_{t+1} \tag{11}$$

$$y_t = \eta y^T_t + (1-\eta) y^N_t \tag{12}$$

$$\begin{aligned} x_t - p^c_t = {} & (1-\phi)(x_{t-1} - p^c_{t-1}) + \phi(x_{t+1|t} - p^c_{t+1|t}) + (1-\phi)\gamma y_t + \\ & \phi\gamma y_{t+1|t} - (1-\phi)\mu(w-p^T)_t - \phi\mu(w-p^T)_{t+1|t} + u^w_t \end{aligned} \tag{13}$$

$$w_t = .5(x_t + x_{t-1}) \tag{14}$$

$$p_t = w_t \tag{15}$$

$$p^T_t = s_t + p^f_t \tag{16}$$

$$p^C_t = (1-\psi) p_t + \psi p^{IM}_t \tag{17}$$

$$\pi^{IM}_{t+1} = \pi^{IM}_t + c(p^T_t - p^T_{t-1} - \pi^{IM}_t) + u^{IM}_{t+1} \tag{18}$$

$$e_t = e_{t+1|t} - .25(r_t - r^f_t) \tag{19}$$

$$r_t \equiv i_t - 4(p_{t+1|t} - p_t) \tag{20}$$

$$r^f_{t+1} = \rho^f_r r^f_t + u^{rf}_{t+1} \tag{21}$$

$$R_t = \frac{1}{\tau} \sum_{s=t}^{t+\tau} r_{s|t} \tag{22}$$

Equation (10) is the supply function of the traded sector. We assume that the representative firm in the traded sector is a price taker on the international, competitive market. Production (y^T_t) increases in the producer real price, $(p^T - w)$. Owing to adjustment costs, the firms set production in a smoothed manner by not deviating too strongly from the production level in the previous period. Adjustment costs also introduce a role for forward-looking behaviour, as production adjustment today may limit the magnitude of such costs tomorrow. Firms are assumed to exploit this and employ resources to produce rational forecasts of producer real wages and react to these forecasts. There is a one-period planning and implementation horizon which implies that firms make production decisions with a one-period lead and are hence based upon a one-period lagged information set. $0 < 1 - \delta < 1$ captures the rate at which traded sector firms "discount" information about expected future producer real wages. This parameter is treated exogenously in this study. However, higher adjustment costs, higher start-up or closure costs pertaining to production facilities may make information about the future more important to the firm and are expected to raise the value of δ. Higher costs of producing rational forecasts may reduce the extent to which firms exhibit forward-looking behaviour, and hence be reflected in a lower value of δ.

By taking expectations in (10) and using the lead operator,[11] expected production may be expressed as

$$y^T_{t+1|t} = \rho_T y^T_t + \frac{\beta\left(p^T_{t+1|t} - w_{t+1|t}\right)}{(1-\delta F)}.$$

This expression can be rearranged to the form $(1-\rho_T L)(1-\delta F)y_{t+1|t} = \beta(p^T_{t+1|t} - w_{t+1|t})$. Combined with the fact that production is predetermined one period in advance, traded sector output can be expressed conveniently as

$$y^T_{t+1} = \frac{\rho_T}{1+\delta\rho_T} y^T_t + \frac{\delta}{1+\delta\rho_T} y^T_{t+2|t} + \frac{\beta}{1+\delta\rho_T}(p^T_{t+1|t} - w_{t+1|t}) + u^T_{t+1}, \tag{23}$$

where u^T represents a white-noise supply shock.

Whereas production in the traded sector is determined by producer real wages, we assume that the non-traded sector operates in a market of monopolistic competition and that aggregate sector output $\left(y^N_t\right)$ is restricted by demand. Due to intertemporal substitution effects in consumption, production may deviate from its equilibrium level. As McCallum and Nelson (1999b) show in a model with consumer optimizing behaviour, demand is driven by the expected future path of the short real interest rate (r_t) as consumers exploit the intertemporal substitution possibilities. In this paper, however, we assume that demand directed towards the non-traded sector is affected by both the long-term and the short-term real interest rate,[12] as expressed by (11). We also assume that consumers may to some extent substitute non-traded goods for traded goods in consumption depending on the relative price. Furthermore, in order for the model to replicate the smoothed movements in output, persistence in demand has been included. Persistence can be justified by the consumers being subject to habit-formation. In the long run, non-traded sector output is determined by equilibrium income. u^N_{t+1} is a stochastic white-noise demand shock. Equation (12) states that (y_t) is the log-linear approximation to aggregate output.

Wages are determined according to the overlapping contract framework of Fuhrer and Moore

[11] The lead operator, F, is defined as $Fx_{s|t} \equiv x_{s+1|t}$.

[12] Batini and Haldane (1999) argue that demand in the UK may be sensitive to the short rate due to the prevalence of floating-rate debt instruments.

(1995) and Fuhrer (1997), as described by equation (13). In this framework there are multiple (in this paper, two) overlapping wage contracts existing at all times and subsequently renegotiated every other period. Agents are concerned that their expected contract real wage should not deviate too much from that of the other contract negotiated in the previous period and the expected contract real wage negotiated in the next period. The parameter ϕ in (13) represents the importance the forward-looking element plays relative to the backward-looking. The forcing variables are tightness in the labor market, represented by the output gap, and the labor share in the traded sector, proxied by the inverse of the producer real wage. The latter factor is not present in the standard formulation of the Fuhrer-Moore staggered contract model. However, both theoretical as well as empirical evidence for small open economies suggests that the labor share has an independent effect upon wage determination.[13] Bargaining theory tends to suggest that the outcome of the wage bargaining process is related to the cost the employers would face in the event of a conflict and strike. These costs would typically be related to the labor share. In our open-economy formulation of the Fuhrer-Moore model as stated in (13), the nominal contract wage is denoted by x, the consumer price level is denoted by p^c, and the producer real wage is denoted by $w - p^T$. As a result of the average contract lasting for two periods, the aggregate wage level (w_t) is the average of the existing contract wage, as described in equation (14).

Given our assumption of monopolistic competition in the non-traded sector, prices are set as a markup on wages, as in equation (15). Given the mixed evidence on how markups vary,[14] it is for the sake of simplicity assumed to be constant and unrelated to the transmission mechanism of monetary policy. The attractiveness of this assumption, together with the Fuhrer and Moore contracting model, is that it gives rise to an expectations augmented Phillips curve with both forward-looking and backward-looking elements. Such a pricing scheme seems to describe the dynamic evolvement of inflation well in many countries.[15]

Purchasing power parity is assumed to hold for the traded goods according to equation (16) where p_t^f is the foreign price level and s_t is the effective nominal exchange rate. Note that we may rewrite (16) as $p_t^T = e_t + p_t$, where $e \equiv p_t^f + s_t - p_t$ is the real exchange rate.

Equation (17) defines the consumer price level as a weighted average of the non-traded goods

[13]See e.g. Kolsrud and Nymoen (1998), Bårdsen et al. (1999) and Bårdsen and Fisher (1999).
[14]See Rotemberg and Woodford (1999) for a recent survey.
[15]See, among others, Batini and Nelson (2001), Batini and Haldane (1999) and Rudebusch (2002).

price and the price of imported goods, p^{IM}. As several empirical studies suggest,[16] imported goods prices adjust sluggishly to exchange rate shocks. Since imported price inflation exerts a strong influence on CPI inflation, accounting for this sluggishness is obviously important in order for the model to give plausible forecasts, which is necessary for evaluating forecast-based rules. For simplicity, we assume that the imported goods prices follow an equilibrium-correction mechanism, i.e.,

$$\pi_{t+1}^{IM} = c(p_t^T - p_t^{IM}),$$

where $\pi_{t+1}^{IM} \equiv p_{t+1}^{IM} - p_t^{IM}$ is quarterly imported goods price inflation. Taking first differences and adding a stochastic white-noise shock, we arrive at the formulation in (18).

The small open economy is assumed to operate in an environment of near-perfect capital mobility where the real exchange rate is determined by uncovered interest rate parity as shown in (19). We allow, however, the economy to be subject to persistent risk premium and foreign interest rate shocks. In accordance with this, we assume here that the risk-premium corrected foreign real interest rate (r_t^f), i.e., the interest rate that is required to expect an unchanged constant real exchange rate, follows an AR(1) process, as in (21). The domestic short-term real interest rate (r_t) is defined by the Fisher identity in (20).

We follow Svensson (2000) in assuming that the long-term real interest rate (R_t) is determined according to the expectations hypothesis, as stated in (22). However, in the simulation of the model we approximate[17] it as

$$R_t \approx \frac{1}{\tau} \sum_{s=t}^{\infty} r_{s|t},$$

where τ is the time to maturity.

Since the foreign short-term real interest rate is modeled as an AR(1) process, the foreign long-term interest rate (R_t^f) would approximately be

$$R_t^f \approx \frac{1}{\tau} \frac{r_t^f}{1 - \rho_{rf}}. \tag{24}$$

By iterating (19), and assuming the transversality condition that the real exchange rate con-

[16] See e.g. Dwyer et al. (1994) and Naug and Nymoen (1996).

[17] The discrepancy will depend on the rate of convergence of the short-term real interest rate in the model. A swift convergence means that the discrepancies will be small and unimportant. Thus the approximation will improve with the effectiveness of policy. Inspection of the impulse response functions due to the different policy rules confirms that the approximation error is negligible.

Table 1
Parameter values

Product market		Financial market	
α	0.125	τ	40
β	0.40	**Foreign sector**	
ρ_T	0.85	ρ_r^*	0.37
ρ_N	0.85	**Monetary policy**	
δ	0.50	θ	$1, 0.50$
ω	0.70	h	$2-8$
η	0.25	**Labor market**	
ϵ	0.20	ϕ	0.20
c	0.50	γ	0.20
κ	0.5	μ	0.12

verges to its equilibrium level $\lim_{s\to\infty} e_{t+s|t} = 0$, we have

$$e_t = .25\left[\sum_{s=t}^{\infty} r^f_{t+s|t} - \sum_{s=t}^{\infty} r_{t+s|t}\right].$$

By combining this expression with the expressions for the long real interest rates, we can write the long interest rate as a function of the foreign equivalent and the real exchange rate

$$R_t = R_t^f - \frac{4}{\tau}e_t. \tag{25}$$

The above model leaves the short nominal interest rate as an exogenous policy variable. The nominal interest rate is endogenized according to the interest rate implication of inflation-forecast targeting, represented by equation (9).

3.1. Calibration

A detailed account of the calibration of the model is given in Appendix A. As stated above, most of the parameter values were obtained from Batini and Haldane (1999), but other parameters were set at values that did not seem a priori unreasonable for a small open economy. In any case, the qualitative properties of the model are robust to reasonable changes in the parameter values. The parameters used are replicated in Table 1.

We use the residuals from a quarterly, recursively identified vector autoregressive model of order four with contemporaneous restrictions for the UK economy as estimates of the structural shocks. The variables included are: OECD GDP, German three-month interest rate, hourly wages, manufacturing output, non-manufacturing output, three-month interest rate, real ef-

Table 2
Correlation matrix of structural shocks with standard deviations (as percentages) in parentheses.

Shocks	*Non-traded demand*	*Traded supply*	*Imported goods inflation*	*Wages*	*Risk premium*
NT	1(0.29)	−.03	.08	−.01	−.25
TS	–	1(.43)	.04	.08	−.10
IGI	–	–	1(.90)	−.07	.11
W	–	–	–	1(.44)	.68
RP	–	–	–	–	1(11.59)

fective exchange rate and imported goods prices. Constants and seasonal dummies were also included and the regressions were made over the period 1983(1)-1993(1). The ordering of the variables reflects the small country assumption as foreign variables are viewed as exogenous to the UK economy and put first. The correlation matrix is shown in Table 2.

4. Policy evaluation and analysis

We now turn to the task of evaluating inflation-forecast targeting within the above model. Under inflation-forecast targeting, the central bank will need to choose two important parameters: the forecast-targeting horizon and how 'strict' it should be in interpreting the inflation-forecast target. In this section, we first discuss some principal questions of forecast-targeting in the above model, and then go on to discuss the stabilizing properties of inflation-forecast targeting conditional on the choice of the two parameters.

4.1. Interest rate stabilization, the Taylor principle and long-run inflation expectations

Two important issues should be discussed in relation to the use of forecast targeting in the above model. First, is the rational expectations equilibrium determinate? Second, in what way does inflation-forecast targeting provide an anchor for long-run inflation expectations? Let us consider these questions in turn.

The model features three forward-looking state variables ($e_t, y^T_{t+1|t}$ and π_t) and hence the Blanchard and Kahn (1980) condition for a determinate rational expectations equilibrium requires three unstable roots of the dynamic system. This condition is satisfied for inflation-forecast targeting horizons of two and three quarters, but not for longer horizons, where there are fewer unstable roots. In order to understand this, first observe from Table 3 the implicit reaction functions (as deviations from the equilibrium nominal interest rate) for different forecast-

Table 3
Implied reaction functions.

Coefficients	Strict inflation-forecast targeting: $\theta = 1$ $h=2$	$h=3$	$h=4$	$h=6$	$h=8$	Flexible inflation-forecast targeting: $\theta = .5$ $h=2$	$h=3$	$h=4$	$h=6$	$h=8$
y_t^N	1.27	.77	.73	.02	.00	2.59	.86	.74	.02	.00
y_{t-1}^N	1.38	.54	.27	−.00	−.00	.85	.49	.27	−.00	−.00
y_t^T	.42	.26	.24	−.02	−.00	.86	.29	.25	−.02	−.00
$y_{t\|t-1}^T$	.10	.04	.02	−.00	−.00	.06	.03	.02	−.00	−.00
y_{t-1}^T	.38	.15	.07	−.00	−.00	.23	.13	.07	−.00	−.00
$\pi_{t\|t-1}$	2.10	.82	.41	−.00	−.00	1.29	.74	.41	−.00	−.00
π_{t-1}	27.56	2.37	1.18	−.01	−.00	14.80	2.15	1.19	−.01	−.00
$\pi_{t\|t-1}^{im}$	−.38	−.15	−.07	.00	.00	−.23	−.13	−.07	.00	.00
π_t^{im}	4.63	2.03	1.25	−.02	−.00	2.81	1.86	1.26	−.02	−.00
π_{t-1}^{im}	6.89	.59	.29	−.00	−.00	3.70	.54	.30	−.00	−.00
u_t	13.25	7.72	5.08	−.05	.00	8.93	7.17	5.12	−.05	.00
u_{t-1}	9.51	3.70	1.84	−.02	−.00	5.86	3.37	1.86	−.02	−.00
r_t^f	.80	.70	.61	−.01	−.00	.68	.68	.61	−.01	.00
r_{t-1}^f	−.06	−.02	−.01	.00	.00	−.04	−.02	−.01	.00	.00
e_{t-1}	1.31	.21	−.21	.00	.00	.86	.16	−.22	.00	.00
i_{t-1}	0.05	.02	.01	−.00	−.00	.03	.02	.01	−.00	−.00

targeting horizons. Note that for long forecast-targeting horizons, the interest rate should only be adjusted marginally from its equilibrium level in response to changes in factors determining future inflation. The *Taylor principle*[18] commands that the nominal interest rate should be moved in a sufficiently strong manner to shocks determining future inflation, so that the real interest rate is moved in the same direction. Violation of this principle is often associated with a failure to satisfy the Blanchard-Kahn conditions. Forecast-targeting horizons above three quarters fail to comply with this principle, as the response is generally too weak, and rational expectations indeterminacy cannot be ruled out. The non-compliance with the Taylor principle and indeterminacy may be a potential problem for inflation-forecast targeting for several reasons. Woodford (1999) argues that compliance with the Taylor principle is important for determining the price level under interest rate rules. Clarida et al. (2000) argue in a similar way that the principle is important for ruling out sunspots solutions of the rational expectations equilibrium, which, if not ruled out, may cause endogenous fluctuations in both inflation and output. The violation of the Taylor principle is potentially an important objection to long-run inflation-forecast targeting.

However, if we are willing to invoke the minimal state variables (MSV) selection criterion (see McCallum, 1983, 1999), which has been done here, inflation-forecast targeting is determinate at all horizons considered. The MSV criterion picks the rational expectations solution which is

[18] See Taylor (1993, 1999), Clarida et al. (1999), Clarida et al. (2000), Woodford (1999, 2000).

represented by the minimal use of state variables. McCallum (2001) argues, however, that the Taylor principle may be important for agents to rule out non-MSV solutions and moreover make the MSV solution E-stable and thus least squares learnable (see Bullard and Mitra, 2000). The desirability of long-horizon inflation-forecast targeting thus hinges upon whether one believes that the MSV selection criterion picks the relevant rational expectations equilibrium.

The second issue is how inflation-forecast targeting provides an anchor for long-run or unconditional inflation expectations in the above model. This is an important question since the model does not have an explicit role for money as the policy instrument, which traditionally plays the role of pinning down nominal variables. We start by noting that in the above model, the choice of the inflation target does not influence any unconditional moments of real variables. This property can be denoted by *long-run superneutrality*. More specifically, the inflation target does not influence the unconditional expected (equilibrium) real interest rate. Exploiting the relationship between the nominal and real interest rate given by the Fisher equation,

$$E[i] = E[r] + 4E[\pi], \tag{26}$$

yields that the unconditional inflation expectations are determined by the unconditional expected value of the policy instrument. Then setting the nominal interest rate in such a way that it hovers around a level given by

$$i^* = E[r] + 4\pi^*, \tag{27}$$

in such a way that $E[i] = E[i^*]$ ensures that $E[\pi] = \pi^*$, and the inflation target plays the role of pinning down inflation expectations. Assume as an example, that the forecast-targeting horizon is sufficiently long so it is either equal to or longer than the time it takes for all inflation inertia to work itself out. Interest rate setting is then given by equation (27), that is, inflation-forecast targeting implies pegging the nominal interest rate. Assume as an example that the inflation target is two per cent and the unconditional expected real interest rate is equal to four per cent. Credibly pegging the the nominal interest rate at six per cent then brings the unconditional inflation expectations in line with the inflation target. The intuition why inflation-forecast targeting aligns inflation expectations in line with the inflation target is simple. Since there is symmetric information between the monetary authorities and the private

Table 4

Unconditional standard deviations in per cent and losses.

Strictness(θ)	π^c	y^N	y^T	y	r	R	e	Δi	$L(.25)$	$L(.00)$	ρ_{TN}
Targeting horizon = 2											
.50	.38	1.40	1.85	.85	11.78	.47	2.26	12.28	38.55	.86	−.61
1.00	.35	1.63	2.21	.92	16.41	.54	2.79	20.00	100.94	.98	−.70
Targeting horizon = 3											
.50	.69	1.12	1.42	.77	8.41	.39	2.03	10.20	27.11	1.08	−.39
1.00	.59	1.19	1.53	.80	9.16	.41	1.99	10.77	29.99	.98	−.45
Targeting horizon = 4											
.50	2.36	.59	1.90	.74	2.80	.20	3.67	8.25	23.13	6.12	.31
1.00	2.22	.60	1.82	.73	2.98	.21	3.57	8.25	22.49	5.47	.32
Targeting horizon = 5											
.50	2.65	1.01	4.56	1.24	11.44	.46	6.04	.72	8.67	8.54	−.20
1.00	2.65	1.02	4.58	1.24	11.50	.47	6.05	.76	8.29	8.29	−.20
Targeting horizon = 6											
.50	2.61	.98	4.46	1.22	10.72	.45	5.90	.12	8.29	8.29	−.18
1.00	2.61	.98	4.47	1.22	11.73	.45	5.90	.12	8.30	8.29	−.18
Targeting horizon = 8											
.50	2.61	.97	4.47	1.22	10.63	.44	5.89	.00	8.32	8.32	−.17
1.00	2.61	.97	4.47	1.22	10.63	.44	5.89	.00	8.32	8.32	−.17
Taylor rule											
	1.44	.79	2.16	.81	6.87	.32	4.19	3.08	5.10	2.73	.02
Optimization of L(.25) *under pre-commitment*											
	1.27	.94	2.16	.90	7.25	.40	3.69	1.91	3.34	2.43	−.06
Optimization of L(.00) *under pre-commitment*											
	.39	1.38	1.89	.82	11.83	.48	2.12	12.02	36.98	.83	−.63

agents in the model, any deviations of long-run inflation expectations from target makes the inflation-forecast targeter adjust the interest rate in an either contractionary or expansionary manner and brings the expectations in line with the target. Since private agents know this (full central bank credibility), there are no reasons for long-run inflation expectations to deviate from the target level in the first place.

4.2. The inflation-output trade-off and social loss

Table 4 considers the unconditional standard deviations[19] (in per cent) of important variables for different forecast-targeting horizons, ranging between two and eight quarters, and strict and flexible ($\theta = .5$) inflation-forecast targeting. A forecast-targeting horizon below two quarters demands too strong movements in the interest rate in order to achieve instrument and model stability and is not considered any further.

The length of the forecast-targeting horizon does affect inflation stability to a great extent.

[19] The unconditional standard deviations have been analytically calculated.

A short forecast-targeting horizon provides tight control of inflation as the interest rate is used intensively in order to have inflation return quickly to target. When the forecast-targeting horizon is extended, inflation is quickly destabilized. As inflation variability increases, however, there is not a consistent decrease in output variability. The reason for this is that since the inflation-forecast targeting is sub-optimal, there is nothing that ensures that performance will move along the inflation-output variance efficiency frontier. Aggregate output does, however, become more stable as the forecast-targeting horizon is increased from two to four quarters. For horizons above four quarters, aggregate output is fairly unstable.

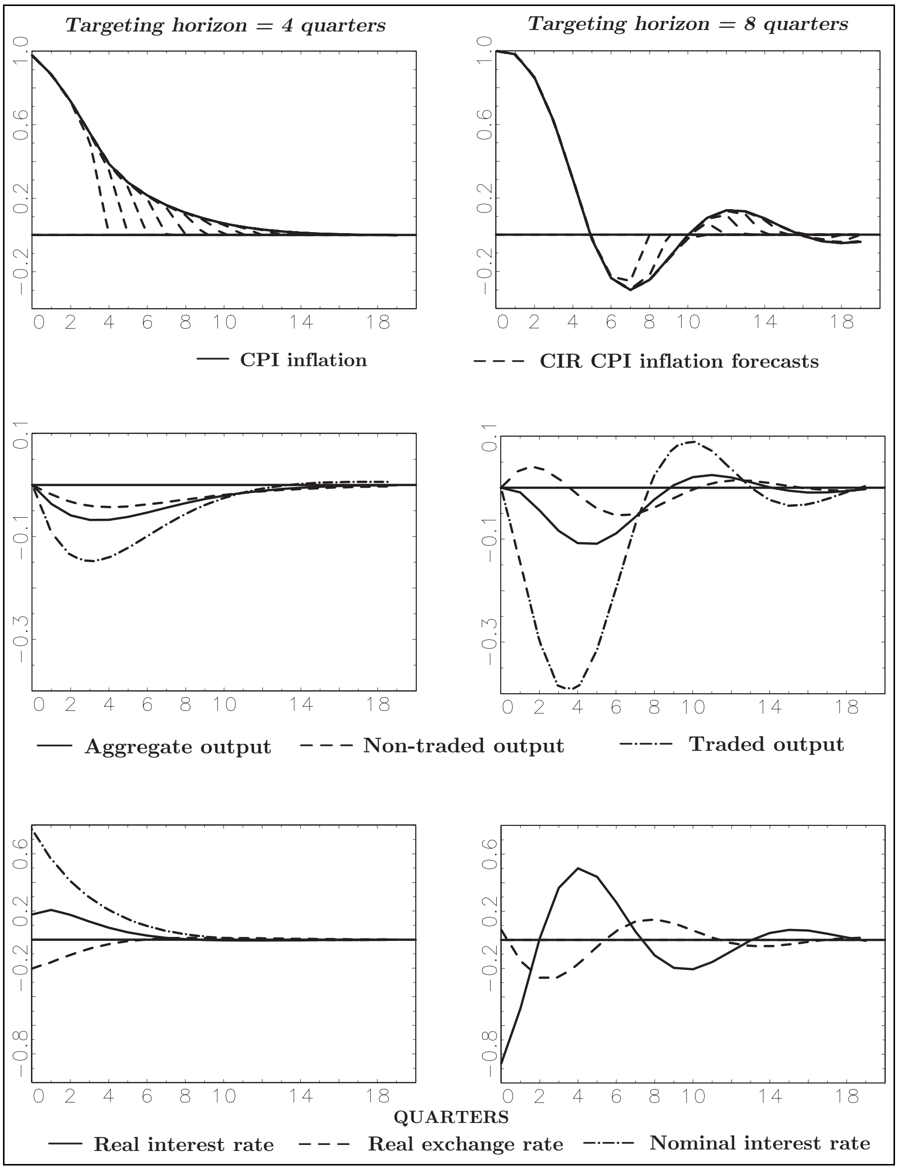

Figure 2: A disinflationary experiment.
A change in the target of one per cent. Measured as deviation from the (new) equilibrium values.

In order to understand the reason behind this, it is useful to study the response of an unanticipated disinflationary shock of one per cent to the model. This is depicted in Figure 2. The upper part of the figure shows the expected inflation movement and the corresponding constant-interest-rate forecasts made in each consecutive quarter. The middle part shows the expected movement of aggregate and sectoral output. The lower part shows the expected movement in both nominal and real interest rates and the real exchange rate. On the left side, the inflation-forecast targeting horizon is four quarters and on the right side, the horizon is eight quarters. Inflation-forecast targeting is assumed to be strict, i.e., $\theta = 1$.

In both cases, the central bank enjoys an immediate announcement effect of the decrease in the inflation target, as long-term inflation expectations adjust to conform to the new target level and the forward-looking variables adjust accordingly. As a result of the lower inflation target, the equilibrium nominal interest rate immediately falls by one percentage point.

In the case of the short forecast-targeting horizon ($h = 4$), this announcement effect needs to be augmented by a rise in the nominal interest rate relative to the equilibrium value. For this particular shock, the reaction in the nominal interest rate is sufficient to increase the real interest rate. As a result, the real exchange rate appreciates and which has a contractionary effect on inflation. The interest rate is then gradually lowered towards its equilibrium value and reaches the new inflation target after about ten quarters.

For a forecast-targeting horizon of eight quarters, the announcement effect alone is almost sufficient to lower inflation expectations at the appropriate rate. There is hence only a small need for the nominal interest rate to react to the determinants of future inflation and hence deviate from its new equilibrium value. The reason is that inflation will have moved sufficiently close to its target level because monetary policy has satisfied the equilibrium conditions of the new inflation target. The real interest rate falls as the nominal interest rate adjusts to the new equilibrium level. The nominal interest rate then remains close to the new equilibrium level, which implies that expected inflation will feed negatively into the real interest rate. Higher expected inflation will therefore have an expansionary and potentially explosive effect on the economy. Stability is, however, ensured by the exchange rate channel. As the nominal exchange rate is expected to remain constant due to a stable nominal interest rate (abstracting from movements in the foreign interest rate level), inflation will feed into the real exchange rate and produce a real appreciation. This has a contractionary effect on the traded sector and inflation itself that ensures the stability of the economy.

To summarize the aggregate performance of inflation-forecast targeting in the above model, it is appropriate to consider a measure of the social loss caused at different forecast-targeting horizons. We postulate a quadratic loss function of the type

$$L(v) = \left[(\pi_t^c - \pi^*)^2 + y_t^2 + v(i_t - i_{t-1})^2\right], \tag{28}$$

where society is assumed to care equally about inflation and aggregate output stability, and also about smoothing of interest rate movements.[20] The tenth and eleventh columns of Table 4 show the unconditionally expected loss, $EL(v)$, with ($\nu = .25$) and without ($\nu = 0$) weight on the interest rate smoothing argument. Given that these loss functions span the variables of interest, we see that interest rate smoothing is the prime reason for considering a forecast-targeting horizon beyond two or three quarters where there is a greater degree of interest rate stabilization. Without such a concern, inflation-forecast targeting compares very favorably to the overall optimal policy when the central bank minimizes loss under pre-commitment, whose outcome is shown in the last rows of Table 4.

4.3. Sectoral stability and the exchange rate

Policymakers may, however, also be concerned about other variables. In particular, the policymaker may care about sectoral variability. If monetary policy achieves aggregate output stability by influencing the sectors in a way that expansion in one sector is offset by a contraction in the other sector, aggregate output variability will be an insufficient and misleading measure of the cost of adjustment in the economy.

From Table 4 we observe that the choice of the forecast-targeting horizon has important implications for sectoral stability. The non-traded sector is most exposed to adjustment at a fairly short forecast-targeting horizon. The policymaker is then using the interest rate vigorously in order to control inflation. The short-term real interest rate is therefore quite volatile and heavily influences the non-traded sector. When extending the length of the horizon up to some point, there is more nominal interest rate stability and this sector enjoys greater stability. However, when the horizon is longer than a year, inflation is destabilized for the reasons stated above. The short-term real interest rate and the real exchange rate move in a cyclical manner which mildly destabilizes this sector. Although the short-term real interest rate is quite volatile,

[20] This is the targeting definition of interest rate smoothing, i.e., when the change in the nominal interest rate is an argument in the loss function. The instrument rule definition of interest rate smoothing, however, refers to a situation when the monetary policymaker gradually moves the instrument towards the optimal rate, e.g., $i_t = \zeta i_{t-1} + (1-\zeta) i_t^*$.

the long real interest rate, which is the most important forcing variable for the non-traded sector, is fairly stable. The reason is that the short real interest rate moves in an oscillating way, causing the expected future average rate to be only modestly affected.

The traded sector, being driven largely by the real exchange rate, is heavily influenced by volatile exchange rate movements. The exchange rate is relatively volatile at a very short forecast-targeting horizon of two quarters where the exchange rate channel is extensively used in order to achieve a strict inflation target (see Svensson, 2000). At a longer forecast-targeting horizon, the failure to stabilize inflation produces an unstable real exchange rate. As noted above, the nominal exchange rate is expected to remain constant. Inflation shocks then feeds directly through to the real exchange rate, but also indirectly by influencing the equilibrium nominal exchange rate. Since the exchange rate market is fully forward-looking, this has an immediate effect on the nominal exchange rate at the time of the shock. This can be shown by stating the nominal uncovered interest rate parity condition, solving it forward and imposing the long-run equilibrium real exchange rate transversality condition, i.e. $\lim_{j\to\infty} q_j = \lim_{j\to\infty}(s_j - p_j) = 0$.

$$
\begin{aligned}
s_t &= s_{t+1|t} - i_t \\
&= -\sum_{s=0}^{\infty} i_{t+j|t} + \lim_{j\to\infty} s_{j|t} \\
&= -\sum_{s=0}^{\infty} i_{t+j|t} + \lim_{j\to\infty} p_{j|t}
\end{aligned}
$$

where foreign variables have been disregarded. We see that the nominal exchange rate is influenced by the future expected nominal interest rate (differentials), but also the long-run equilibrium price level path. A long forecast-targeting horizon produces a stable nominal interest rate and we conclude that nominal exchange rate movements are not driven by large interest rate differentials. Rather, the nominal exchange rate is driven by the failure to keep inflation close to the target level, causing the expected long-run price level to drift and therefore affect the equilibrium nominal exchange rate accordingly.

Since exchange rate movements feed quickly through to inflation, the exchange rate process exacerbates the reason why the monetary policymaker should react quickly and sufficiently to shocks influencing inflation expectations, by choosing a relative short forecast-targeting horizon and therefore comply with the Taylor principle. Traded sector stability is achieved balancing the adverse effects of having a long forecast-targeting horizon with the adverse effects caused by a volatile monetary policy when having a short forecast-targeting horizon, pointing to some intermediate forecast-targeting horizon.

The last column of Table 4 shows the coefficient of autocorrelation between the traded and non-traded sectors. A coefficient different from unity indicates that aggregate stability is achieved at the expense of traded and non-traded sector variability. This is in particular true at a very short targeting horizon where the coefficient is very close to -1. Aggregate output then conceals much of the adjustment in each sector. At longer targeting horizons, this effect is also present but to a much smaller degree.

4.4. Flexible inflation-forecast targeting and relative performance

So far we have discussed strict inflation-forecast targeting. Most of the results from the analysis are, however, kept when considering flexible inflation-forecast targeting. There is some evidence that flexible inflation-forecast targeting implies greater real stability at the shortest horizons, but for longer horizons there is no indication of this. The reason behind this is that the conflict between real and nominal stability is mostly present in the short-run, where output needs to be contracted in order to offset a positive inflation shock. The oscillating movements of inflation and output under long-horizon inflation-forecast targeting also weaken the intuition behind resorting to flexible inflation-forecast targeting for stabilizing output to a greater degree.

The last rows of Table 4 show the comparable performance of a simple Taylor (1993) rule[21] and the optimal pre-commitment policy. Compared to inflation-forecast targeting, we see that the Taylor rule does a better job in stabilizing inflation and output without resorting to a very active monetary policy in terms of strong interest rate movements. We do, however, see that short-horizon flexible inflation-forecast targeting does a very good job in stabilizing inflation and output relative to the optimal policy when interest rate movements are not being penalized.

5. Conclusions

Lags in the effect of monetary policy on inflation require a forward-looking monetary policy. In this paper we have investigated the performance of simple inflation-forecast targeting within a

[21] The Taylor rule has the form $i_t = 1.5\bar{\pi}^c + .5y_t$.

New Keynesian, open-economy model. Forecast-targeting implies that the interest rate should be set in order to minimize the constant-interest-rate inflation forecast deviations from the target level. A long forecast-targeting horizon implies that inflation does not have to be brought quickly back to target, resulting in weaker interest rate responses to the factors determining future inflation. As inflation deviates from the target level, variable domestic wages and prices not only influence the real interest rate, but also eventually feeds through to the real exchange rate. This implies an unfortunate interplay between the real interest rate and the real exchange rate. We show that this may result in cyclical movements in key macroeconomic variables, and may also imply that the Taylor principle is violated, suggesting a possible indeterminate rational expectations equilibrium.

A shorter forecast-targeting horizon implies stronger reactions to factors influencing future inflation and considerable less smoothing of interest rate movements. However, the analysis does not suggest that a shortening of the forecast-targeting horizon consistently produces higher output variability. Indeed, a shortening of the forecast-targeting horizon from two years to one year *reduces* output variability. Moreover, the length of the forecast-targeting horizons has different implications for the traded and the non-traded sectors. The high exchange rate variability associated with a long forecast-targeting horizon affects the traded sector severely, whereas the cyclical behaviour of the real interest rate produces a relatively stable long real interest rate. Since the long real interest rate is the main forcing variable of the non-traded sector, this sector is less affected by the adverse effects of a long forecast-targeting horizon.

Inflation-forecast targeting implies a rather uncomfortable trade-off between nominal and real stability on the one hand, and interest rate stabilization and smoothing on the other. The Taylor rule generally outperforms inflation-forecast targeting for a reasonable specification of social loss. Introducing flexibility by targeting a weighted average of the output gap and inflation forecasts does not substantially affect the results. However, if the central bank places a sufficiently small weight on interest rate smoothing, short-run inflation-forecast targeting comes remarkably close to the overall commitment solution.

APPENDIX

A. Calibration

The model presented above is calibrated in order to match some macroeconomic characteristics of the UK economy at a quarterly frequency. Batini and Haldane (1999) (BH) calibrate their model with parameter values that are set 'in line with prior empirical estimates' from the Bank of England forecasting model and in order 'to ensure a plausible dynamic profile for impulse responses'. We adopt most of the parameter values from their study. As stated above, our model can be seen as an extension of theirs, as it includes additional plausible macroeconomic effects. In order to obtain values for the extended set of parameters that this implies, some parameters are estimated while others are set at values that do not seem a priori implausible.

Persistence in output is considered to be high and the benchmark values are $\rho_T = \rho_N = 0.85$. Both are close to the persistence value of $\rho = .8$ in the one-sectoral model of BH. The real interest rate impact elasticity on the non-traded sector is set at $\alpha = 0.125$, equal to the value in BH. The intratemporal substitution coefficient is set at $\kappa = 0.05$, which does not seem unreasonable. The long-term interest rate weight in the interest rate index is set somewhat arbitrarily at $\omega = .7$, reflecting the strong theoretical arguments that long-term interest rates dominate the short rate in influencing aggregate demand. The impact elasticity of production in the traded sector with respect to an expected one-period change in the real exchange rate is set at $\beta = .4$. Together with a quarterly informational 'discount' factor of $\delta = .5$ in this sector, the impact elasticity of an expected permanent change in the producer real wage is $\frac{\beta}{1-\delta} = .8$.[22] Traded sector share of output is set at $\eta = .25$ in accordance with the share of the manufacturing sector in the UK economy. The share of imported goods in the CPI index is set at $\psi = .2$. The degree of forward-lookingness in the wage process is set at $\phi = .2$, which makes inflation more persistent than in the original setup of the model in Fuhrer and Moore (1995). The period real wages response to output is set at $\gamma = .2$. The three last choices correspond to values used in the BH study.

There is reasonably strong empirical support for the idea that the capital rent share of output influences the outcome of the wage bargaining process. Bårdsen and Fisher (1999) find in an estimated wage-price system for the UK economy that nominal wages partially respond to the aggregate wage share with an elasticity of $-.13$ each quarter. In the light of these studies, we assume that the contract wage responds to the traded sector producer real wages, and set $(-\mu) = -0.12$. The average time to maturity for long-term loans is set somewhat arbitrarily at $\tau = 40$ quarters. Finally, the rate at which imported

[22] In the BH model, the aggregate output impact elasticity of a change in the real exchange rate is $-.2$. The long-run elasticity is -1. Our choice of coefficients would produce non-traded sector short-run and long-run elasticities of 0.05 and .33 respectively. For the traded sector we assume elasticities of $-.4$ and -2.66 if the change is perceived to be transitory, and $-.8$ and -5.25 if the change is perceived to be permanent. Given that the traded sector accounts for 25% of the economy, these responses seem reasonable.

prices equilibrium corrects to the foreign price is set at $c = .5$, which implies that about 95 per cent of a permanent change in the nominal exchange rate is reflected in imported goods prices after one year.

The empirical study of Fisher et al. (1990) provides support for the uncovered interest parity condition for the UK economy. In view of this, we impose this condition up to an autoregressive risk premium component. As r^f is the foreign risk-premium-corrected real interest rate, it can be calculated from (19) as

$$r_t^f = r_t - 4\Delta\widehat{e}_{t+1|t}. \tag{A.1}$$

In order to derive r_t^f, we proxied e by the UK nominal effective exchange rate deflated by the respective relative CPI price levels. Moreover, r was proxied by the three-month nominal interest rate minus the expected quarterly change in the CPI inflation at an annual rate. Market expectations of the change in the real exchange rate and CPI price level were obtained from the fitted values of two regressions. The quarterly inflation rate was regressed on four lags of itself, and on five lags of the change in the log real exchange rate (as proxied) and the unemployment rate. The quarterly change in the log real exchange rate was regressed on four lags of itself and five lags of the CPI price level, UK and German three-month interest rates and the unemployment rate. A constant and seasonal dummies were added in both regressions and estimated from 1983(1) to 1999(2) and 1998(4) respectively.[23]

The derived foreign risk-premium-corrected real interest rate was then assumed to follow an AR(1) error process. Thus, the following regression was made for the period 1983(2)-1998(4),

$$r_t^f = \underset{(.12)}{.37} r_{t-1}^f + \varepsilon_t^{rf}, \tag{A.2}$$

where a constant and seasonal dummies are not shown but included in the regression. Additional lags were not statistically significant and hence our AR(1) seemed to be a good approximation.

We proceed by using standard structural vector autoregressive methods of obtaining a time series representations of the underlying shocks to the model. Ideally, our model could be estimated and the residuals obtained could be used to estimate the distribution of these shocks. However, our model is highly stylised and may only represent only the most important factors in the monetary policy transmission mechanism. The residuals would therefore partly reflect a mixture of omitted variables and shocks. With that being said, ε_t^{rf} is considered the measure of the foreign financial shocks in our model. For the other shocks, we construct a recursive vector autoregressive model of order four with variables in the following order: OECD GDP, German three-month interest rate, hourly wages, manufacturing output, non-manufacturing output, three-month interest rate, real effective exchange rate and imported goods

[23] This approach is particularly simple and it should be noted that more advanced methods of deriving the risk premium are available. One way would be to estimate the model using maximum likelihood estimation and deriving the risk premium through a Kalman filtering process. Such a procedure, however, relies on a proper specification of monetary policy in the estimation period. Given the different policy regimes involved during the estimation period, this is a serious obstacle to estimating the model.

prices. Constants and seasonal dummies were also included and the regressions were made over the period 1983(1)-1993(1). The ordering of the variables reflects our small country assumption as foreign variables are viewed as exogenous to the UK economy. Inclusion of OECD GDP may be seen as a proxy of the UK trading partners' level of output. This gives us time series for all five shocks to our model.[24] We then proceed by calculating the variance-covariance matrix of these shocks.

[24]Due to the fact that we model the contract wage process in our theoretical model, the distribution of shocks to aggregate wages obtained from the VAR must be corrected. Given the simple two-period overlapping contract structure, contract wage shocks are assumed to be four times the size of the aggregate wage shocks.

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