2000/11

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ISSN 0801-2504

ISBN 82-7553-160-8

The Performance of Inflation Forecast Feedback Rules in Small Open Economies*

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October 2000

Abstract

This paper examines the performance of inflation forecast feedback rules in a two-sector, calibrated model of the U.K. economy. Under such rules, the interest rate responds to the deviation of the unchanged-interest-rate forecast of inflation from the inflation target. We find that this procedure may produce a high degree of nominal and real stability, even outperforming the optimal discretionary (flexible) inflation targeting strategy. In order to take adequate account of the exchange rate channel, the feedback horizon will need to be short. A feedback horizon of a year or more creates exchange rate volatility, resulting in higher variability in inflation and traded sector output.

Keywords: Monetary policy, inflation targeting, inflation feedback rules, simple rules, small open economy.

JEL codes: E61, E47, E43.

*An earlier version of this paper entitled 'Inflation Targeting Strategies in Small Open Economies' was partly written during a visit to the Carnegie Mellon University and Bennett T. McCallum. I would like to thank McCallum for his encouragement and Carnegie Mellon for their hospitality. I would also like to thank Andrew G. Haldane, Steinar Holden, Ragnar Nymoen, Asbjørn Rødseth, Øistein Røisland, Øystein Stephansen and participants at seminars at the Department of Economics at the University of Oslo, Norges Bank, and participants at the session for inflation targeting at the EEA '99 conference for comments on earlier versions. I have benefited from adapted computer routines originally created by Paul Söderlind. Errors in this paper are entirely my own. Views and conclusions expressed are the responsibility of the author alone.

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1. Introduction

The arguably poor performance and robustness of fixed exchange rate systems and monetary targeting has resurrected the belief in more activist policy throughout the 1990s. Such activism is normally associated with the central bank's discretionary use of the interest rate in order to steer policy directly toward price stability, in the sense of low and stable inflation. Such a framework is often referred to as *inflation targeting*. Inflation targeting has been formally introduced in several countries, such as, New Zealand, Canada, Sweden, the United Kingdom and Australia, where the central banks have been made independent and given explicit targets for inflation.

The results of almost a decade of inflation targeting are starting to unfold. Although inflation targeting has generally been regarded as successful, most notably in bringing inflation down to an appropriate level, there are also challenges that remain partly unresolved. In particular, several inflation targeting countries, such as Sweden, the U.K. and New Zealand, have experienced periods of rather high real exchange rate fluctuations which influence manufacturing sector output and inflation volatility. In the U.K., a rather contractionary policy since 1997 has arguably led to real exchange rate appreciation, which has contributed to a strong contraction in the manufacturing sector. The Reserve Bank of New Zealand, which has practised inflation targeting since 1989, faced some of the same problems in 1992. At that time, a strongly appreciating currency caused difficulties for the monetary policymakers wanting to raise interest rates in order to head off increasing domestic inflationary pressure. During the last three years Sweden has experienced volatile imported goods prices caused partly by a fluctuating exchange rate, which has brought CPI inflation out of its tolerance band of $2 \pm 1\%$.

In view of this, a theory that provides a possible explanation for the connection between inflation targeting and real exchange rate variability, would be welcome. In this paper we explore one particular explanation, related to how inflation targeting is being implemented. In particular, we will argue that the choice of the forecast horizon may play an important role in explaining real exchange rate variability. Existing theoretical frameworks used in evaluating inflation targeting do not lead us to expect excessive real exchange rate variability (see, e.g., Svensson, 2000a; Leitemo and Røisland, 2000), although Leitemo (2000) provides an alternative, but related, explanation to the one presented here.

This paper argues, as in Svensson (1999a), that the gap between the forecast of inflation at some horizon contingent on an unchanged nominal interest rate and the inflation target, may be a good indicator for the appropriate monetary policy stance. The appropriateness of an indicator is defined here by its performance when used as an argument in the reaction function of the monetary policymaker. The present paper examines the performance of such a forecast feedback rule in a model of an open economy. It thus extends the analysis in Rudebusch and Svensson (1999) for the closed economy by introducing additional monetary policy channels that is important to the open economy and argues that the conclusions, and hence the policy recommendations, are changed in important ways.

The analysis is carried out in an extended version of a model developed by Batini and Haldane (1999). Their model is calibrated to the U.K. economy and used as a forecasting tool at the Bank of England (1999). Our model is extended in several ways, the most important change being the addition of a traded, competitive sector. Within a two-sector framework, it is possible to gain additional insight into how inflation targeting exploits the different transmission channels of monetary policy to achieve the inflation target. In particular, this framework may address issues connected to how the burden of adjustment is shared between the sectors.

The outline for the rest of the paper is as follows: section 2 discusses the general characteristics of inflation targeting and the intuition behind forecast feedback rules. Section 3 presents a quarterly, two-sectoral model of a small open economy in an environment of near-perfect capital mobility. Section 4 presents the simulation results from using forecast-feedback rules in the model and discusses the best choice of the feedback horizon. Moreover, some structural conditions for the successful targeting of inflation are discussed. Finally, section 5 provides a conclusion.

2. The monetary policy framework

In several papers, Svensson (1997, 1999b, 2000a) defines *strict inflation targeting* as a monetary policy strategy that discretionarily uses all available information in minimising the unconditional variance of inflation around a given target level. *Flexible* inflation targeting means that the central bank also targets other variables, such as output, although to a lesser degree, by minimising a weighted average of the unconditional variances of the target variables. Assuming that the central bank targets output and the change in the interest rate in addition to the inflation rate itself, the period loss function is given by

$$L_t^{cb} = (\tilde{\pi}_t^c - \tilde{\pi}^{c*})^2 + \lambda_y^{cb} y_t^2 + \lambda_{\Delta i}^{cb} (\Delta i_t)^2, \tag{2.1}$$

where $\tilde{\pi}^c$ is the four-quarter consumer price (CPI) inflation rate; $\tilde{\pi}^{c*}$ is the inflation target; y is the output gap, that is, the percentage deviation of actual output from the natural rate; Δi is the quarterly change in the short-term interest rate, considered to be the policy instrument; λ_y^{cb} and $\lambda_{\Delta i}^{cb}$ are the relative weights attached by the monetary policymaker to output stabilisation and interest rate smoothing arguments respectively. The central bank's problem is then intertemporally to minimise its expected loss, i.e.,

$$\min_{\{i_{t+j}\}_{j=0}^{\infty}} E_t \sum_{s=t}^{\infty} L_s^{cb}, \tag{2.2}$$

subject to its understanding of the monetary policy transmission mechanism.

Although this definition of targeting has attractive theoretical properties, not least from an optimal control perspective, the practical implementation of policy using such a procedure may present several problems. First, there is little consensus on how the economy works. Two different descriptions of the economy may lead to mutually inconsistent policy recommendations. Indeed, optimal policy in a given model may produce a disastrous outcome in another. Another problem posed by optimal control is that, given that our models only uses a (small) portion of available information, incorporating information that is external to the model in the policy decisions may be of considerable interest. In practice, however, such information is difficult to formalise. Integrating it with information provided by formal models, and exploiting it, may be difficult. A third problem is related to the presence of forward-looking behaviour in the model. The optimal policy with forward-looking behaviour is in most circumstances time-inconsistent. That is, the policy requires an appropriate commitment today about policy tomorrow in order to influence agents expectations, so as to get the best possible trade-off between policy targets both across and within periods.[1] Since the central bank is normally assumed not to possess such commitment technology, optimal policy is narrowed down to the set of time-consistent discretionary policies, which, if forward-looking behaviour is central in the transmission mechanism, may well be far less favourable than the commitment solution.

Given these problems of practical implementation of optimal control in a discretionary setting, there has been a focus on achieving the goals of monetary policy through simpler and more transparent procedures. Indeed, an alternative way of defining inflation targeting is by the requirement that the instruments of the central bank should respond to measures of inflation (forecast) deviation from the target level.[2] In order to keep these two definitions separate, we follow Batini and Nelson (2000) in denoting the alternative definition of inflation targeting *inflation forecast feedback rules* as opposed to the optimal discretionary inflation targeting rule defined by (2.1). A representation of a feedback rule may be

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\beta_\pi \left[\tilde{\pi}^c_{t+h|t} - \tilde{\pi}^{c*}\right], \tag{2.3}$$

where notation from here follows $x_{t+h|t} = E_t x_{t+h}$. The interest rate (as deviation from the equilibrium rate) responds to the h quarter forecast of CPI inflation, ($\tilde{\pi}^c_{t+h|t}$). h is denoted the *forecast feedback horizon*. The forecast feedback horizon should not be mixed

[1]See Svensson and Woodford (1999) for a more detailed treatment.

[2]There is an ongoing debate regarding the appropriateness of this alternative definition. Svensson (2000b, p.1-2) notes:

> "[Inflation targeting means] that all relevant information is used in conducting monetary policy. It also implies that there is no explicit instrument rule, that is, the current instrument setting is not a prescribed explicit function of current information. Nevertheless, the procedure results in an endogenous reaction function, which expresses the instrument as a function of the relevant information. ...it will depend on....anything affecting the central bank's conditional inflation forecast... Furthermore, the reaction function is generally not only a function of the gap between the inflation forecast....and the inflation target. In the literature, "targeting" .. are frequently associated with a particular information restriction for the reaction function, namely that the instrument must only depend on the gap between the ... target variable and the target level (and lags of this gap). I find this information restriction rather unwarranted."

McCallum and Nelson (2000, Appendix A, p. 36-37), on the other hand, have a different opinion:

> "Svensson's basic criticism of traditional terminology is as follows. A rule that responds to deviations of [inflation] does not constitute targeting because 'to target [inflation]', means 'using all relevant information to bring [inflation] in line with the target path'. ... And in typical cases, optimal instrument rules will entail responses to other variables in addition to [inflation]. But here 'optimal' actually means optimal with respect to one particular objective function and one particular model of the economy. But the point of a simple rule such as $i_t = \mu_0 + \mu_1(\pi_t - \pi^*) + \mu i_{t-1}$ is that with $\mu_1 > 1 - \mu_3$ it will call for i_t adjustments that will keep π_t close to its target value π^*, without being dependent upon any particular objective function or model. ..... A second reason for retaining the traditional language is that it corresponds more closely, in our judgement, to actual practice of 'inflation targeting' as represented by the central banks of Canada, New Zealand, and the United Kingdom."

with the target horizon, i.e., the expected duration before inflation has returned to its target level (see Batini and Nelson, 2000).[3]

The idea behind (2.3) is simple: set a high (low) nominal interest rate if the inflation forecast is above (below) target, and increase (decrease) the interest rate in the next period if the forecast remains above (below) target.

There is, however, a problem with the forecast-based approach. If the horizon employed in producing the inflation forecast is longer than the control lag of the policy instrument, the forecast depends not only on the present stance of policy, but also on the future policy stance. There is hence a need for conditioning the forecast on a particular policy over the forecast horizon. One way to proceed is to condition on the expected policy, i.e., produce a rule-consistent forecast. This is the approach followed by Batini and Haldane (1999), Batini and Nelson (2000) and Levin et al. (1999a,b). In this way, the strategy is self-referential. The forecast is based upon the specific rule and the rule is based on the forecast. Such a rule is an equilibrium condition between the interest rate and the inflation forecast. Such equilibrium conditions will depend on the *specific* model and cannot easily incorporate information that is external to the model efficiently. In that respect, it is hampered by some of the same problems as the model-dependent optimal strategy. Svensson (1999a) argues that the forecast should be based upon an unchanged interest rate, and that the deviation between the forecast and the target is the appropriate indicator for inflationary pressure. He also argues that it may be easier to incorporate outside-of-the-model information under such a procedure. The reason being that such information may take the form of the policymakers' intuition regarding non-modelled factors that influence the forecast of inflation, given that the policy stance remains unchanged.[4] Rudebusch and Svensson (1999) examine interest rate rules where the interest rate reacts to the unchanged interest rate forecast of inflation in a backward-looking model of the U.S. economy and find that it performs close to the optimal policy.

[3]These two horizon concepts will only coincide when the length of the horizons is of such a magnitude that inflation will have returned to the equilibrium rate of inflation without any reactions by the monetary authority to disequilibrium states, i.e., the interest rate is kept constant at its equilibrium value. In this case, $\pi_{t+h|t} = \pi^* = \pi^e$, and $i_t = i^e = r^e + \pi^e$, where superscript 'e' denotes an equilibrium value and r is the short-term real interest rate.

[4]Leitemo (1999b) develops a method for calculating the rational expectations equilibrium under the assumption of a constant interest rate in the forecast period.

Equation (2.3) may be reformulated along these lines to

$$i_t = \rho i_{t-1} + (1-\rho_i)\beta_\pi \left[\tilde{\pi}^c(\bar{i}_{t-1})_{t+h|t} - \tilde{\pi}^{c*}\right], \tag{2.4}$$

where $\tilde{\pi}(\bar{i}_{t-1})_{t+h|t}$ is the four-quarter CPI inflation forecast contingent on a unchanged interest rate in the forecast period. Equation (2.4) can be denoted by a *constant-interest-rate inflation forecast feedback rule*, or CIIF rule, for short.

With respect to the practical relevance of such rules, we note that both the Bank of England and Sveriges Riksbank publish inflation forecasts based upon an unchanged interest rate in the forecast period, and discusses policy in relation to them. Sveriges Riksbank (1999) *Inflation Report* 3/99, p.58 states:[5]

> 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.

There could thus be reasons to believe that CIIF rules approximate how inflation targeting is carried out in practice.[6] In the remainder of the paper, we shall consider how such rules may perform in an open economy setting. In particular, we want to inquire whether such a procedure may explain some of the (excessive) exchange rate movements experienced in these economies.

3. The model

In order to study the implications of inflation forecast responding in a small open economy, we present a quarterly, 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). Our model is similar to the one presented in Leitemo (1999a, 2000), and the description of the model closely follows the presentation given

[5] Jansson and Vredin (2000) discuss Sveriges Riksbank monetary policy of inflation targeting in relation to CIIF rules.

[6] An alternative interpretation is offered in Leitemo (2000), where I study the effects of setting the interest rate so as to have the constant-interest-rate forecast of inflation equal to target at some given horizon.

there. The model is not explicitly based on optimising behaviour, although it contains several elements that are likely to be found in such models, e.g., forward-looking behaviour, demand is partly determined by intertemporal substitution effects and hence the long-term real interest rate, and production in the traded sector is based upon profit maximisation in the sense that the inverse of the producer real wage determines output on the international, competitive market.

The differences between BH's model and our model can be summarised in four points:

- Our model incorporates a competitive, internationally traded goods sector.
- In addition to pressure in the labour market, wage determination is influenced by the capital income share in the traded sector, as supported by empirical evidence.[7]
- Demand for non-traded goods is partly determined by the long-term real interest rate.
- The empirical evidence in support of the sluggish adjustment of import prices to exchange rate changes is captured in an equilibrium correction mechanism.[8]

We consider a two-sector framework for several reasons. A central objective of monetary policy may be to keep adjustment costs caused by nominal and transitory shocks low. Stabilisation of output may therefore be an important goal of monetary policy, in addition to price stability. However, aggregate output fluctuations will not in general suffice as a measure of adjustment costs. One reason for this is that sectoral fluctuations may cancel out at the aggregate level. Assume, for instance, that one sector contracts when the another sector expands; then the variability of aggregate output will conceal the extent to which the economy is exposed to adjustment.[9] A one-sector framework may thus be too restrictive as a device for studying these potentially important issues. This argument is strongly reinforced if monetary policy works through different channels which have asymmetrical effects upon each sector. A fundamental difference may be between that of the traded and the non-traded sectors. While the internationally traded sector is considerably exposed to the exchange rate channels of monetary policy, the non-traded

[7] See Bårdsen and Fisher (1999) for an empirical model of U.K. wage- and price-setting.

[8] For evidence, see, e.g., Naug and Nymoen (1996) and Dwyer et al. (1994).

[9] Assume, for instance, that one sector is hit by a positive demand shock, which may imply a tightening of policy, leading to contraction in all sectors. Then aggregate output would conceal much of the adjustment taking place.

sector is probably more exposed to the domestic interest rate channel. This means that monetary policy is likely to affect these sectors very differently and be a source of sectoral fluctuations.[10] We therefore believe that monetary policy analysis in small open economies may benefit from using two-sector frameworks which will enhance our understanding of how monetary policy is transmitted and how the burden of adjustment is shared between the sectors of the economy.

The core of the model is a traditional open-economy AD/AS model with forward-looking agents. Monetary policy influences demand for non-traded sector goods by setting the short-term interest rate and thereby expectations about its future movements, as well as by affecting the relative price of non-traded in terms of traded goods. Nominal rigidities are introduced through overlapping wage contracting, enabling monetary policy to influence 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. Moreover, there is sluggish adjustment of imported goods prices to exchange rate movements due, e.g., to the existence of price contracts of some length in the import sector.

All variables, except interest rates,[11] are measured as logarithmic deviations from their (possibly time-varying) long-run equilibrium values, which are assumed to be independent

[10] Another argument for focusing on sectoral stability rather than aggregate stability is if adjustment costs differ across the sectors. If a given change in output in one of the sectors is achieved at a higher cost than a change in other sectors, it makes sense to stabilise the first sector to a larger degree.

[11] The interest rates we exploit the fact that $\ln(1+i_t) \approx i_t$, where i_t is measured as a deviation from its equilibrium value.

of monetary policy.[12] The model is summarised by the following equations:

$$y_{t+1}^T = \rho_T y_t^T + \beta \sum_{s=0}^{\infty} \delta^s (p_{t+1+s|t}^T - w_{t+1+s|t}) + u_{t+1}^T \quad (3.1)$$

$$y_{t+1}^N = \rho_N y_t^N - \alpha(\omega R_t + (1-\omega) r_t) + \kappa(p_t^T - p_t) + u_{t+1}^N \quad (3.2)$$

$$y_t = \eta y_t^T + (1-\eta) y_t^N \quad (3.3)$$

$$\begin{aligned} x_t - p_t^c &= (1-\phi)(x_{t-1} - p_{t-1}^c) + \phi(x_{t+1|t} - p_{t+1|t}^c) + (1-\phi)\gamma y_t + \\ &\quad \phi\gamma y_{t+1|t} - (1-\phi)\mu(w - p^T)_t - \phi\mu(w - p^T)_{t+1|t} + u_t^w \end{aligned} \quad (3.4)$$

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

$$p_t = w_t \quad (3.6)$$

$$p_t^T = s_t + p_t^* \quad (3.7)$$

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

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

$$q_t = q_{t+1|t} - .25(r_t - r_t^f) \quad (3.10)$$

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

$$r_{t+1}^f = \rho_{rf} r_t^f + u_{t+1}^{rf} \quad (3.12)$$

$$R_t = \frac{1}{\tau} \sum_{s=t}^{t+\tau} r_{s|t} \quad (3.13)$$

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 inverse of the producer real wage ($p^T - w$). 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 introduces 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

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

discount information about the future expected producer real wages. Higher adjustment 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. Higher costs of producing (reliable) 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 (3.1) and using the lead operator,[13] expected production can 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 in the form $(1-\rho_T L)(1-\delta F)y_{t+1|t} = \beta(p^T_{t+1|t} - w_{t+1|t})$. Since production is predetermined one period in advance, traded sector output can be expressed conveniently as

$$y^T_{t+1} = \frac{\rho_T}{1+\delta\rho_T} y^T_t + \frac{\delta}{1+\delta\rho_T} y^T_{t+2|t} + \frac{\beta}{1+\delta\rho_T}(p^T_{t+1|t} - w_{t+1|t}) + u^T_{t+1}, \qquad (3.14)$$

where u^T represents a stochastic supply, white noise shock.

Whereas production in the traded sector is determined by product real wages, we assume that the non-traded sector operates in a market of monopolistic competition, and aggregate sector output $\left(y^N_t\right)$ is restricted by demand. Demand for non-traded products is given by (3.2). Due to intertemporal substitution effects on consumer decisions, and intratemporal substitution effects between non-traded and traded goods, demand and hence production of non-traded products may deviate from their long-run equilibrium level. As McCallum and Nelson (1999b) show in an optimising model, demand is driven by expected future short-term real interest rates (r_t) through an Euler equation relationship. According to the expectations hypothesis of the term structure of interest rates, the long-term real interest rate is equal to the average of the expected future path of the short-term real interest rate. In this paper we adopt the position that demand directed towards the non-traded sector is affected by both the long (R_t) and the short real interest rate,[14] as expressed in (3.2). There is a degree of habit-persistence, as demand is assumed to evolve

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

[14] 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.

gradually to the level determined by the interest rates and the sector price differentials. In the long-run, non-traded sector output is determined by equilibrium income. u^N_{t+1} 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.

The clear separation of the traded and non-traded sectors in this paper is an abstraction. In reality, we would expect that firms to exercise varying degrees of market power, depending on the properties of their specific products and history. The clear distinction offered here, however, is made in order to highlight the fact that monetary policy may affect the firms differently, depending on the degree of (international) competition.

Wages are determined according to the overlapping contracting framework of Fuhrer and Moore (1995) and Fuhrer (1997a), but extended along the lines of Blake and Westaway (1996) in order to adapt the framework to an open economy. In this framework multiple (in this paper two) overlapping wage contracts exist at all times and are renegotiated every other period. Agents are concerned with their expected contract real wage not deviating too much from that of the other contract wage negotiated in the previous period, on the one hand, and the expected contract real wage negotiated in the next period, on the other. The forcing variables are pressure in the labour market, represented by the output gap, and capital share of income in the traded sector, proxied by the inverse of the producer real wage. The last factor is not present in the standard formulation of the Fuhrer-Moore staggered contract model. However, both theory and empirical evidence for small open economies suggest that the capital share of income has an effect upon wage determination.[15] Bargaining theory tends to suggest that the outcome of the wage bargaining process is related to the cost employers would face in the case of a conflict and strike. These costs would typically be positively related to capital share of income. Hence, this argument implies a separate role for capital share of income as an argument in wage determination. This argument would be reinforced by any leadership role of the traded sector in wage determination.

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 producer real wage is denoted by $w - p^T$. Because the average contract lasts for two periods, the aggregate wage level (w_t) is the average of existing contract wages as

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

described in equation (3.5).

Given our assumption of monopolistic competition in the non-traded sector, prices are set as a mark-up on wages, as in equation (3.6). The existence of adjustment costs in non-traded sector production would affect the mark-up level. However, given the mixed evidence on the cyclicality of mark-ups,[16] it is for simplicity considered to be constant and unrelated to the transmission mechanism of monetary policy. Purchasing power parity holds[17] (on average) for traded sector products 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 $p_t^T = q_t + p_t$ where $q_t \equiv p_t^* + s_t - p_t$ 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 imported goods, p^{im}. As several empirical studies indicate,[18] there is sluggish adjustment of imported goods prices to exchange rate shocks. This can be explained by the existence of price contracts, or a more informal understanding between the importer and the exporter to smooth adjustment in prices in order not to lose consumer confidence. For this reason, we choose to model 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 and p_t^T is given by equation (3.7). Alignment of imported goods prices with the international price level (measured in domestic currency units) is assumed to be an intermediate-run phenomenon. By taking differences and adding a disturbance term, we arrive at the expression 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). However, we allow the economy to be subject to persistent risk premium and foreign interest rate shocks. In accordance with this, we assume that the risk-premium corrected foreign real interest rate (r_t^f), i.e., the interest rate that is required to produce expectations of 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

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

[17] The crucial assumption affecting our conclusions is not whether PPP holds constantly for traded sector goods, but that any deviations from PPP are unrelated to the monetary policy behaviour.

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

the Fisher identity in (3.11).

We follow Svensson (2000a) in assuming that the long real interest rate (R_t) is determined according to the expectations hypothesis, as stated in (3.13), with time to maturity, $\tau = 40$ (quarters).[19] Since the foreign short-term real interest rate is modelled as an AR(1) process, the foreign long-term interest rate (R_t^f) would be approximately

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

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

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

where the real exchange rate is given by the infinite sum of expected future foreign and domestic short-term real interest rates. By combining this expression with the expressions for long-term real interest rates, we can write the long-term interest rate as a function of its foreign equivalent and the real exchange rate

$$R_t = R_t^f - \frac{4}{\tau} q_t. \tag{3.16}$$

Table 3.1 shows the benchmark parameter values used when evaluating the CIIF rules. None of the parameters seem implausible and should correspond to the values given by work on similar models, most notably Batini and Haldane (1999). A detailed account of the calibration is given in Appendix A, however.

4. Policy evaluation

The above model leaves the short-term nominal interest rate as an exogenous policy variable. The nominal interest rate is endogenised according to the interest rate implications of (2.4). The performance of (2.4) can be examined along three dimensions, by studying different values of the feedback coefficient (β_π), the feedback horizon (h) and the persistence or smoothing parameter (ρ_i). To restrict the scope of the paper, we address only

[19] When simulating the model, we set $\tau = \infty$. The error made in doing so is negligible.

Table 3.1
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	β_π	$1.5, 5.0, 10.0$
ω	0.70	ρ_i	0.50
η	0.25	h	$0-8$
ϵ	0.20	**Labour market**	
c	0.50	ϕ	0.20
κ	0.5	γ	0.20
		μ	0.09

two of these dimensions: choice of horizon and feedback coefficient, and set the smoothing parameter to $\rho_i = 0.5$. Since monetary policy, by construction, is assumed not to affect the unconditional expectations of the real variables in the model and there is a given inflation target level, macroeconomic performance is measured by the unconditional standard deviation of variables. In order to rank the different outcomes, we need to decide on a loss function that reflects social welfare in a reasonable way. Following Rudebusch (1999), Svensson (2000a), McCallum (1999) among others, we explore a quadratic approximation of the underlying social loss function

$$L(\lambda_y, \lambda_{\Delta i}) = E_t \sum_{s=0}^{\infty} L_s, \tag{4.1}$$

where the periodic loss function is given by

$$L_s = \left(\tilde{\pi}^c_{t+s} - \tilde{\pi}^{c*}\right)^2 + \lambda_y y^2_{t+s} + \lambda_{\Delta i}(\Delta i_{t+s})^2. \tag{4.2}$$

We use $\lambda_y = 1$ and $\lambda_{\Delta i} = \frac{1}{2}$ as benchmark parameter values, assuming society values inflation and aggregate output stability equally, and, moreover, dislikes large interest rate adjustments, for example for reasons related to financial stability.

4.1. Analyzing policy

Table 4.1 shows the unconditional standard deviations in percentages of some central variables for different policy rules.

Table 4.1
Losses and unconditional standard deviations. Per cent.

β_π	π^c	y	y^N	y^T	q	Δi	$L^S(1,1,\frac{1}{2})$
Commitment optimum $L^{cb}(1,1,\frac{1}{2})$							
-	0.9	0.9	1.0	2.2	2.3	2.3	7.6
Discretionary optimum $L^{cb}(1,1,\frac{1}{2})$							
-	1.1	0.8	0.8	1.8	3.4	3.6	14.8
Constant-interest-rate inflation forecast responding rules							
Feedback horizon = 0							
1.5	1.5	0.9	0.9	2.7	4.6	2.4	16.0
5.0	1.0	0.9	1.0	2.1	3.9	4.7	15.3
10.0	0.9	0.9	1.2	2.1	3.8	7.1	27.4
Feedback horizon = 1							
1.5	1.4	0.9	0.8	2.4	4.3	2.4	17.4
5.0	**0.8**	**0.8**	**1.0**	**1.8**	**3.3**	**4.2**	**12.4**
10.0	0.7	0.9	1.2	1.9	3.1	5.8	18.7
Feedback horizon = 2							
1.5	1.6	0.9	0.7	2.4	4.3	3.0	27.4
5.0	0.8	0.8	1.0	1.6	2.9	5.4	13.0
10.0	0.5	0.8	1.3	1.8	2.4	12.8	83.6
Feedback horizon = 3							
1.5	2.4	0.8	0.6	2.1	3.9	16.5	215.0
5.0	1.1	0.7	1.1	4.7	3.1	1.2	13.0
10.0	1.2	0.6	1.1	4.6	3.2	1.0	14.3
Feedback horizon = 4							
1.5	4.0	1.9	2.0	8.0	9.6	1.5	149.0
5.0	4.4	2.1	2.2	8.7	10.4	1.5	181.0
10.0	4.5	2.1	2.3	8.9	10.5	1.5	188.4
Feedback horizon = 5							
1.5	16.1	7.6	8.8	31.8	32.4	0.9	2807.0
5.0	18.0	8.5	9.9	35.6	36.0	1.0	3517.0
10.0	18.4	8.7	10.2	36.5	36.8	1.0	3699.3
Feedback horizon = 6							
1.5	5.7	3.3	3.5	12.0	10.0	0.06	390.0
5.0	5.7	3.2	3.5	11.9	9.9	0.06	381.9
10.0	5.6	3.2	3.5	11.8	9.9	0.06	380.2
Feedback horizon = 7							
1.5	2.4	1.6	1.4	5.2	4.8	0.01	59.6
5.0	2.4	1.6	1.4	5.2	4.8	0.01	59.5
10.0	2.4	1.6	1.4	5.2	4.8	0.01	59.5
Feedback horizon = 8							
1.5	2.2	1.3	1.0	4.6	5.4	0.00	43.1
5.0	2.2	1.3	1.0	4.6	5.4	0.00	43.1
10.0	2.2	1.3	1.0	4.6	5.4	0.00	43.1

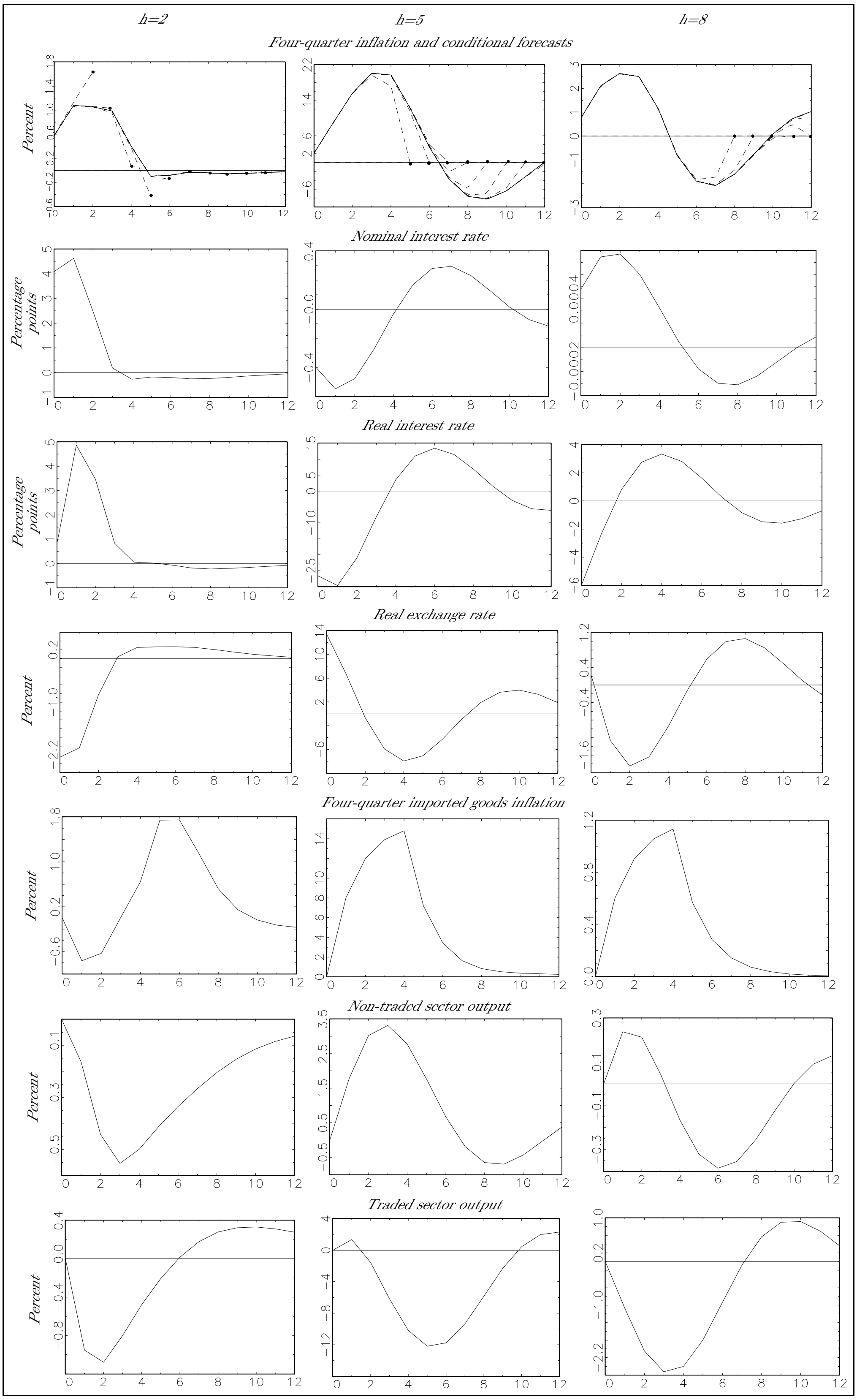
The first two rows show the outcome of optimal monetary policy. The *commitment* solution, where the monetary policymaker possesses an ability to commit to a particular strategy in a credible way, represents the overall optimal policy under the loss function in (4.1). Such a policy is time-inconsistent, as the policymaker faces advantages in breaking the promise inherent in the commitment in subsequent periods. By requiring the policies to be time-consistent, the best outcome is the discretionary optimal policy. This policy is the outcome of a Stackelberg game between the central bank and the agents of the economy. The central bank act as leader and chooses the best policy reaction, given that the agents subsequently play rational expectations.[20] In our case, both policies represent a basis of comparison for the performance of CIIF rules. We note that the commitment optimum is far better than the discretionary optimum, with only half the loss. The advantages are manifested in both smoother interest rate movements and marginally lower inflation variability. This suggests that the forward-looking structure may potentially play an important role in the monetary transmission mechanism.

The CIIF rules perform best with a relatively short feedback horizon of one to two quarters with a relatively strong feedback coefficient of $\beta_\pi = 5$. The CIIF rule is then outperforming the discretionary optimal policy by producing less inflation variability and about the same degree of aggregate output volatility. Policy is, however, somewhat more volatile, as the degree of interest rate smoothing is lower. At the shortest horizons, an increase in the feedback coefficient results in the reduction of inflation variability at the cost of stronger movements in the interest rate. There is almost no effect on aggregate output variability. However, there are interesting sectoral differences that will be discussed below.

There is a distinct hump-shaped pattern in the standard deviations of all variables as the feedback horizon increases. Whereas standard deviations of most variables are relatively low for horizons of up to three quarters, the standard deviations of the variables rise quickly and reach a very high degree of variability at a horizon of five quarters. Beyond five quarters, variability drops significantly but without reaching the level of variability obtained for the shortest feedback horizons. We note that this pattern is independent of the size of the feedback coefficient. In order to understand the reason behind this phenomenon, it is helpful to study the impulse responses to different shocks. Figures 4.1 and 4.2 show the impulse responses of some important variables to cost-push and non-traded (domestic demand) shocks respectively. It turns out that we can classify the different feedback horizons between zero and eight quarters into three categories depending on general characteristics: short-run, intermediate-run and "long"-run, represented in the figures by feedback horizons of $h = 2$, $h = 5$ and $h = 8$ quarters, respectively.

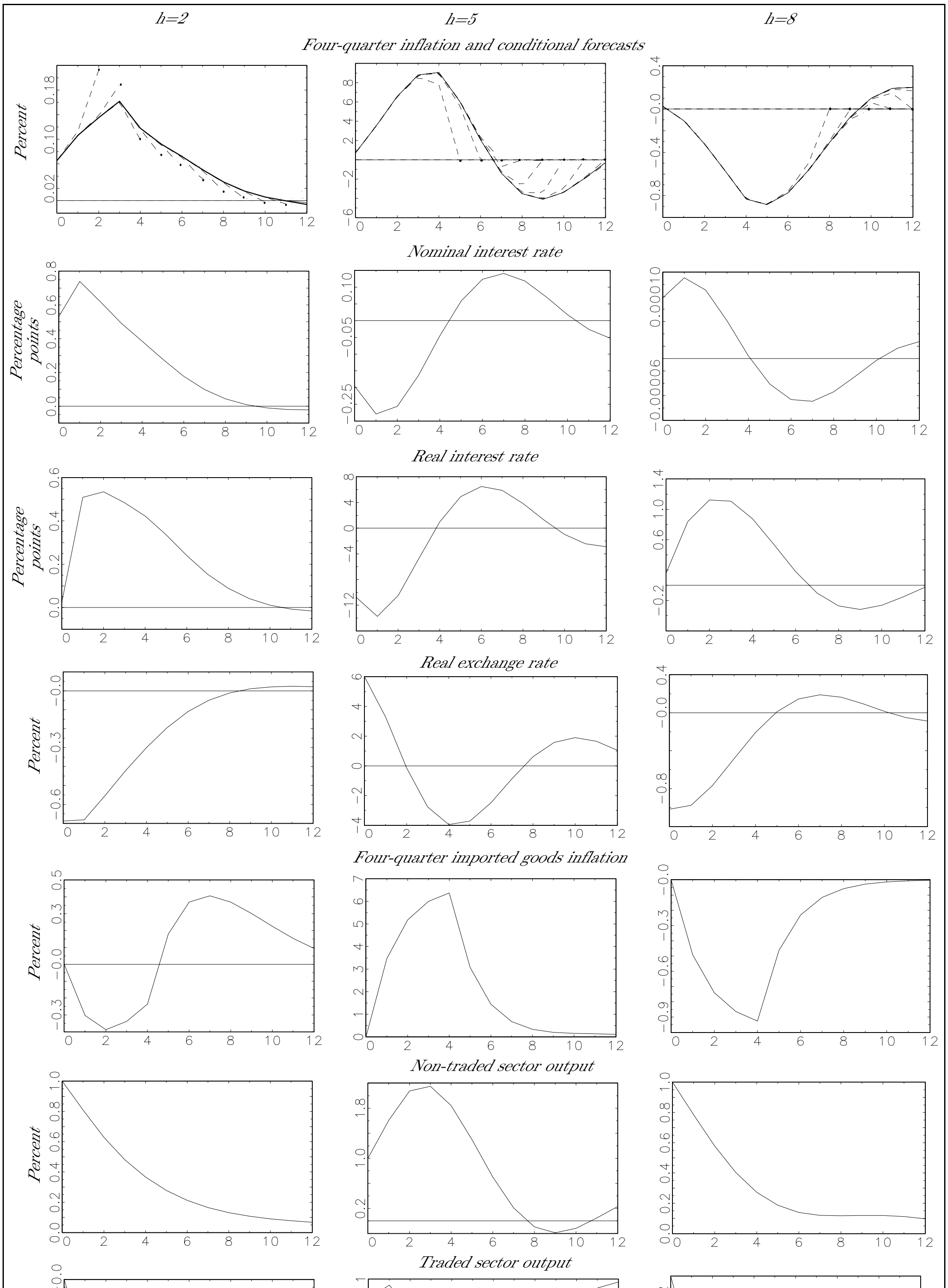
[20] A technical description of optimal policies under different assumptions about commitment technology is given in Backus and Driffill (1986).

Figure 4.1



Quarterly impulse responses due to a one per cent transitory cost-push shock for feedback horizons of $h = 2, 5$ and 8. Note different scales in the figures. $\beta_\pi = 5$.

Figure 4.2



Quarterly impulse responses due to a one per cent transitory non-traded demand shock for feedback horizons of $h = 2, 5$ and 8. Note different scales in the figures. $\beta_\pi = 5$.

The first row of Figures 4.1 and 4.2 shows the response to four-quarter inflation, and, as dashed lines, the conditional, unchanged-interest-rate forecasts of inflation made in each quarter for the respective feedback horizons.

Consider first the case of a short feedback horizon, $h = 2$. Under both types of shocks, the two-quarter inflation forecasts immediately increase above the target level and the nominal interest rate is increased. The rise is stronger than the increase in inflation expectations and hence the real interest rate increases. The rise produces an immediate nominal and real exchange rate appreciation, followed by a gradual real exchange rate depreciation. The contractionary response of policy produces a decline in output in both the traded and non-traded sectors, with maximum impact after two to four quarters. With this short feedback horizon, there is a strong response to a cost-push shock as the nominal interest rate increases immediately by four percentage points. As cost-push shocks feed directly into a relatively persistent inflation process, such shocks will have a relatively strong and long-lasting effect on inflation, given that monetary policy remains passive. However, as policy reacts to the increase in the inflation forecast, it produces strong monetary policy contractions for just the same reason.

The dynamic responses become very different when the feedback horizon is extended to five quarters. In this case, inflation is almost out of control. The five-quarter unchanged-interest-rate forecast now shows a slight *undershooting* of the target level. If monetary policy remains passive, keeping interest rates unchanged, by the end of the horizon inflation will have produced a real appreciation that has reduced labour market pressure and the capital share of income. Both of these effects contribute to disinflation, bringing the inflation rate below the target. The monetary policy response is to *lower* the nominal interest rate in order to avoid this undershooting. As the inflation rate increases, the real interest rate drops even further and policy becomes even more expansionary, resulting in strong oscillations in all variables. Equilibrium is eventually achieved through excessive movements in the real exchange rate, driven by large movements in the rate of inflation.

With a feedback horizon of eight quarters, we see some of the same type of adjustments taking place. The case of a cost-push shock, the unchanged-interest-rate forecast of inflation at this horizon, is slightly above the target level. The proximity of the forecast to the target follows essentially from the same mechanisms described above. At this horizon, however, inflation would have remained below target for a while, creating a real depreciation which is contributing to an increase in inflation at the end of the forecast feedback horizon. Owing to the overshooting of the target, the nominal interest rate increases, but only modestly, not substantially affecting the mechanisms for achieving equilibrium. In the case of a non-traded demand shock, there is a nominal exchange rate appreciation which completely offsets the increase in labour market pressures caused by the shock. Inflation falls, supported by a decline in imported goods price inflation.

As is evident from the impulse responses, the nominal interest rate responds only modestly to shocks when a longer forecast feedback horizon is used. It is, however, interesting to note that according to the uncovered interest rate condition, the nominal exchange rate responds immediately, not only to expected future interest rate differentials, but also to shocks that (given the monetary policy regime) influence the expected long-run differential between domestic and foreign price levels. The nominal version of the uncovered real interest rate parity condition, in (3.10), is given by

$$s_t = s_{t+1|t} - i_t + i_t^*.$$

By forward substitution, the nominal exchange rate may be expressed as

$$\begin{aligned} s_t &= \sum_{s=0}^{\infty} \left(i_{t+s|t}^* - i_{t+s|t} \right) + \lim_{j \to \infty} s_{t+j|t} \\ &= \sum_{s=0}^{\infty} \left(i_{t+s|t}^* - i_{t+s|t} \right) + \lim_{j \to \infty} \left(p_{t+j|t} - p_{t+j|t}^* \right), \end{aligned}$$

where we have used $e \equiv s + p^* - p$ and $\lim_{j \to \infty} e_{t+j|t} = 0$. Exchange rate movements that reflect a change in the long-run price differential, $\lim_{j \to \infty} \left(p_{t+j|t} - p_{t+j|t}^* \right)$ have a transitory effect upon CPI inflation through imported goods price inflation. If the feedback horizon is sufficiently long, these effects on inflation may have petered out by the end of the forecast feedback horizon. Hence, there are no monetary policy responses to these effects, and monetary policy has an accommodating stance, thus letting such shocks have effects on the long-run price differentials. There may therefore be strong movements in the nominal exchange rate even though the interest rate differentials may be modest, as is the case when the feedback horizon is fairly long. This explains why imported goods inflation, in spite of a high degree of interest rate stability, is rather volatile at longer feedback horizons.

These examples show the important role the exchange rate channel plays in the model. A longer forecast horizon tends to make interest rate policy more passive and the exchange rate channel "takes over" as an important means of achieving equilibrium. The choice of a forecast feedback horizon influences heavily what role each sector plays in the monetary transmission mechanism.

It is also interesting to note that the Bank of England since 1997 has published eight-quarter inflation forecasts (conditional on an unchanged interest rate) in the Bank's quarterly Inflation Reports which all show that the forecast at the end of the horizon is approximately on target. This is consistent with using CIIF rules with a fairly long forecast feedback horizon in our model, as can be seen from the conditional forecasts of inflation in the above figures.

4.2. Sectoral differences

The traded sector is consistently more volatile than the non-traded sector. This partly reflects the fact that the variance of the structural shock hitting the traded sector is about twice the size of the shocks hitting the non-traded sector.[21] However, not all of the differences can be attributed to structural shocks, as the propagation mechanisms vary considerably with the length of the horizon and on the size of the feedback coefficient, as seen from Table 4.1. As discussed in the section above, when the horizon is sufficiently long, the exchange rate channel is the dominant equilibrium-correcting mechanism of monetary policy. Since the traded sector is the sector most exposed to this channel, it would also fluctuate the most under a longer feedback horizon.

A high feedback coefficient produces stronger real interest rate reactions to the determinants of future inflation. As the real interest rate mainly affects the non-traded sector, a high feedback coefficient produces stronger fluctuations in this sector for feedback horizons of up to five quarters. For horizons between six and eight quarters, there is no such effect, as inflation would be close to its target level anyway.

There is a similar, but reverse, tendency for the traded sector. As the exchange rate reacts to expectations of future interest rate differentials, it is not so much the short term interest rate movements that affect the exchange rate and hence output decisions

[21] As seen from Table A.1 in Appendix A, non-traded demand shocks has a standard deviations (in percent) of .29 and traded sector shocks has a standard deviations of .43.

in the traded sector, as persistent interest rate deviations from the foreign exchange rate. This is thus an argument for using a high feedback coefficient for reducing traded sector output volatility. At the shorter horizons, a high feedback coefficient produces a more stable traded sector. However, this reasoning does not hold when the feedback horizon is extended beyond two quarters, as a higher feedback coefficient then exacerbates interest rate differentials and hence exchange rate and traded sector output variability.

4.3. Structural considerations

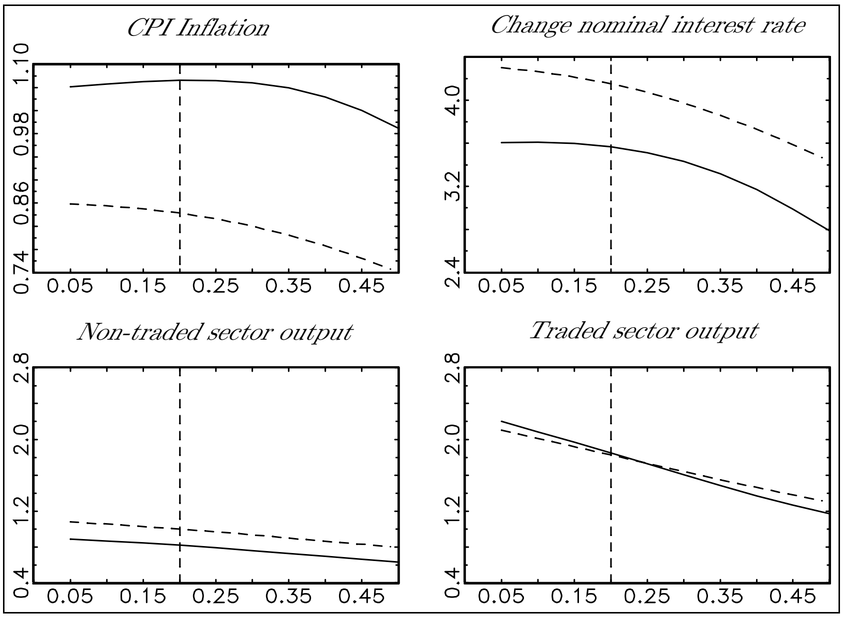
In this section we study some aspects of the underlying economic structure that may influence the outcome of inflation targeting in general. We consider both CIIF rules and the discretionary optimal (flexible) inflation targeting policy to provide some robustness to the conclusions with respect to how inflation targeting may be carried out. Of special interest are the effects on the rules' ability to control inflation as well as to affect sectoral fluctuations.

4.3.1. The degree of forward-lookingness in the wage process

In assigning a rather small value of $\phi = .2.$, we assume that the real contract wage is set in such a way that the situation in the current period has stronger influence than future periods. This results in higher and more realistic inflation persistence than a setup with more symmetrical treatment of the periods (Fuhrer, 1997b). In this section we ask what effect this 'imperfection' in the labour market has on macroeconomic performance under inflation targeting. This is shown in Figure 4.3 by plotting the unconditional standard deviations (in percent) of some central variables for different values of ϕ.

Increasing the forward-looking component of wage determination leads consistently to greater stability in all variables considered. The general reason for this is that the supply side is to a greater extent able to take into account its effect upon the forcing variables, such as output and the real exchange rate. As the real exchange rate shows persistent movements subsequent to a shock, a more forward-looking wage process will imply that wages will respond strongly to these expected movements. If the exchange rate is expected to appreciate, this will have a stronger dampening effect on wages, so that domestic inflation will drop to a larger extent and the real exchange rate will thus become more stable. Traded sector stability is thus the most important result of more

Figure 4.3



Standard deviations, as percentages. Effects of varying the degree of forward-lookingness factor in wage determination. Discretionary optimising flexible inflation targeting rule (solid line) and CIIF rule at $h = 1$ and $\beta_\pi = 5$.

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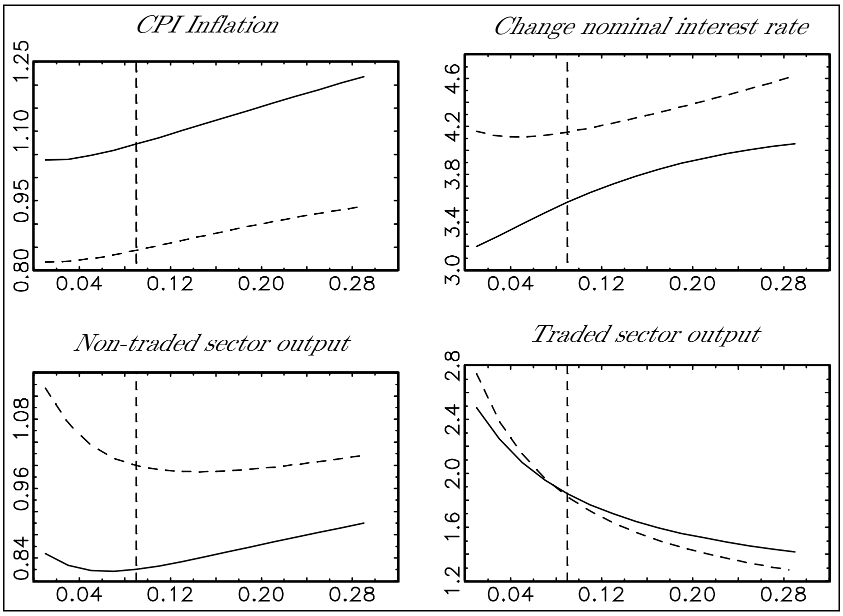
forward-looking wage determination. As the economy becomes more self-stabilising, the interest rate will react less, leading to extended interest rate smoothing.

4.3.2. The effects of wage response to the level of cost-competitiveness in the traded sector.

The wage process has been modelled in such a way that the capital share of income, approximated by the inverse of the producer real wage in the traded sector, has an important effect on wage determination. If the producer real wage is high, i.e., the real exchange rate is appreciated, this will have a restrictive effect on nominal contract wages and hence on domestic inflation.

If wage setting becomes more sensitive to the producer real wage, monetary policy becomes more potent. The reason is that wages and domestic inflation become more sensitive to the exchange rate channel. If the interest rate unexpectedly rises due to an increased deviation between the conditional inflation forecast and the target level, this will in most circumstances lead to a nominal exchange rate appreciation. The appreciation of the exchange rate will worsen the level of competitiveness and hence to a larger extent

Figure 4.4



Standard deviations, as percentages. Effects of varying the competitiveness factor in wage determination. Discretionary optimising flexible inflation targeting rule (solid line) and CIIF rule at $h = 1$ and $\alpha_\pi = 5$.

influence the domestic component of the inflation rate. The exchange rate channel therefore has a stronger role in the monetary transmission mechanism. Traded sector output variability drops markedly, as seen from Figure 4.4, when inflation becomes dependent on the producer real wage. However, the unconditional standard deviation of CPI increases. The reason is that shocks to the nominal exchange rate now have a stronger impact on inflation, as a nominal exchange rate depreciation will decrease the producer real wage, and thus raise wages and domestic inflation. The most important source of shocks to the exchange rate is risk premium shocks, which, as calibrated, has a tenfold standard deviations relative to the size of the other shocks to the model.[22] Greater exposure of inflation to this shock has a destabilising effect on inflation.

5. Conclusion

Targeting inflation in a small open economy is a quite different and more demanding challenge than targeting inflation in a closed economy. The reason is that the exchange

[22] As seen from Table A.1 in the appendix, the standard deviations (in percent) of the shock to the risk premium are more than ten times the size of the standard deviations of the next largest shock, to imported goods inflation.

rate channel is an important element of the transmission mechanisms in an open economy. This channel not only influences demand for goods traded on the international market, but also imported goods prices, wages and inflation. Taking adequate account of the exchange rate channels are thus of considerable importance to policy.

In this paper we have considered a particular form of policy that implies that the interest rate reacts to the deviations of the forecast of inflation from its target. Such rules may closely approximate how inflation targeting is carried out in practise. The performance of the CIIF rules is directly linked to the length of the forecast feedback horizon. With a long forecast feedback horizon, the nominal interest rate need only respond weakly to shocks, because inflation, by and large, will have returned to its target level without any policy response by the end of the forecast horizon. The exchange rate channel plays an important role in achieving this. When inflation remains persistently away from target as a result of a relatively long forecast targeting horizon, it produces real exchange rate movements that influence inflation by affecting the wage pressure and output in the traded sector. Moreover, weak interest rate responses to shocks provide a source for long-run changes in the domestic-foreign price differential, resulting in nominal exchange rate responses that will intensify CPI inflation variability. The analysis suggest that in order to take adequate account of the exchange rate channel under CIIF rules, the forecast feedback horizon should be relatively short, probably (much) shorter than in a closed economy. We find some evidence of a relatively more stable non-traded sector when using a smaller feedback coefficient on the inflation forecast deviation term in the CIIF rule when the forecast feedback horizon is not too long.

Appendix

A. Calibration

The model presented in section 3 is calibrated to match some macroeconomic characteristics of the UK economy at a quarterly frequency. Batini and Haldane (1999) calibrate their model with parameters 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' (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 overemphasise our belief in the parameters chosen, given the problems of obtaining precise macroeconomic estimates. However, our aim is not to produce a fully specified model for the U.K. 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 to be adequate.

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 long interest rate weight in the interest rate index is somewhat arbitrarily set at $\omega = .7$, reflecting the strong theoretical arguments that long-term interest rates have a stronger influence than short rates on 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 information discount rate of $\delta = .5$ in this sector, the impact elasticity of an expected, permanent change in the product real wage is $\frac{\beta}{1-\delta} = .8$[23]. 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 rate more persistent than in the original model of 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 wage or capital share of output influences 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 as being in the range of -0.14 to -0.26 using annual observations. Furthermore, Bårdsen et al. (1999) estimate that U.K.

[23]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 real exchange rate change was perceived to be transitory, and -.8 and -5.25 if it was perceived to be permanent. In the non-traded sector the impact and long-run elasticities are .05 and .33, respectively. Given that the traded sector accounts for 25% of the economy, these responses seem reasonable.

wages error-correct to the equilibrium level of the wage share by a factor of -0.156 on a quarterly basis. 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 $\tau = 40$ quarters. Finally, the rate at which imported prices equilibrium corrects to the foreign price is set at $c = .5$ which implies 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 an uncovered interest rate parity condition for the U.K. economy. Consequently, we impose this condition, but allowing for an autoregressive risk premium component. As r^f is the foreign real interest rate corrected for risk premium, it can be calculated from (3.10) 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 3-month nominal interest rate minus the expected quarterly change in the CPI at an annual rate. Market expectations of the change in the real exchange rate and the CPI price level were 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.[24]

The derived foreign real interest rate corrected for risk premium 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 valid approximation.

Realising the difficulties in obtaining measurements of the true structural shocks to the economy, we proceed using standard structural vector autoregression methods for obtaining (approximations of) time series representations of the underlying shocks. Ideally, our model could be estimated and the residuals

[24] 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 techniques and deriving the risk premium through a Kalman filtering process. Such a procedure, however, would rely on an estimate of the historical monetary policy reaction function to close the model. As no such reliable estimates of a reaction function exist, possibly due to changes in the monetary regime historically, we decide to pursue a simpler strategy.

Table A.1: 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)

obtained could be used to estimate the distribution of these shocks. However, our model is stylised 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^{rf} 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 reflects our small country assumption, as foreign variables are viewed as exogenous to the U.K. economy. Inclusion of the OECD GDP can be seen as a proxy of the U.K. trading partners production level. As the U.K. is a part of the OECD, there is a simultaneity problem that distorts the measure of the structural shocks, but only to a small degree, and so it is disregarded. This gave us time series for all five shocks to our model.[25] We then proceeded by calculating the variance-covariance matrix of these shocks. The corresponding correlation matrix is

B. Analytical derivation of policy

Start by considering a general model on state space form, i.e.,

$$X_{t+1} = AX_t + Bi_t + \varepsilon_{t+1}, \tag{A.3}$$

(A.4)

where A is the companion matrix and B is a vector of interest rate impact multipliers; X is a vector of state variables. Using repeated substitutions, we can write the expected value of the state vector at time $t+h$ made at time t as

$$X_{t+h|t} = A^h X_t + \sum_{i=1}^{h} A^{h-i} B i_{t+i-1|t}.$$

[25]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.

Providing the state variables and the interest rate level in the previous period being kept throughout the forecast horizon, we may write the constant-interest-rate forecast as

$$X_{t+h|t}(\bar{\imath}_{t-1}) = A^h X_t + \sum_{i=1}^{h} A^{h-i} B i_{t-1}. \tag{A.5}$$

Assume that the state vector includes the relevant variables so we can set

$$\begin{aligned} \tilde{\pi}_t^c &= K_\pi X_t, && \text{(A.6)} \\ i_{t-1} &= K_i X_t. && \text{(A.7)} \end{aligned}$$

for some appropriately defined K_π and K_i. We can then insert (A.6) and (A.7) into (A.5) to get the constant-interest-rate forecast of the four-quarter inflation rate as

$$\begin{aligned} \bar{\pi}_{t+h|t}^c(\bar{\imath}_{t-1}) &= K_\pi X_{t+h|t}(\bar{\imath}_{t-1}) \\ &= K_\pi A^h X_t + K_\pi \sum_{i=1}^{h} A^{h-i} B K_i X_t. && \text{(A.8)} \end{aligned}$$

The inflation forecast feedback rule is given from (2.4),

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\beta_\pi \tilde{\pi}_{t+h|t}^c(\bar{\imath}_{t-1}),$$

where $\pi^* = 0$. Using (A.6), (A.7) and (A.8), this rule may be written as a function of the state vector as

$$i_t = F X_t, \tag{A.9}$$

where $F = \rho_i K_i + (1-\rho_i)\beta_\pi K_\pi A^h + (1-\rho_i) K_\pi \sum_{i=1}^{h} A^{h-i} B K_i$.

If the state vector consists of both backward-looking, x_{1t}, and forward-looking, x_{2t}, variables, i.e., $X_t = \begin{bmatrix} x_{1t} & x_{2t} \end{bmatrix}'$, then the state space form in (A.3) may be written as,

$$\begin{bmatrix} x_{1t+1} \\ x_{2t+1|t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} i_t + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}. \tag{A.10}$$

The interest rate rule in (A.9) may be written as $i = \begin{bmatrix} F_1 & F_2 \end{bmatrix} \begin{bmatrix} x_{1t} & x_{2t} \end{bmatrix}'$. After inserting the interest rate rule in (A.10), we get

$$\begin{aligned}
\begin{bmatrix} x_{1t+1} \\ x_{2t+1|t} \end{bmatrix} &= \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} \begin{bmatrix} F_1 & F_2 \end{bmatrix} \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix} \\
&= \left(\begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} + \begin{bmatrix} B_1F_1 & B_1F_2 \\ B_2F_1 & B_2F_2 \end{bmatrix} \right) \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix} \\
&= \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}, \qquad \text{(A.11)}
\end{aligned}$$

where the C-matrix is defined accordingly. Given a linear model, we postulate a solution to the forward-looking variables as a linear function of the backward-looking variables,

$$x_{2t} = Hx_{1t}, \qquad \text{(A.12)}$$

which implies $x_{2t+1|t} = Hx_{1t+1|t}$. In order to get a solution for H, note that A.3 implies $x_{1t+1|t} = C_{11}x_{1t} + C_{12}x_{2t}$, hence

$$\begin{aligned}
x_{2t+1|t} &= H(C_{11}x_{1t} + C_{12}x_{2t}) \\
&= H(C_{11}x_{1t} + C_{12}Hx_{1t}) \\
&= H(C_{11} + C_{12}H)x_{1t}. \qquad \text{(A.13)}
\end{aligned}$$

where we have used (A.12). From (A.11) we obtain another expression for the forward-looking variables, as

$$\begin{aligned}
x_{2t+1|t} &= (C_{21}x_{1t} + C_{22}x_{2t}) \\
&= (C_{21}x_{1t} + C_{22}Hx_{1t}) \\
&= (C_{21} + C_{22}H)x_{1t} \qquad \text{(A.14)}
\end{aligned}$$

Equalisation of the expressions for x_{2t} in (A.13) and (A.14), yields a quadratic solution for H, as

$$H(C_{11} + C_{12}H) = (C_{21} + C_{22}H). \qquad \text{(A.15)}$$

The reaction function of the central bank will now be given from (A.15) and (A.9) by

$$\begin{aligned}
i_t &= F_1x_{1t} + F_2x_{2t} \\
&= (F_1 + F_2H)\, x_{1t.}
\end{aligned}$$

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.

Batini, Nicoletta and Edward Nelson (2000). "Optimal Horizons for Inflation Targeting." Sveriges Riksbank Working Paper No. 103.

Blake, Andrew and Peter Westaway (1996). "Credibility and the Effectiveness of Inflation Targeting Regimes." *Manchester School of Economic and Social Studies*, 64(0):28–50.

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

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.

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

— (1997b). "The (Un)Importance of Forward-Looking Behaviour in Price Specification." *Journal of Money, Credit and Banking*, 29 (3):338–350.

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

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

Jansson, Per and Anders Vredin (2000). "Forecast-Based Monetary Policy in Sweden 1992-1998: A Transparent Analysis." Manuscript Sveriges Riksbank.

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." Norges Bank Arbeidsnotat 13/99. Available at *http://home.c2i.net/kai_leitemo*.

— (2000). "Open-Economy Inflation Forecast Targeting." Norges Bank Arbeidsnotat 2/2000. Available at *http://home.c2i.net/kai_leitemo*.

Leitemo, Kai and Øistein Røisland (2000). "The Choice of Monetary Policy Regime for Small Open Economies." Norges Bank Arbeidsnotat 5/2000. Available at *http://home.c2i.net/kai_leitemo*.

Levin, Andrew, Volker Wieland, and John C. Williams (1999a). "The Performance of Forecast-Based Monetary Policy Rules under Model Uncertainty." Paper presented at the ECB conference on Monetary Policy-Making under Uncertainty.

— (1999b). "Robustness of Simple Policy Rules under Model Uncertainty." In John B. Taylor (ed.), "Monetary Policy Rules," pp. 263–299. The University of Chicago Press, Chicago.

McCallum, Bennet T. and Edward Nelson (2000). "Nominal Income Targeting in an Open-Economy Optimizing Model." NBER Working Paper No. W6675. Working paper version of McCallum and Nelson (1999a).

McCallum, Bennett T. (1999). "Role of the Minimal State Variable Criterion in Rational Expectations Models." *International Tax and Public Finance*, 6(4):621–639. NBER Working Paper 7087.

McCallum, Bennett T. and Edward Nelson (1999a). "Nominal Income Targeting in an Open-Economy Optimizing Model." *Journal of Monetary Economics*, 43(3):553–578.

— (1999b). "An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis." *Journal of Money, Credit and Banking*, 31(3):296–316. 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.

Rudebusch, Glenn and Lars E.O. Svensson (1999). "Policy Rules for Inflation Targeting." In John B. Taylor (ed.), "Monetary Policy Rules," pp. 203–262. University of Chicago Press, Chicago.

Rudebusch, Glenn D. (1999). "Is the Fed Too Timid? Monetary Policy in an Uncertain World." Working Paper, Federal Reserve Bank of San Fransisco.

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

— (1999a). "Inflation Targeting as a Monetary Policy Rule." *Journal of Monetary Economics*, 43(3):607–654.

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

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

— (2000b). “Open-Economy Inflation Targeting.” NBER Working Paper W6545. Working paper version of Svensson (2000a).

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.

Kai Leitemo: The Performance of Inflation Forecast Feedback Rules in Small Open Economies

Arbeidsnotat 2000/11

KEYWORDS:

Monetary policy
Inflation targeting
Inflation feeback rules
Simple rules
Small open economy

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