2000/2

Oslo
May 11, 2000

Arbeidsnotat

Research Department

Open-Economy Inflation Forecast Targeting.

by

Kai Leitemo

NORGES BANK

Arbeidsnotater fra Norges Bank
kan bestilles over Internett:
www.norges-bank.no/publikasjoner
eller ved henvendelse til
Norges Bank, Abonnementsservice,
PB 1179 Sentrum, 0107 Oslo
Telefon 22 31 63 83, Telefaks 22 41 31 05

Norges Banks arbeidsnotater inneholder
forskningsarbeider og utredninger som
vanligvis ikke har fått sin endelige form.
Hensikten er blant annet at forfatteren
kan motta kommentarer fra kolleger og
andre interesserte.

Synspunkter og konklusjoner
står for forfatterens regning.

*Arbeidsnotater/working papers from
Norges Bank can be ordered via Internet:
www.norges-bank.no/english/publications
or from Norges Bank, Subscription service,
P.O.Box. 1179 Sentrum, 0107 Oslo, Norway.
Tel. +47 22 31 63 83, Fax. +47 22 41 31 05*

*Norges Bank's Working papers present
research projects and reports
(not usually in their final form),
and are intended inter alia to enable
the author to benefit from the comments
of colleagues and other interested parties.*

*Views and conclusions expressed are the responsibility
of the author alone.*

ISSN 0801-2504
ISBN 82-7553-158-6

Open-Economy Inflation Forecast Targeting*

Kai Leitemo†

First draft: December 1999
This version: May 2000

Abstract

The paper shows that the procedure of inflation forecast targeting arguably implemented by Sveriges Riksbank and the Bank of England may lead to high nominal and real variability; the latter being manifested most notably in the traded sector. A long inflation forecast targeting horizon results in extensive smoothing of interest rate movements. This implies only weak nominal interest rate responses to disequilibrium conditions, causing the real interest rate and hence the real exchange rate to fluctuate persistently. The paper offers an explanation for the recent large variability of Swedish inflation and UK manufacturing sector output.

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

JEL codes: E52, E47, E43.

*I especially thank Steinar Holden for useful comments and suggestions. I have also benefitted from discussing some of the ideas presented in this paper with Anders Vredin, Ulf Söderström and Marianne Nessén at the Sveriges Riksbank. I also thank Ingvild Svendsen for general comments and Gunnar Baardsen, Ragnar Nymoen and Kenneth Wallis for making data available. This paper has made use of modified computer algorithms originally created by Paul Söderlind. Remaining errors are entirely my own. The views expressed in this paper are those of the author and not necessarily those of the Central Bank of Norway.

†The author is in the Research department at Norges Bank (Central Bank of Norway), P.O. Box 1179 Sentrum, 0107 OSLO.

... the slower when running will never be overtaken by the quicker; for that which is pursuing must first reach the point from which that which is fleeing started, so that the slower must necessarily always be some distance ahead. [”The Achilles Paradox”]

— *Zeno of Elea (5th Century BC)*

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 the 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 CBs. Due to the traditional arguments of lags in the monetary policy transmission mechanism, e.g. as modelled in the influential article of Svensson (1997), the inflation forecast plays an important role in the conduct of monetary policy. The argument is that since the instrument, i.e. the interest rate, of the monetary policymaker has the strongest impact on inflation several quarters ahead, policy should be directed towards targeting the forecast of inflation at an appropriate horizon. Short-sightedness should be avoided, since such a policy could produce high output and interest rate volatility. The transmission mechanisms underlying such arguments get their empirical support from closed-economy VARs[2] in which the interest rate channel affects inflation with a lag through its effect on aggregate demand. In the open economy, short-sightedness may be even more undesirable as the exchange rate channel may open the possibility of stabilizing inflation at a very short horizon leading to high real variability (Svensson, 2000) most notably in the traded sector of the economy (Leitemo and Røisland, 1999).

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

$$\bar{\pi}_{t+h|t} = \pi^*, \tag{1.1}$$

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

[2] See Christiano et al. (1999).

where h is the forecast horizon or (forecast) targeting horizon; $\bar{\pi}_{t+h|t}$ is the CB'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 *control lag*), (1.1) 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 control lag, equation (1.1) does not fully determine policy. There is then an infinitum of instrument paths that are consistent with this formulation. For concreteness, assume that the forecast horizon is three periods and the 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 both cases the target can be reached at the specified horizon[3].

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 horizon. Both Sveriges Riksbank and the Bank of England publish such inflation forecasts in their quarterly inflation reports for a forecast horizon of up to eight quarters. 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

$$\bar{\pi}_{t+h|t}(\bar{i}) = \pi^*, \tag{1.2}$$

where policy is well-defined in a mathematical sense. The interest rate is now set in such a way that the forecast is on target. If the forecast at the forecast horizon is not on target given the prevailing interest rate level, the interest rate is adjusted so as to correct for this. Denote this policy by *CIR-targeting*. Svensson (1999b) expresses support for this way of implementing inflation targeting.

CIR-targeting does, however, introduce time-inconsistency in monetary policymaking. As shown in Leitemo (1999b), CIR-targeting does not necessarily imply that inflation will be back

[3] Note, however, that the choice made in the initial period places restrictions on the expected future development of the instrument so as to have the expectations of inflation equal to target in the time following the initial target period.

on target at the end of the h-period targeting horizon, if h is a number great than the shortest lag at which the instrument of monetary policy affects inflation. Under CIR-targeting the chosen interest rate will realize the inflation target under the condition that the interest rate is kept constant within the forecast horizon. But if the CB follows CIR-targeting, this condition would not in general be valid. The reason for this is that the forecast targeting horizon is moving as time progresses. The return to the target is therefore steadily "postponed" because the interest rate is adjusted in order for the new constant-interest-rate forecast to be on target one period later than in the previous period. In this sense, the forecast period is not analogue with the expected time at which inflation has returned to its target level.

This paper discusses some other implications of CIR-targeting, first in a general setting, and then within a model of a small open economy. As will be shown below, CIR-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. With a longer forecast horizon, there is less need for a strong interest rate response as inflation can be brought more softly back to target over a longer period of time. Hence, a longer forecast targeting horizon implies more interest rate smoothing. However, extensive interest rate smoothing means that the interest rate reacts less strongly to disequilibrium conditions and the economy is in general less stabilized by policy. As will be shown below, this implies that inflation fluctuates more, causing the short *real* interest rate and hence the real exchange rate to fluctuate persistently. As the real exchange rate affects the traded sector relatively more than the non-traded sector, we show that if the CIR-targeting central bank chooses a long forecast horizon, the traded sector will be relatively more exposed to fluctuations than the traded sector.

The analysis is carried out in a context of a small macroeconomic model of a small open economy. The model has a structure similar to the model of Batini and Haldane (1999) which is a dynamic AD/AS-model with nominal rigidities explicitly modelled by staggering wage contracts and forward-looking agents. The Batini-Haldane-model is adopted as one of the forecasting models of the Bank of England (1999). Analysis within this model should therefore be of considerable interest as the policymakers repose seemingly great confidence in its description of the monetary transmission mechanism. The model presented here represents an extension to the above mentioned model. It refines the view on how monetary policy influences the traded and non-traded sectors of the economy asymmetrically and tries to throw light on how any particular inflation targeting strategy may induce fluctuations in each sector. We adopt a two-sectoral model in order to address these issues not commonly raised in the monetary policy debate: how policy may influence each sector differently when the CB is maintaining its inflation target. The model is similar to the model in Leitemo (1999a) where a number of strategies for the implementation of inflation targeting in small open economies are discussed.

The rest of the paper is organized as follows. Section 2 starts by developing some intuition on how a CIR-targeting policy may work in general. Moreover, we look at the evidence for the Bank of England and Sveriges Riksbank actually carrying out policy according to CIR-targeting. Finally, we derive the CIR-targeting policy for a general dynamic model and shows that it implies a particular rule for the interest rate. Both the UK and Sweden have experienced problems in the implementation of the inflation target. These problems pertain to large inflation variability (in Sweden) and large traded sector output fluctuations (in the UK). In order to address these issues more closely, we need to study these phenomena in the context of a model that outlines the monetary transmission mechanism. Such a model is presented in section 3 and analysed in section 4. Section 5 concludes.

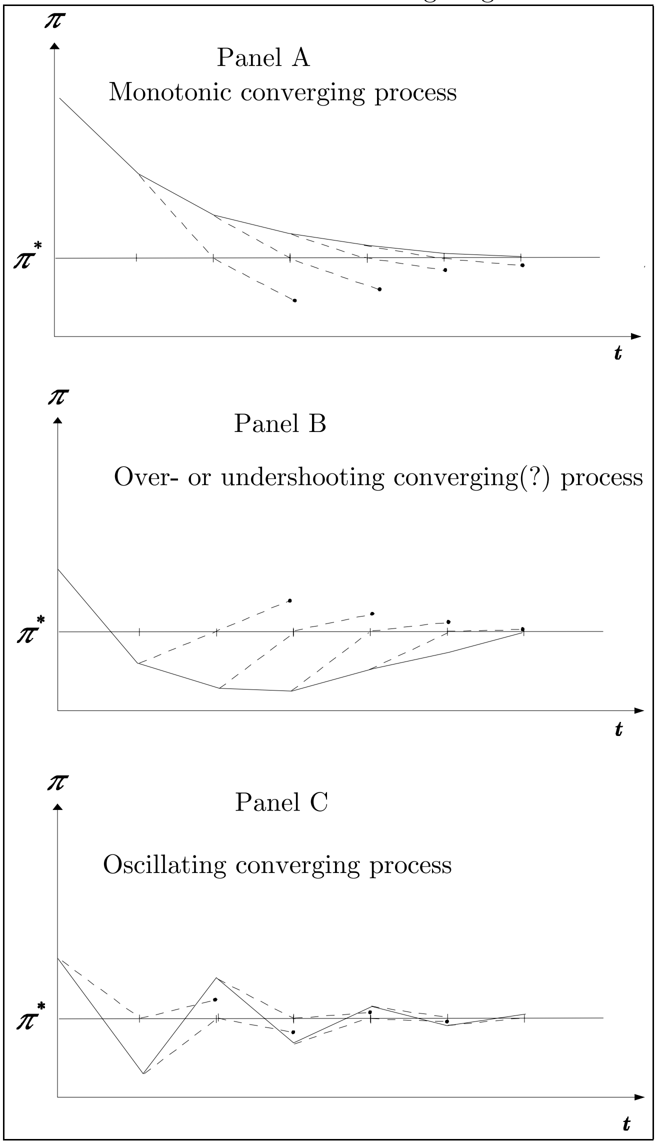
2. Constant-interest-rate forecast targeting

2.1. General comments

In order to understand what inflation-dynamics CIR-targeting may induce, it can be fruitful to study some stylized examples. Figure 2.1 shows three possible developments of inflation under two-period CIR-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 CIR-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 CIR-forecasts coincide with the expected development during the first period, but then deviates as policy is updated to conform to the new forecast horizon.

Figure 2.1

Constant-interest-rate forecast targeting illustration



In panel A, CIR-targeting induces a monotonic convergence of inflation toward the target level. The two-period forecasts show that the interest rate is appropriate in order to have the conditional two-period inflation forecast on target. For illustrational purposes, we have also added, as noted above, the three-period inflation forecast, showing considerable undershooting of the target. As time passes on to the next period, and assuming no new information arrives, the three-period forecast becomes the two-period forecast at the prevailing interest rate, and due to the undershooting, the interest rate is lowered accordingly. This example is consistent with flexible inflation targeting in the model of Svensson (1999a) where the central bank cares both about inflation and output not deviating too much from their equilibrium/target values. In Svensson's model, increased concern for output stabilization result in inflation having a slower convergence to its target.

Panel B shows a situation in which the inflation rate is required to temporarily undershoot the target in order to have a constant-interest-rate forecast that is in line with the target. As time passes on, the two-period forecast now implies overshooting of the target, so the interest rate is raised, causing a further decline in the CPI inflation rate. As the panel shows, inflation converges to the target level, but with CPI inflation being persistently away from the target level.

Panel C shows an oscillating inflation process. If the forecast of inflation one period after the forecast targeting horizon moves away from the target in the opposite direction of the one in panel B, this could imply that monetary policy would produce erratic movements in the interest rate and hence possibly in the inflation rate[4].

It should be noted, however, that the inflation development displayed in all three panels are not necessarily inconsistent with monetary policy being optimal as overshooting and oscillating movements may both be parts of optimal policy when the policymaker also cares about stabilizing other variables in addition to inflation. The argument is, however, that these movements complicate the nature of CIR-targeting, showing that the apparent intuitive character of this framework may be misleading.

All three panels illustrate that when the forecast targeting horizon is longer than the length of the control lag, inflation will not have returned to target at the end of the targeting horizon. The reason for this is that as time passes, the end of the targeting horizon will shift into the future. As policy is updated to conform to the new forecast horizon, the policy change also affects the forecast of inflation for the period that one period ago was on the forecast horizon. CIR-targeting is thus not time-consistent.

[4]If the exchange rate plays an important role in influencing CPI inflation in the short-run, and the exchange rate is influenced to a high degree by interest rates movement, this example could possibly be the outcome in some open-economy models.

This logical point may not be as harmless as one in the first place may believe. As a constant-interest-rate inflation forecast potentially deviates a lot from the rational expectations path, it may have limited information for agents who base their nominal contracts on the most likely future development of inflation. At the start of the targeting horizon, inflation follows the constant-interest-rate inflation forecasts indicating a convergence to target within the targeting horizon. However, when policy is updated so as to have a less steep decent of inflation in order not to undershoot the target (in the case of panel A), inflation will only in the limit reach the target level. This could be interpreted as the central bank not placing a high enough effort on stabilizing inflation and signal a loss of credibility of the central bank. A loss of credibility may be a problem for reasons outlined in Svensson (1999c). 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 inflicting large output movements, i.e., increase the sacrifice ratio.

Problems pertaining to time-inconsistency may arguably lie at the heart of forecast targeting. In order for the rationally expected forecast of inflation being an optimal indicator of inflationary pressure, it must condition on the most likely future outcome of the economic processes, including the relevant policy process. Under forecast targeting, however, the policy process depends on the forecast and hence a circularity is introduced, leading to targeting of a forecast that does not condition on all relevant information. Some auxiliary policy assumptions will be needed when deriving the forecast, that will bring time-inconsistency into the solution. The problem, however, goes away when the length of the targeting horizon is equal to length of the control lag, which is the assumption made in Svensson (1999a).

2.2. Relevance

In this section we discuss the evidence for the Sveriges Riksbank and Bank of England actually carrying out CIR-targeting. Neither bank has announced any strict mechanical way on how they explicitly set interest rates. Thus, the arguments here are based on an interpretation of information made available by the respective banks[5]. We do think, however, that the evidence is strong enough to conclude that both banks conduct policy within a framework quite similar to that of CIR-targeting, with the possibility that policy can deviate somewhat from the strict interpretation made in this article.

The United Kingdom

The most important piece of evidence of CIR-targeting is the forecasts published by the Bank of England. Figure 2.2 show the forecasts of inflation made within the period of central bank independence from August 1997 to November 1999 by so-called fan charts. These forecasts are all based upon the assumption that the interest rate is constant within the forecast horizon, and they all show that the mode of the two-year forecast of inflation is on the target of 2.5 percent. Indeed, the May 1997 Inflation report, published right before the bank gained its independence, showed constant-interest-rate forecasts that overshot the target at the two-year horizon (not shown here). This forecast may have been one, if not *the* one, reason for the disagreement between the Governor and the Chancellor on not raising interest rates in early 1997. Figure 2.3 summarizes the forecasts made in the period August 1997 to August 1999 in terms of their means, medians and modes at the different forecast horizons by considering their arithmetic means over the period. The forecasts can be interpreted to be consistent with the view that the forecast targeting horizon is about eight quarters for the Bank of England when the mode of the forecasts is considered, or a somewhat shorter horizon when either the mean or the median of the forecasts are considered.

Goodhart (1999), who is a member of the UK Monetary Policy Committee, expresses his views on how to operationalize the inflation targeting regime. His views do indeed correspond well with the impression one gets after observing the Bank of England constant interest rate forecasts. He states,

[5] There is certainly a possibility that policy is being conducted in a way different from what the central banks describe in their official documents. One should, however, think that such a strategy would be fatal to the credibility of the central bank if it was ever disclosed. Given the high degree of transparency and hence verifiability inherent in modern monetary policy, such a strategy would arguably not be viable. A cynic may, however, argue, that the traditional degree of secrecy and non-transparency in central bank behaviour may indicate that lying and getting away with it, could still appear to be an option in central bank circles.

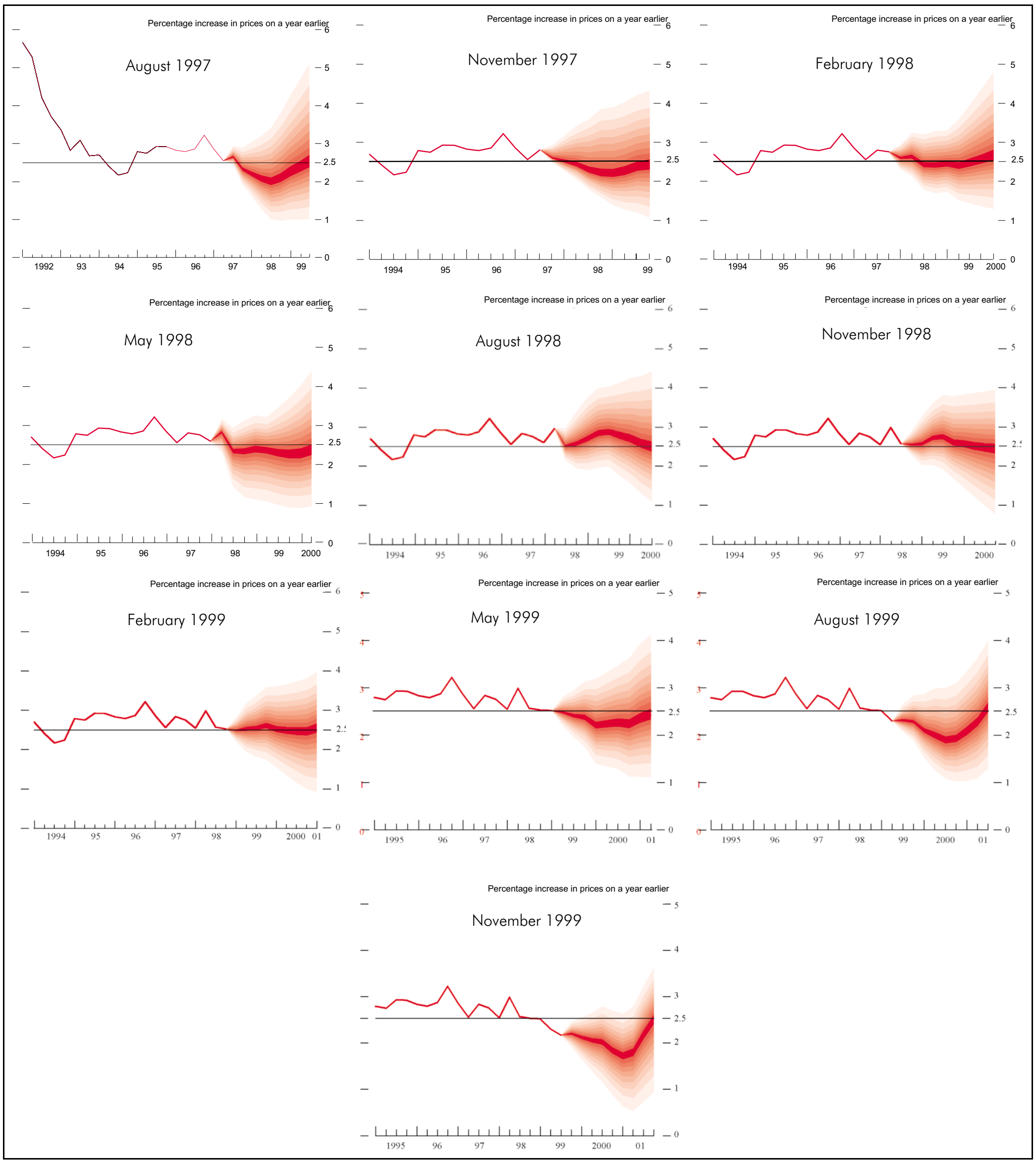


Figure 2.2: Constant-interest-rate inflation projections by the Bank of England

The key point is that the MPC should choose an appropriate future horizon at which to aim to return to the inflation target set by the Chancellor. By doing so, they should be able to minimise the variance of both output and inflation. Given that horizon, how then should the monetary authorities operate, according to the principles that follow from our models of the economy[?]...

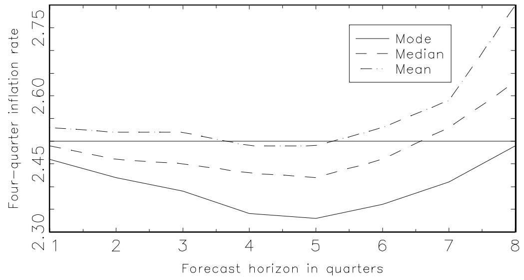
and he continues,

The answer to that conditional question is fairly clear. We should *each month* alter interest rates so that the expected value of our target, the forecast rate of inflation at the appropriate horizon about 18 months to two years hence, should *exactly equal* the desired rate of 2.5%. Lars Svensson has written several papers on the optimality of such a procedure. If we start from an initial

Figure 2.3
Average measures of RPIX Inflation projections at different horizons over the period August 1997 to August 1999.

Horizon	Mode	Median	Mean
1	2.46	2.49	2.53
2	2.42	2.46	2.52
3	2.39	2.45	2.52
4	2.34	2.43	2.49
5	2.33	2.42	2.49
6	2.36	2.46	2.53
7	2.41	2.53	2.59
8	2.49	2.63	2.80

Source: Bank of England



position in which the predicted forecast value of inflation is already close to the objective, then as a first approximation we should expect interest rates to respond to the unanticipated elements in the incoming news. Since this is by definition a martingale series, often somewhat loosely termed a 'random walk', then, on these assumptions, an optimally conducted interest path also ought to be nearly random walk, as should also, of course, be the voting pattern of individual members of the MPC. (Italics mine)

Note that Goodhart favours a procedure that updates policy each month in order to have the then prevailing forecast of inflation at the appropriate horizon equal to the target level. Also note that the argument of interest rate being a random walk and hence its changes unpredictable, hinges on a critical assumption. The assumption is that the constant-interest-rate level not only suffices to keep the inflation forecast at the specific forecast targeting horizon equal to target, *but also* the forecasts for the subsequent periods. This will generally not be the case. As the forecast targeting horizon moves forward in time for each new meeting of the Monetary Policy Committee, the target of monetary policy becomes the forecast of inflation for a new period which may require an interest rate adjustment that is not necessarily due to the arrival of new information.

Sweden

Sveriges Riksbank (1999) *Inflation Report 3/99, p.58* states,

Monetary policy is sometimes described with a simple rule of thumb: if the overall picture of inflation prospects (based on an unchanged repo rate) indicates that in twelve to twenty-four months' time inflation will deviate from the target, then the repo rate should normally be adjusted accordingly.

Table 2.1
Sweden constant-repo-rate CPI inflation forecasts in annual averages

Date of forecast	1998	1999	2000	2001
February 1998	1.6	2.1	2.0	
May 1998	.7	1.5	2.1	
September 1998	.6	.8	1.9	
November 1998	.3	.5	1.2	
March 1999		.3	1.0	
May 1999		.2	1.0	1.6
October 1999		.3	1.1	1.8
November 1999			1.4	1.9

Source: Sveriges Riksbank

This conforms to CIR-targeting as described above. If the constant-interest-rate forecast of inflation is either above or below target at some horizon, the interest rate should be adjusted in order to have inflation forecast, conditional on having the appropriate interest rate constant within the forecast targeting horizon, on target.

The inflation forecasts of the Sveriges Riksbank published throughout 1998 and 1999 are shown in table 2.1. These forecasts are based on a constant repo-rate, and the two-year forecasts are roughly in line with the target of 2 percent of annual inflation. This is consistent with the interpretation of the quote stated above. The slight deviation from this in May 1999 regarding the forecast of 2001 could possibly be due to a flexible interpretation of the target as a quicker return to the target could have undesirable effects either on output or interest rates.

2.3. Deriving the policy implications

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

$$L_t = \frac{1}{2}\left[\theta\left(\bar{\pi}_{t+h|t}\left(\bar{i}\right) - \pi^*\right)^2 + (1-\theta)\left(y_{t+h|t}(\bar{i}) - y^*\right)^2\right], \tag{2.1}$$

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; y^* is the output target, assumed to be equal to the natural rate. For the remaining of the paper, the inflation target (π^*) and the natural rate (y^*) are both normalized to zero. According to (2.1), the central bank is concerned about both having the forecast of inflation close to its target and the forecast of output not deviating too much from its natural rate. $\theta \in [.5, 1]$ is a parameter reflecting the central bank preference for inflation forecast stabilization relative to output stabilization[6]. A lower value reflects a central bank that is relatively more concerned about output forecast targeting, denoted a flexible inflation forecast targeter. The first order condition of (2.1) is

$$\theta \frac{\partial \bar{\pi}_{t+h|t}\left(\bar{i}\right)}{\partial i} \bar{\pi}_{t+h|t}\left(\bar{i}\right) + (1-\theta) \frac{\partial y_{t+h|t}(\bar{i})}{\partial i} y_{t+h|t}(\bar{i}) = 0. \tag{2.2}$$

According to (2.2), 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 has upon the respective forecasts. A CIR-targeting central bank with some preferences for output forecast targeting ($\theta < 1$), 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 (2.2) as

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

which implies a conditional inflation target. If the forecast of output is well below the natural rate, the inflation target rises above its normal rate, e.g. to the upper level of the target band.

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[7]

$$X_{t+1} = AX_t + Bi_t + \epsilon_{t+1}, \tag{2.3}$$

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

$$X_{t+h|t} = A^h X_t + \sum_{j=0}^{h-1} A^j B i_{t+h-1-j|t}, \tag{2.4}$$

[6]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.

[7]See Leitemo (1999b) for the derivation of policy in the context of models with forward-looking behaviour.

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

$$X_{t+h|t}(\bar{\imath}) = A^h X_t + \sum_{j=0}^{h-1} A^j B i_t. \tag{2.5}$$

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 appropriately defined.

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 state today,

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

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 (2.2), 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

$$
\begin{aligned}
i_t &= \frac{\Omega}{\Omega \sum_{j=0}^{h-1} A^j B} A^h X_t \\
&= F_{cir} X_t
\end{aligned}
\tag{2.6}
$$

where $\Omega = \left(-\theta K_\pi \sum_{j=0}^{h-1} A^j B K_\pi + (1-\theta) K_y \sum_{j=0}^{h-1} A^j B K_y\right)$ and F_{cir} is defined accordingly. Equation (2.6) denotes the CIR-targeting central bank's reaction function and yields the following proposition.

Proposition 2.1. *Given that A is positive semidefinite and has eigenvalues of value less than 1, extending the length of the forecast targeting horizon reduces the absolute value of the coefficients in the reaction function.*

There are two effects that produce this outcome. The first, which refers to $\sum_{j=0}^{h-1} A^j B$ in the denominator of (2.6), is the effect of the interest rate level on the forecast when extending the forecast 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 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, then 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 targeting horizon, the inflation targeting central bank will be exploiting these effects to a greater degree than a central bank with a shorter horizon. The result is less need for an equilibrium-correcting policy.

The interest rate is a function of the prevailing state of the economy, as the next period interest rate will be a function of the next-period state, $i_{t+1} = F_{cir} X_{t+1}$. The next-period state is a combination of the rationally expected forecast of the state pluss new (unpredictable) information as represented by ϵ. This can formally be shown by setting (2.6) into (2.3), which yields

$$
\begin{aligned}
X_{t+1} &= AX_t + BF_{cir} X_t + \varepsilon_{t+1}, \\
&= (A + BF_{cir}) X_t + \varepsilon_{t+1}, \\
&= X_{t+1|t} + \varepsilon_{t+1}.
\end{aligned}
$$

The next-period state forecast based on present information ($X_{t+1|t}$) will deviate from the present state as $(A + BF_{cir}) \neq I$. This implies that interest rate movements are forecastable as $i_{t+1|t} = F_{cir}X_{t+1|t} \neq F_{cir}X_t$, and the interest rate does not become a random walk as maintained by some observers[8]. The CIR-targeting framework does violate its own assumption of interest rate constancy in a systematic way.

3. An open-economy model

In order to study the implications of CIR-targeting in a small open economy, we present a rational expectations, forward-looking model with a traded and non-traded sector. The model is an extension of the one-sector model of Batini and Haldane (1999) (BH) which has recently been adopted as one of the forecasting models of the Bank of England (1999). The extension consists partly of letting the long real interest rate play a role in demand determination, partly of introducing sluggish adjustment of imported goods prices to exchange rate movements and finally the addition of a competitive traded sector. This model is similar to the one presented in Leitemo (1999a) where a number of strategies for implementing inflation targeting in a small open economy are analyzed. The model is not explicitly based on optimizing behaviour, although it contains several elements that are likely to be found in such models, e.g. forward-looking behavior, demand is determined partly by the long real interest rates and production in the traded sector is based upon profit-maximization in the sense that real product price determines output in an internationally competitive market.

Optimizing models, like the one presented in McCallum and Nelson (1997), are extremely forward-looking in nature. The combination of this with rational expectations implies behaviour of key variables representing demand and supply that is extremely sensitive to the arrival of new information. Estrella and Fuhrer (1998) criticize this type of behaviour to be at odds with the empirical facts. This is obviously an important objection if the policy implications and policy formulation are of central interest. In this author's opinion, the major problem with optimizing modelling is that we are as yet not able to specify the agents' optimizing problem in any great

[8] The Economist,15 January, 2000, p.35, comments on the forecastability of UK interest rate movements:"Although rates will probably go up further, the MPC [Monetary Policy Committee] makes no predictions about their future course. It insists that it adjusts rates each month in the light of the economic news since its last meeting. Its inflation forecasts, the next of which will be published next month, are predicated on the assumption that rates will not change. (If we expected that rates would need to be adjusted, runs the implicit argument, then we would have changed them already.)" The analysis in this paper shows that the outlined MPC-argument is false and the Economist's reasoning is correct.

detail. The problem is not only that we are not able to pay enough respect to the preferences of the decision-makers, but also to specify the technology or setting in which the decisions are being made. Information restrictions, habit and expectations formations, degree of learning etc., are all certainly important mechanisms that we have a very limited understanding of. Until we are able to deal with these issues in a satisfactory way, policy advisors will always feel somewhat guilty with respect to the Lucas (1976) critique. Given this arguably weak empirical foundation of pure optimising models, it could also be useful to study monetary policy in models in which not every structural relationship is derived from explicit optimization but has somewhat stronger empirical foundations. This is the way we proceed in this paper.

The core of the model is a traditional open-economy AD/AS-model with forward-looking agents. Demand for the non-traded sector goods is influenced by monetary policy through the current short real interest rate and expectations about its future development. Nominal rigidities are introduced through overlapping wage contracts in the spirit of Fuhrer (1997) and Fuhrer and Moore (1995) creating a role for having monetary policy influencing real variables in the short run. The traded sector operates in a perfectly competitive market and takes prices as given. Adjustment costs introduce a role for forward-looking behaviour in this sector. There is sluggish adjustment of imported prices to exchange rate movements due, e.g., to the existence of price-contracts of some length in the import sector.

All variables, except the interest rates, are measured as log-deviations from their (possibly time-varying) long run equilibrium values which are assumed to be independent of monetary policy[9]. To make notation easier to read, we generally write $x_{t+s|t} \equiv E_t x_{t+s}$. The model is summarized by the following equations:

$$y^T_{t+1} = \rho_T y^T_t + \beta \sum_{s=0}^{\infty} \delta^s (p^T_{t+1+s|t} - w_{t+1+s|t}) + u^T_{t+1} \tag{3.1}$$

$$y^N_{t+1} = \rho_N y^N_t - \alpha(\omega R_t + (1-\omega) r_t) + u^N_{t+1} \tag{3.2}$$

$$y_t = \eta y^T_t + (1-\eta) y^N_t \tag{3.3}$$

$$\begin{aligned} x_t - p^c_t = {} & (1-\phi)(x_{t-1} - p^c_{t-1}) + \phi(x_{t+1|t} - p^c_{t+1|t}) + (1-\phi)\gamma y_t + \\ & \phi\gamma y_{t+1|t} - (1-\phi)\mu(w - p^T)_t - \phi\mu(w-p^T)_{t+1|t} + u^w_t \end{aligned} \tag{3.4}$$

$$w_t = .5(x_t + x_{t-1}) \tag{3.5}$$

[9]For some interesting views on how the choice of the 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

$$p_t = w_t \tag{3.6}$$

$$p_t^T = s_t + p_t^* \tag{3.7}$$

$$p_t^C = (1-\psi)p_t + \psi p_t^{IM} \tag{3.8}$$

$$\pi_{t+1}^{IM} = \pi_t^{IM} + c(p_t^T - p_{t-1}^T - \pi_t^{IM}) + u_{t+1}^{IM} \tag{3.9}$$

$$e_t = e_{t+1|t} - .25(r_t - r_t^*) \tag{3.10}$$

$$r_t \equiv i_t - 4(p_{t+1|t} - p_t) \tag{3.11}$$

$$r_{t+1}^* = \rho_r^* r_t^* + u_{t+1}^{r*} \tag{3.12}$$

$$R_t = \frac{1}{T}\sum_{s=t}^{t+T} r_{s|t} \tag{3.13}$$

Equation (3.1) 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) is increasing in the real product price ($p^T - w$). Given a rising marginal cost schedule, this is consistent with profit maximization. Due to adjustment costs, the firm sets production in a forward-looking manner by anticipating future development in prices. Due to the same reason, it sets production in a smoothed manner by not deviating too strongly from the production level in the last period. An assumed one-period planning and implementing horizon implies that the firm carries out production decisions with a one-period lead and are henced based upon a one-period lagged information set. $0 < \delta < 1$ captures the rate at which the representative traded sector firm devalues future information about the real product price. Risk averse behaviour could typically reduce this value, letting the decision-maker be more occupied with present than future conditions. High adjustment costs and (irreversible) start-up or close-down costs pertaining to production facilities, should make information about the future more important to the firm and raise the value of δ.

By taking expectations in (3.1) and using the lead operator[10], expected production can be expressed as

$$y_{t+1|t}^T = \rho_T y_t^T + \frac{\beta\left(p_{t+1|t}^T - w_{t+1|t}\right)}{(1-\delta F)}.$$

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

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

output can be expressed conveniently as

$$y_{t+1}^T = \frac{\rho_T}{1+\delta\rho_T} y_t^T + \frac{\delta}{1+\delta\rho_T} y_{t+2|t}^T + \frac{\beta}{1+\delta\rho_T} (p_{t+1|t}^T - w_{t+1|t}) + u_{t+1}^T, \tag{3.14}$$

where u^T represents a stochastic supply shock with zero expectation and a finite variance.

Whereas production in the traded sector is determined by real product prices, we assume that the non-traded sector operates in a market of monopolistic competition and aggregate sector output $\left(y_t^N\right)$ is determined by demand. Due to intertemporal substitution effects in consumption, production can deviate from its long run trend. As McCallum and Nelson (1997) show in a model of optimizing behaviour, demand is driven by expected future short real interest rates (r_t) - corresponding to the Euler equation for optimal consumption in non-monetary models. According to the expectations hypothesis of the term structure of interest rates, the expected future path of the short real interest rate is equivalent to the long real interest rate (R_t). In this paper we take the stand that demand directed towards the non-traded sector is affected by both the long and the short real interest rate[11], as expressed in (3.2). In the long-run, non-traded sector output is determined by equilibrium income. u_{t+1}^N is a stochastic demand shock with zero expectations and finite variance. Equation (3.3) 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 (1995) and Fuhrer (1997), as described by equation (3.4). In this framework there are multiple (in this paper two) overlapping wage contracts existing at all times and renegotiated subsequently every other period. Agents are concerned with their expected real wage development not deviating too much from that of the other contract not being negotiated and the expected contract real wage negotiated in the next period. The parameter ϕ in (3.4) represents the importance the forward-looking element plays relative to the backward-looking. The forcing variables are pressure in the labour market, represented by the output-gap, and the capital rent share in the traded sector, proxied by the real product price. The last 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 capital rent share of output (in the traded sector) has an effect upon wage determination[12]. Bargaining theory tends

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

[12] See e.g. Kolsrud and Nymoen (1998), Bårdsen et al. (1999) and Bårdsen and Fisher (1999).

to suggest that the outcome of the wage bargaining process is related to the cost the employers would face in the case of a conflict and strike. These costs would typically be related to the capital rent share. In our open-economy formulation of the Fuhrer-Moore model as stated in (3.4), the nominal contract wage is denoted by x; the consumer price level is denoted by p^c; and the product real wage is denoted by $w - p^T$. As a result of having the average contract lasting for two periods, the aggregate wage level (w_t) is the average of the existing contract wages as described in equation (3.5).

Given our assumption of monopolistic competition in the non-traded sector, prices are set as a markup on wages as in equation (3.6). Given the mixed evidence on the cyclicality of markups[13], the markup is for simplicity considered to be constant and unrelated to the transmission mechanism of monetary policy as laid out in this model. PPP holds for the traded goods prices according to equation (3.7) where p_t^* is the foreign price level and s_t is the effective nominal exchange rate. Note that we may rewrite (3.7) as $p_t^T = e_t + p_t$ where $e \equiv p_t^* + s_t - p_t$ is the real exchange rate.

Equation (3.8) defines the consumer price level as a weighted average of the non-traded goods price and the price of the imported goods, p^{IM}. As several empirical studies indicate[14], there is sluggish adjustment of imported goods prices to exchange rate shocks. We therefore choose to model the imported goods prices as the outcome of 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. Equalisation of imported goods prices to the international price level (measured in domestic currency units) is a long-run phenomenon. Due to the existence of price contracts, or informal understanding between the exporting firms and the distributors in the domestic economy to smooth price changes in order to enhance goodwill, imported goods prices will have their own dynamics. Taking first differences and adding a disturbance term, we arrive at the formulation in (3.9).

The small open economy is assumed to be operating in a environment of near-perfect capital mobility where the real exchange rate is determined by uncovered interest rate parity as shown in (3.10). 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

[13]See Rotemberg and Woodford (1999) for a recent survey

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

foreign real interest rate (r_t^*), i.e., the interest rate that is required to expect an unchanged constant real exchange rate, follows an AR(1)-process, as in (3.12). The domestic short real interest rate (r_t) is defined by the Fisher identity in (3.11).

We follow Svensson (2000) in assuming that the long real interest rate (R_t) is determined according to the expectational hypothesis, as stated in (3.13). However, in the simulation of the model we approximate[15] it as

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

where T is the time to maturity. Since the foreign real interest rate is modelled as an AR(1) process, the foreign long interest rate (R_t^*) would approximately be

$$R_t^* \approx \frac{1}{T} \frac{r_t^*}{1 - \rho_{r^*}}. \tag{3.15}$$

By iterating on (3.10), assuming that the real exchange rate converges to its equilibrium level $\lim_{s \to \infty} e_{t+s|t} = 0$, we get that

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

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

$$R_t = R_t^* - \frac{4}{T} e_t. \tag{3.16}$$

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 CIR-targeting, represented by equation (2.6).

3.1. Calibration

The model presented above is calibrated in order to match some macroeconomic characteristics of the UK economy at a quarterly frequency. BH calibrate their model with parameters values that are set 'in line with prior empirical estimates' from the Bank of England forecasting model

[15] The discrepancy will depend on the rate of convergence of the short real interest in the model. A quick 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.

and in order 'to ensure a plausible dynamic profile for impulse responses' (BH). We therefore 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, others set to values that do not seem a priori implausible. We do not want to overemphasize our belief in the choice of parameters given the problems in obtaining 'tight' macroeconomic estimates. Our aim is, however, not to produce a fully specified model for the UK economy. Rather, it is to give a likely description of the outcome of following a special type of inflation targeting strategy in a (plausible) small open economy. For that purpose, we consider our approach as sufficient.

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 to $\alpha = 0.125$ equal to the value in BH. The long interest rate weight in the interest rate index is somewhat arbitrarily set to $\omega = .7$ reflecting the strong theoretical arguments that long 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 product real wage is $\frac{\beta}{1-\delta} = .8$[16]. 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 the inflation rates 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 are reasonably strong empirical support for the idea that the wage share of output influence the outcome of the wage bargaining process. Nymoen (1999) reports estimates of the elasticity of real wages with respect to changes in the wage share for the Nordic countries in the range of -0.14 to -0.26 on annual data. Furthermore, Bårdsen et al. (1999) estimate that

[16] In the BH model, the aggregate output impact elasticity of a change in the the real exchange rate is $-.2$. The long-run elasticity is -1. Our choice of coefficients would produce traded sector 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.

quarterly wages error-correct to the equilibrium level of the wage share by a factor of -0.156 for the UK. Moreover, Bårdsen and Fisher (1999) find in an estimated dynamically specified 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 light of these studies, we assume that the contract wage respond to the traded sector product real wages, and set $(-\mu) = -0.09$ which is a conservative estimate. The average time to maturity for long-term loans is set somewhat arbitrarily to $T = 40$ quarters. Finally, the rate at which imported prices equilbrium corrects to the foreign price is set at $c = .5$ which imply that about 95 percent of a permanent change in the nominal exchange rate is reflected in imported goods prices after a year.

The empirical study of Fisher et al. (1990) reports support for 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^* is the foreign risk premium corrected real interest rate, it can be calculated from (3.10) as

$$r_t^* = r_t - 4\Delta\widehat{e}_{t+1|t}. \tag{3.17}$$

In order to derive r_t^*, we proxied e by the UK nominal effective exchange rate deflated by the respective relative CPI price levels. Moreover, r was proxied by the 3-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 the CPI price level was obtained from the fitted values of two regressions. The quarterly inflation rate was regressed on four lags of itself, 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 3-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[17].

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),

[17] This approach is particularly simple and it should be noted that there exist more advanced methods of deriving the risk premium. 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 heavily on the structure of the model taking account of every argument in forming market expectations. Given our limited understanding of how the private agents form their expectations, we view our approach as sufficient for the questions analyzed in this paper.

$$r_t^* = \underset{(.12)}{.37}\ r_{t-1}^* + \varepsilon_t^{r*}, \tag{3.18}$$

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 valid approximation.

Realizing the difficulties in obtaining measurement of the true structural shocks to the economy, we proceed by using standard structural vector autoregression methods of obtaining (approximations of) time series representations of the underlying shocks. Ideally, our model could be estimated and the residuals obtained could be used to estimate the distribution of these shocks. However, our model is stylized and reflects possibly only the most important factors in the monetary policy transmission mechanism. The residuals would therefore partly reflect a mixture of omitted variables and shocks. We do, however, take ε_t^{r*} as a measure of the foreign financial shocks in our model. For the other shocks, we construct a recursive vector autoregression model of order four with variables in the following order: OECD GDP, German 3-month interest rate, hourly wages, manufacturing output, non-manufacturing output, 3-month interest rate, real effective 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 reflect our small country assumption as foreign variables are viewed as exogenous to the UK economy. Inclusion of the OECD GDP can be seen as a proxy of the UK trading partners production level. As the UK is a part of the OECD, there is a simulaneity problem that distorts the measure of the structural shocks, however only to a small degree and hence is disregarded. This gives us time series for all five shocks to our model.[18] We then proceeded by calculating the variance-covariance matrix of these shocks.

4. Policy evaluation and analysis

4.1. A disinflationary experiment

In order to see how the model responds to CIR-targeting, it may be useful to study the implications of a reduction in the level of the inflation target. Figure 4.1 shows the effects of an unexpected, deliberate reduction of the target by one percentage point. The first column considers a rather short targeting horizon of about four quarters, and the second, a slightly

[18]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.

longer targeting horizon of eight quarters[19].

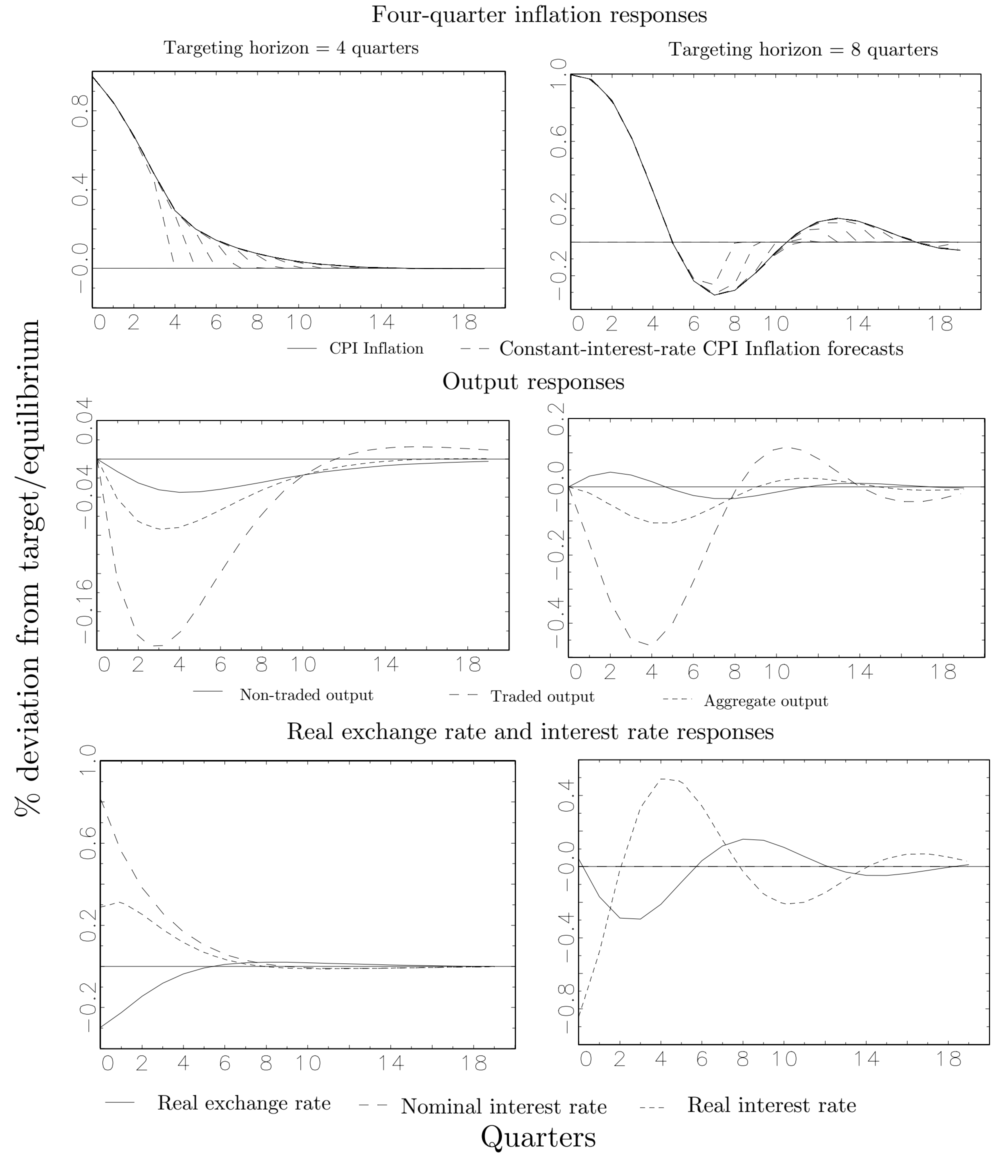


Figure 4.1
Reducing annual CPI inflation by one percent

The first row of the figure shows the implied dynamics for annual CPI inflation. For the short targeting horizon, inflation is monotonically brought down to the new target level within a three-year period. The new and lower inflation target combined with a short targeting horizon, induces the CB to set its nominal interest rate so as to let the lowered inflation expectations increase the real interest rate. Output in the non-traded sector is brought down through decreased demand. The rise in the real interest rate causes an immediate real appreciation which has

[19]Note that a change in the inflation target changes the equilibrium nominal interest rate as defined by $i^* = r^* + 4\pi^*$. Thus, as we consider only the deviations from equilibria, the full change in the level interest rate is not reflected in the figure.

a contractionary effect in the traded sector. The maximum impact on output is after three quarters when the traded sector has contracted by 0.2% and the non-traded sector by a much smaller number, 0.04%. The initial appreciation brings imported inflation down, and, together with decreased real product wages in the traded sector, brings wages down and decreases CPI inflation. As the prospective inflation forecasts indicate decreasing deviations of inflation from target, the nominal and real interest rates gradually decline towards their equilibria.

When the forecast targeting horizon is extended to eight quarters, the dynamics of the model are changed in important ways. First of all, and as would be expected from proposition 2.1, the interest rate is set closer to its new lower equilibrium value reflecting the reduction in the inflation target, and is roughly kept at its new level with only negligible reactions to disequilibrium conditions (more on this later). As a consequence, the real interest rate drops and creates a boom in the non-traded sector. However, the real exchange rate gradually appreciates due to expectations of a positive real interest rate differential in the intermediate run. Imported goods prices decline and reduced product real wages induce wages and domestic prices to grow at a slower rate, which brings the inflation down, slightly undershooting its target. There is a high degree of persistent policy-induced oscillations in the model.

There are fundamental differences in how the reduction of inflation is achieved, depending on the length of the forecast targeting horizon. Whereas a short forecast targeting horizon implies a dependence on the traditional demand channel in influencing wages and inflation, a longer horizon relies more on the exchange rate channel in bringing inflation down. The result is that *the traded sector undertakes a relatively large part of the output adjustments during the disinflationary period when the forecast targeting horizon is long, whereas the non-traded sector plays a relatively more important role at horizons.* When considering an eight-quarter targeting horizon, the total loss of output during the time of disinflation are 2% for the traded sector, as low as .01% for the non-traded sector and .5% for aggregate output. In the case of a four-quarter targeting horizon, the corresponding numbers are 1.05% for the traded sector, .33% for the non-traded and .51% for aggregate output.

The reason for this is the nature of the relationship between the real interest rate and the real exchange rate inherent in the unconvered interest parity condition. As this condition implies that the real exchange rate reflects expected future real interest rate differentials, the exchange rate will react strongly to persistent deviations between the domestic and the foreign interest rate. Figure 4.2 gives an illustration of this. It considers the effects of reducing annual inflation

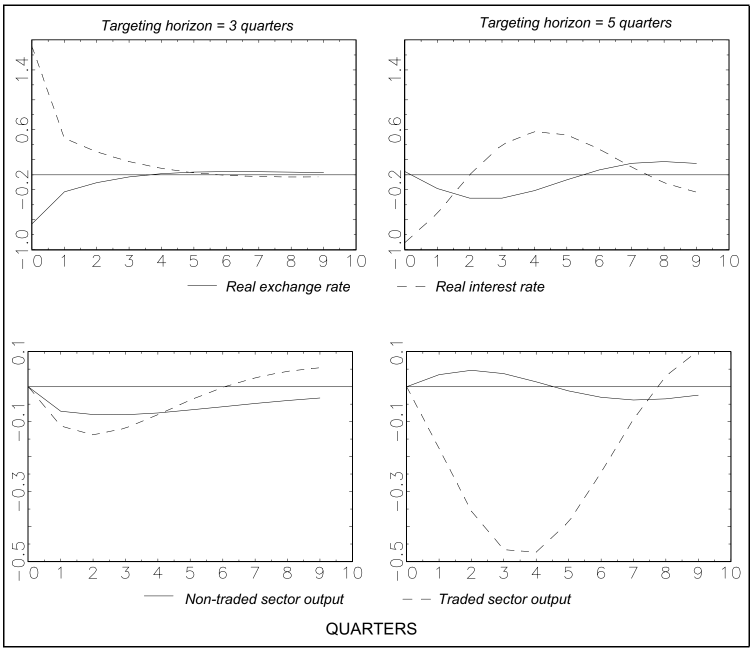


Figure 4.2: An illustration of the asymmetrical impact on the different sectors

by one percentage point, now with a targeting horizon of three and five quarters. Under a short targeting horizon, there is a strong inital reactions to the real interest rate which quickly fades out within a year. The reaction to the real exchange rate is hence moderate and the weak persistence in the real interest rate brings it quickly towards equilibrium. As the traded sector is assumed only to respond to expected future real product prices due to a one-period planning horizon, the initial unexpected reaction in the exchange rate has no influence upon traded sector output decisions. Given the rapid real exchange rate equilibrium-correction, there are no important causes for adjusting production in the traded sector.

When extending the forecast targeting horizon to five quarters, the movement in the real interest rate and the real exchange rate is more persistent. The uncovered interest rate condition implies that persistent real interest rate movements will lead to a stronger and more persistent effects on the real exchange rate. A given level of the real exchange rate is therefore expected to last longer, and the forward-looking agents of the traded sector adjusts output accordingly. The real exchange rate appreciates gradually as a result for expected future real interest rate differentials and the traded sector contracts. The real interest rate shows persistent and long-lasting smooth oscillations, thus the reactions to the long real interest rate is hence moderate as agents expect future short real interest rates to fluctuate around its equilibrium. The non-traded sector hence undertake only a small degree of the adjustment necessary for the central bank to hit its new target compared with a shorter horizon.

Table 4.1
Implied reaction functions

	Strict inflation forecast targeting: $\theta = 1$					Flexible inflation forecast targeting: $\theta = .5$				
Coefficients	$h = 3$	$h = 4$	$h = 5$	$h = 6$	$h = 8$	$h = 3$	$h = 4$	$h = 5$	$h = 6$	$h = 8$
y_t^N	.90	.72	−.54	.03	.01	1.04	.76	−.41	.04	−.01
y_{t-1}^N	.70	.28	−.03	−.01	−.00	.58	.28	−.03	−.01	−.00
y_t^T	.30	.24	−.11	−.03	−.00	.35	.25	−.11	−.03	−.00
$y_{t\|t-1}^T$	.05	.02	−.00	−.00	−.00	.04	.02	−.00	−.00	−.00
y_{t-1}^T	.19	.08	−.01	−.00	−.00	.16	.08	−.01	−.00	−.00
$\pi_{t\|t-1}$	1.10	.44	−.05	−.01	−.00	.91	.44	−.05	−.01	−.00
π_{t-1}	3.10	1.24	−.13	−.03	−.00	2.56	1.23	−.13	−.03	−.00
$\pi_{t\|t-1}^{im}$	−.19	−.08	.01	.00	.00	−.16	−.08	.01	.00	.00
π_t^{im}	2.62	1.32	−.13	−.03	−.00	2.19	1.32	−.14	−.03	−.00
π_{t-1}^{im}	.78	.31	−.03	−.01	−.00	.64	.31	−.03	−.01	−.00
u_t	9.54	5.33	−.57	−.12	−.00	8.21	5.27	−.57	−.11	−.00
u_{t-1}	4.85	1.94	−.20	−.04	−.00	4.00	1.92	−.20	−.04	−.00
r_t^*	.73	.56	−.07	−.01	−.00	.68	.56	−.07	−.01	−.00
r_{t-1}^*	−.02	−.01	.00	.00	.00	−.02	−.01	.00	.00	.00
e_{t-1}	.18	−.29	.02	.01	.00	.09	−.30	.03	.01	.00
i_{t-1}	.02	.01	−.00	−.00	−.00	.01	.01	−.00	−.00	−.00

4.2. Reaction functions and stabilization properties

We now turn to study the implied reaction functions of CIR-targeting and their properties under stochastic simulations when the model is being exposed to the historical distribution of shocks. The implied interest rate reaction functions of constant-interest-rate targeting, as stated in equation (2.6), are shown in table 4.1. Two general comments can be made on the form of the reaction function. First of all, which follows from (2.6), it is model-dependent. If a change is made to the underlying model, this would have direct implications for the inflation forecasts and hence the reaction function. The reaction function is of a "complex" nature, i.e. reaction is made to every state variable in the model. Such "complexity" and model-dependency are also found in optimizing rules that follows from the minimization of a quadratic loss function under discretion.

The response coefficients in the reaction functions are all relatively small. The absolute value of the coefficients are decreasing in the length of the forecast targeting horizon, as implied by proposition 2.1 above. There seems to be a clear distinction between the choice of a targeting horizon of four quarters on one side, and longer targeting horizons on the other. A targeting horizon of four quarters implies a reaction to inflation and output that is reasonably close to the one in the Taylor (1993) rule[20]. However, CIR-targeting implies additional strong reactions to wage shocks which has persistent effects and hence influence the forecast to an important

[20]The Taylor rule has the following form: $i_t = 1.5\pi_t^C + .5y_t$.

Table 4.2
Unconditional standard deviations in percent and losses

Strictness(θ)	π^c	y^N	y^T	y	Δi	L
Targeting horizon = 3						
.50	.63	1.24	1.98	.78	10.54	28.79
1.00	.48	1.36	2.20	.82	11.84	35.96
Targeting horizon = 4						
.50	1.81	.72	1.73	.69	7.79	18.97
1.00	1.64	.77	1.67	.70	7.97	19.06
Targeting horizon = 5						
.50	2.96	.87	5.46	1.22	1.12	10.52
1.00	2.96	.88	5.49	1.22	1.22	10.65
Targeting horizon = 6						
.50	2.93	.82	5.31	1.20	.22	10.03
1.00	2.92	.82	5.31	1.20	.23	10.04
Targeting horizon = 7						
.50	2.94	.81	5.32	1.21	.04	10.09
1.00	2.94	.81	5.32	1.21	.04	10.09
Targeting horizon = 8						
.50	2.94	.81	5.32	1.21	.01	10.12
1.00	2.94	.81	5.32	1.21	.01	10.12
Taylor rule						
	1.38	.73	2.32	.78	2.88	4.57
Optimization under full credibility						
	1.16	.86	2.78	.84	1.39	2.53

degree. Extending the targeting horizon to five or six quarters changes the reaction function considerably. The reaction coefficients are not only smaller in magnitude, but may also change signs. Oscillations in the model are the key to understand this phenomenon. If the constant interest rate forecast of the target variable at a given horizon is above target, it may well be below target at another horizon. Switching between targeting horizons may therefore yield quite the opposite answers to how the interest rate should respond to the state.

Turning to the macroeconomic properties of the model under CIR-targeting, we consider the unconditional standard deviations in table 4.2. Targeting horizons between three and eight quarters are considered in addition to flexible targeting with $\theta = .5$. Targeting horizons below three quarter are unstable in the model, leading to exploding oscillations. The columns show the unconditional percent standard deviations of the (quarterly) CPI inflation rate, non-traded output, traded output, aggregate output and the change in the interest rate.

To summarize the performance of CIR-targeting, it is convenient to consider a standard, quadratic loss function, of the form

$$L = E_t \sum_{s=0}^{\infty} \left[(\pi^c_{t+s} - \pi^*)^2 + y^2_{t+s} + .25(i_{t+s} - i_{t+s-1})^2 \right],$$

where the policy-maker cares equally about inflation and aggregate output variability but also attaches some weight on an interest rate smoothing objective. The value of this loss is shown in the last column of the table.

Quarterly CPI inflation is most stable with a targeting horizon as low as three quarters. Performance is, however, very sensitive to a small change of targeting horizons, as extending the horizon by one quarter almost triples the standard deviation. It would be of no great exaggeration to say that CIR-targeting provides only a small degree of inflation stability at the horizons normally associated with inflation forecast targeting. This comes as a result of real exchange rate movement associated with this policy which has an important effect on imported goods prices and wages in the open-economy model presented.

Both sectors of the economy are quite stable at a surprisingly short horizon. The non-traded sector is more stable than the traded sector where variability increases rapidly with the length of the targeting horizon. A longer targeting horizon smooths interest rate movements and makes policy become less active, making the traded sector play the role of the stabilizing sector. As illustrated earlier, when the nominal interest rate movements are smoothed, the real interest rate fluctuates persistenly around its equilibrium. This brings about large exchange rate movements that affect the traded output. At a shorter horizon, this effect is milder as the interest rate is moved more vigourously in order to rapidly achieve equilibrium corrections. The (larger) non-traded sector then takes a more central role in stabilizing the model.

There does not seem to be a clear case for "flexible" inflation forecast targeting with $\theta = .5$. CPI inflation variability increases and output variability decreases at a forecast horizon of three quarters, however, at any other horizon, flexible targeting does not yield any large differences in performance.

For reasons of comparion, the second row from the bottom of table 4.2 shows the properties of a Taylor (1993) rule, that has received much attention recently[21]. The bottom row shows the properties of a rule that follows from minimizing (4.2) when the central bank is able to credibly commit to a policy that is time-inconsistent[22]. In terms of expected losses, CIR-targeting is

[21]See e.g. Taylor (1999).

[22]See Backus and Driffill (1986), Svensson and Woodford (1999) and Woodford (2000) for discussions on the

not only far from delivering properties close to the overall optimal policy, but also performs worse than the Taylor rule. The Taylor rule scores well in stabilizing both inflation and output without the need for strong movements in interest rates compared with CIR-targeting at any length of the forecast horizon. The ability to commit to the optimal policy has first and foremost additional welfare-improving effect by the smoothing of interest rate movements.

The lowest value of the expected loss is obtained when the targeting horizon is six quarters. This is roughly in line with the two-year horizon arguably implemented by the Bank of England and the Sveriges Riksbank.

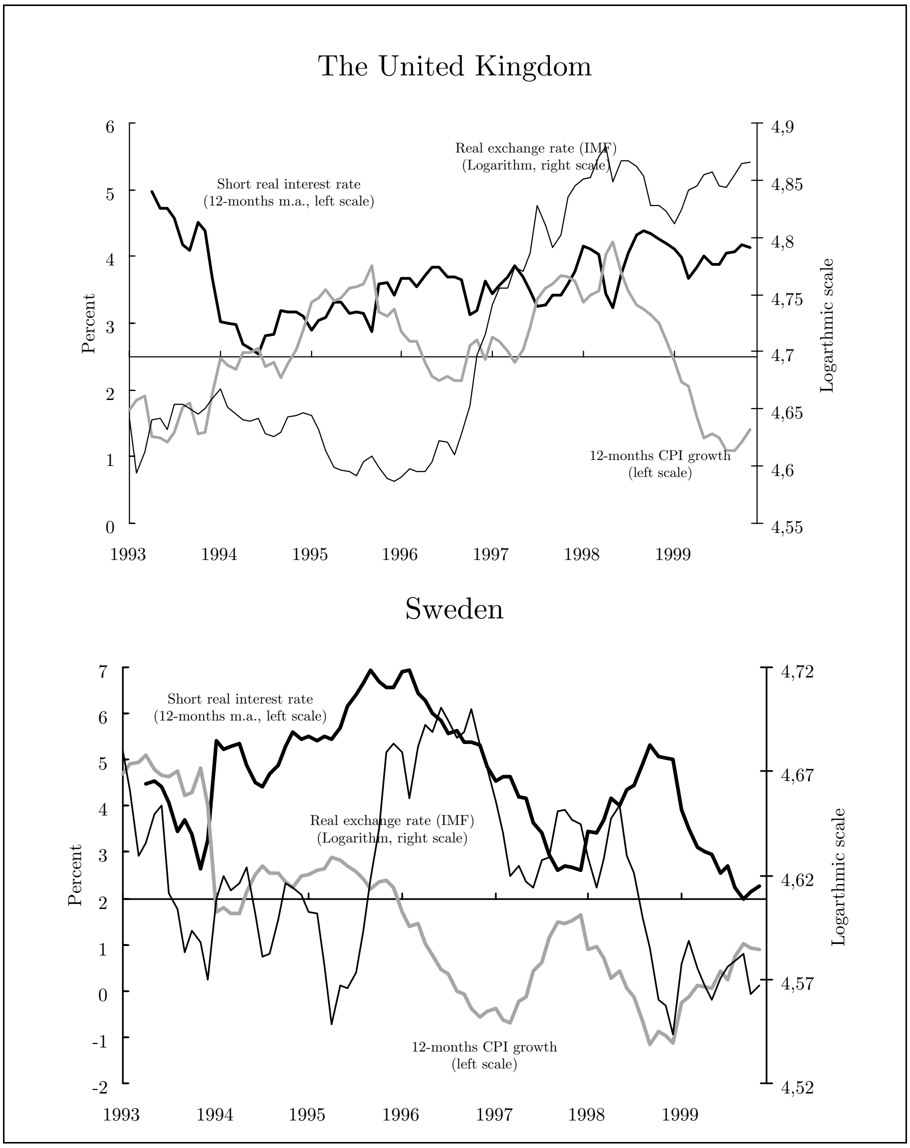


Figure 4.3: The recent monetary history of the UK and Sweden

Figure 4.3 shows the recent inflation targeting history of the United Kingdom and Sweden,

overall optimal, but time-inconsistent policy.

spanning the 1993-1999 period. CPI inflation, the short real interest rate[23] and the CPI-based real effective exchange rate as recorded by the IMF are shown. In both countries the real exchange rate fluctuates persistently over the whole period of inflation targeting, with movements being particularly pronunciated in the second part of the period. The real interest rate shows a considerable degree of persistence, most noticeable for Sweden. Both these observations are consistent with a rather long forecast targeting horizon in the model. The real exchange rate seems to influence CPI inflation in both countries with a lag, contributing to explaining some of its variability in both countries. The appreciations of the Swedish krone in 1995-1996 and 1997-1998 were followed by a persistent reduction of CPI inflation rate in the subsequent quarters. The appreciating pound sterling in 1997 was also followed by a fall in the CPI inflation rate during 1998. This story is broadly consistent with the predictions of the model with strong, persistent movements in all three variables.

5. Conclusions

This paper has analyzed the properties of constant-interest-rate inflation forecast targeting, first by pointing to some general features of CIR-targeting and then analysed it within the context of a small open-economy model. CIR-targeting has a simple and charming appeal, implying an increase in the interest rate when the forecast of inflation is above target and a decrease in the interest rate when below. We believe that it is perceived to be one of the foremost alternatives of implementing inflation targeting.

This paper have tried to show that this strategy may also have some less attractive features. There is a time-inconsistency problem in CIR-targeting. The reason for this is the use of a non-valid assumption of a constant interest rate in the forecast horizon. This may seriously distort the information content of the forecast as well as the credibility of the inflation targeting central bank that publishes them, leading agents to base their inflation expectations on other sources of information. This may reduce the central bank's ability in achieving the inflation target at low costs.

In an open-economy context, the exchange rate channel may distort the attractive appeal of CIR-targeting even further. In an open economy the real exchange rate plays an important role in affecting CPI inflation and traded sector output decisions. Hence stabilizing the real

[23] Defined as the ex-post four-quarter moving average real interest rate, i.e., $\bar{r}_t = \frac{1}{4}\left(\sum_{j=0}^{3} i_{t-j}\right) - \bar{\pi}_t^c$.

exchange rate becomes an important objective for nominal and real stability. The real exchange rate will be strongly affected by persistent, strong movements in the real interest rate in the context of the uncovered interest rate parity condition. It is therefore important to stabilize the economy rather quickly in order to avoid enduring real interest rate deviations from equilibrium. When the CIR-targeting central bank uses a rather long forecast targeting horizon, such fast equilibrium corrections are not achieved. The implied interest rate reaction function produces too much nominal interest rate smoothing in order for this to happen. Hence, CPI inflation and the real exchange rate fluctuates. When the central bank chooses a shorter horizon, there is stronger nominal interest rate responses, causing more stabilization of inflation and the exchange rate, and the interest rate channel plays a more important role in achieving stability. However, this is achieved at the cost of a strongly unsmoothed movements in the nominal interest rate. Compared to the policy that follows from optimization of the 4.2 function, nominal and real stability is achieved at a much higher cost of policy activism.

We believe that CIR-targeting may indeed contribute to explaining the high degree of persistent real exchange rate movements that the UK has experienced in the second part of the 1990s. The high variability in Swedish CPI inflation and, somewhat less pronunciated, in the Swedish real exchange rate, may also partly be a result of the CIR-targeting policy.

References

Backus, David and John Driffill (1986). "The Consistency of Optimal Policy in Stochastic Rational Expectations Models." CEPR Discussion Paper No. 124.

Bank of England (1999). *Economic Models at the Bank of England.* Bank of England, London.

Bårdsen, Gunnar, Paul Fisher, and Ragnar Nymoen (1999). "Business Cycles: Real Facts or Fallacies?" In Steinar Strøm (ed.), "Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium," Cambridge University Press.

Bårdsen, Gunnar and Paul G. Fisher (1999). "Economic Theory and Econometric Dynamics in Modelling Wages and Prices in the United Kingdom." *Empirical Economics*, 24:483–507.

Batini, Nicoletta and Andrew Haldane (1999). "Forward-Looking Rules for Monetary Policy." In John B. Taylor (ed.), "Monetary Policy Rules," chap. 4, pp. 157–201.

Bratsiotis, George and Christopher Martin (1999). "Stabilisation, Policy Targets and Unemployment in Imperfectly Competitive Economies." *Scandinavian Journal of Economics*, 101(2):241–256.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans (1999). "Monetary Policy Shocks: What Have We Learned and to What End?" In John B. Taylor and Michael Woodford (eds.), "Handbook of Macroeconomics," pp. 65–148. Elsevier.

Dwyer, Jacqueline, Christopher Kent, and Andrew Pease (1994). "Exchange Rate Pass-Through: Testing the Small Country Assumption for Australia." *The Economic Record*, 70:408–423.

Estrella, Arturo and Jeffrey C. Fuhrer (1998). "Dynamic Inconsistencies: Counterfactual Implications of a Class of Rational Expectations Models." Federal Reserve Bank of Boston Working Paper 98-1.

Fisher, Paul G., S. K. Tanna, K. F. Wallis, and J. D. Whitley (1990). "Econometric Evaluation of the Exchange Rate in Models of the UK Economy." *The Economic Journal*, 100:1230–1244.

Fuhrer, Jeffrey C. (1997). "Inflation/Output Variance Trade-Offs and Optimal Monetary Policy." *Journal of Money, Credit, and Banking*, 29(2):214–234.

Fuhrer, Jeffrey C. and George R. Moore (1995). "Inflation Persistence." *Quarterly Journal of Economics*, 110:127–59.

Goodhart, Charles A. E. (1999). "Central Bankers and Uncertainty." *Bank of England Quarterly Bulletin*, pp. 102–114.

Holden, Steinar (1998). "Wage Setting under Different Monetary Regimes." Mimeo University of Oslo.

Kolsrud, Dag and Ragnar Nymoen (1998). "The Open Economy Wage-Price Spiral." *Journal of Economic Studies*, 25(6):450–467.

Leitemo, Kai (1999a). "Inflation Targeting Strategies in Small Open Economies." Working paper 21/99, Department of Economics, University of Oslo.

— (1999b). "Targeting Inflation by Constant-Interest-Rate Forecasts." Arbeidsnotat 13/99, Norges Bank.

Leitemo, Kai and Øistein Røisland (1999). "Choosing a Monetary Policy Rule: Effects on the Traded and Non-Traded Sectors." Working paper no 4/99, Department of Economics, University of Oslo.

Lucas, Robert E., Jr. (1976). "Econometric Policy Evaluation: A Critique." *Carnegie-Rochester Conference Series on Public Policy*, 1:19–46.

McCallum, Bennett T. and Edward Nelson (1997). "An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis." NBER Working Paper No. W5875.

Naug, Bjørn and Ragnar Nymoen (1996). "Pricing to Market in a Small Open Economy." *Scandinavian Journal of Economics*, 98(3):329–50.

Nymoen, Ragnar (1999). "Equilibirum Rates of Unemployment. Concepts and Nordic Evidence." Mimeo. University of Oslo.

Rotemberg, Julio J. and Michael Woodford (1999). "The Cyclical Behavior of Prices and Costs." In "Handbook of Macroeconomics," vol. 1B, chap. 16, pp. 1051–1135. Elsevier Science B.V.

Svensson, Lars E.O. (1997). "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review*, 41:1111–1146.

— (1999a). "Inflation Targeting: Some Extensions." *Scandinavian Journal of Economics*, 101(3):337–61.

— (1999b). "Monetary Policy Issues for the Eurosystem." *Carnegie-Rochester Conference Series on Public Policy*, 51-1:79–136.

— (1999c). "Price Stability as a Target for Monetary Policy: Defining and Maintaining Price Stability." In "The Monetary Transmission Process: Recent Developments and Lessons for Europe," MacMillan, London.

— (2000). "Open-Economy Inflation Targeting." *Journal of International Economics*, 50:155–183.

Svensson, Lars E.O. and Michael Woodford (1999). "Implementing Optimal Policy Through Inflation-Forecast Targeting." Working paper, Department of Economics, Princeton University.

Sveriges Riksbank (1999). *Inflation Report no. 3.* Sveriges Riksbank.

Taylor, John B. (1993). "Discretion versus Policy Rules in Practice." *Carnegie Rochester Conference Series on Public Policy*, 39(0):195–214.

— (1999). "Introduction." In John B. Taylor (ed.), "Monetary Policy Rules," pp. 1–14. The University of Chicago Press.

Woodford, Michael (2000). "Pitfalls of Forward-Looking Monetary Policy." Forthcoming, American Economic Review Papers and Proceedings, May 2000.

Kai Leitemo: Open-Economy Inflation Forecast Targeting

Arbeidsnotat/Working Paper 2000/2

KEYWORDS:

Inflation targeting
Forecast targeting
Monetary policy
Small open economy

20832