

Targeting Inflation by Constant-Interest-Rate Forecasts*

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Abstract

The paper reviews the concept of constant-interest-rate inflation forecast targeting employed by several inflation targeting central banks. It provides a new method for constructing such forecasts in the context of models with forward-looking variables. It furthermore explores a standard closed-economy macromodel in the context of forecast targeting. The analysis suggests that the main reason for choosing a relatively long forecast horizon lies in the monetary authorities' objective to smooth interest rate movements and not in order to stabilize inflation and output variability. A strongly forward-looking inflation process brings the outcome of forecast targeting closer to the optimal discretionary policy, whereas a backward-looking process may lead to model instability.

Keywords: Monetary policy, inflation targeting, forecast targeting.

JEL classification numbers: E52, E43, E37.

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1 Introduction

Inflation targeting is considered to be the new framework for monetary policy of the 1990's. It has sparked off extensive research by both academic scholars and central bank researchers since it was introduced in New Zealand in 1990¹. Inflation targeting has a relatively precise definition as posed by Svensson (1999b). It can be described to be a framework of monetary policy in which the central bank has inflation deviations from some specific target level as the main argument in its loss function, and where the bank enjoys instrument independence in minimizing this loss. Transparency with respect to policy formulation which enhances the accountability of the central bank is another important aspect of the inflation targeting regime that lead Bernanke and Mishkin (1997) to conclude that inflation targeting is a framework of *constrained discretion* on the part of the central bank. This discretion has arguably lead to different ways of implementing the inflation targeting policy. Policy optimization may in principle be the best way of deriving the correct policy responses. However, given little consensus among economists about what the true economic model look like, adherence to a particular model may produce rules of 'optimal' policy instrument responses that may be quite complex and difficult for the agents of the economy to interpret and comprehend. Indeed, optimal rules in one model may perform quite poorly in another. Most economists seem to agree with the view that transparency and accountability indicate to a large degree simplistic and 'intuitive' action from the central bank. Optimization within large, complex, "well-specified" models can produce results that would be at odds with that requirement. If forward-looking variables play an important role in the real world, then explaining the consistency of policy is important in order to reduce the volatility of and, indeed, have some influence upon these variables.

A host of theoretical as well as empirical papers have stressed the importance of having an inflation targeting policy that is forward-looking². The instruments available to the monetary policy maker are usually assumed to have the largest impact upon the rate of inflation at some horizon. A good policy should therefore react to the underlying determinants of future inflation in order to influence it in a favourable way. Svensson (1999b) argues that the rational expectation forecast of inflation is the optimal indicator of these determinants. Targeting the forecast of inflation could therefore come close to the optimal policy in minimizing deviations of inflation from target and in addition offer a procedure that

¹See Leiderman and Svensson (1995) and Bernanke and Posen (1999) for an overview.

²See, e.g., Batini and Haldane (1999) and Svensson (1999c) for arguments in having a forward-looking policy.

is intuitive and transparent. Such a policy can be denoted by

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

where $\bar{\pi}_{t+h|t}$ is the rational forecast of the four-quarter inflation rate at horizon h and $\bar{\pi}^*$ is the inflation target level. However, a problem with this definition is that there exists an infinitum of policy instrument paths that satisfy (1) as long as h is a number greater than the shortest time-lag at which the policy instruments influence inflation. There is thus a need for additional assumptions in order to pin down policy. One possibility is to place conditions on the future development of the instruments - assumed only to be the short nominal interest rate in this paper. '*Constant-interest-rate inflation forecast targeting*' (henceforth referred to as *CII-targeting*), which imposes an constancy assumption of the interest rate over the targeting horizon in deriving policy, has arguably been implemented by both the Bank of Sweden and the Bank of England. Under CII-targeting the central bank computes a forecast of inflation several periods ahead for different constant-interest-rate levels. The particular interest rate level that is consistent with having the inflation forecast h periods ahead on target is chosen. The parameter h is normally referred to as the forecast targeting horizon or simply, the targeting horizon. This type of policy can be denoted by

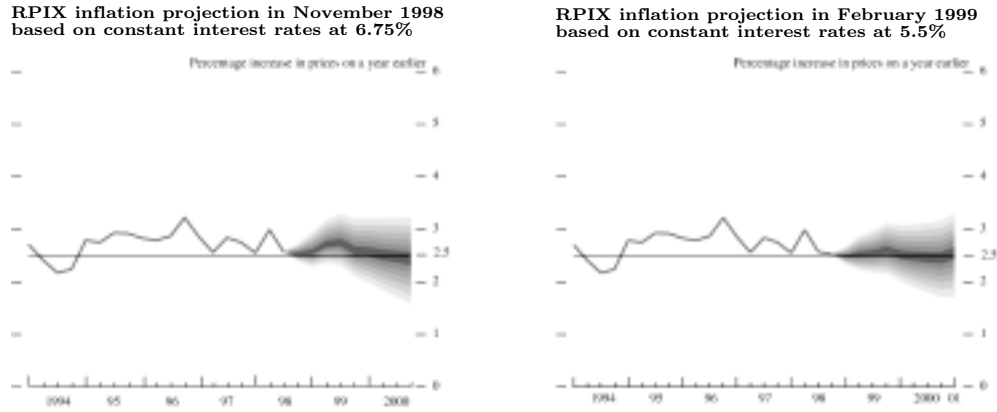
$$\bar{\pi}_{t+h|t}(\bar{i}) = \bar{\pi}^*, \quad (2)$$

where $\bar{\pi}_{t+h|t}(\bar{i})$ is the four-quarter inflation forecast contingent on a constant-interest-rate over the targeting horizon. Given the well-known lags in the monetary transmission process and therefore in the effects of the instruments of monetary policy upon inflation, CII-targeting is intuitive and provides forceful arguments for setting an interest rate that is in line with the policy target.

As an example, figure 1 shows the inflation projections of the Bank of England taken from its February 1999 Inflation Report.

The chart on the right side of the figure shows the inflation projection for the horizon period given that the interest rate prevails at the February 1999 5.50 percent level. The other chart shows the corresponding projection for inflation in their November 1998 Inflation Report at the then prevailing interest rate of 6.75 percent. Even though both charts both show that inflation is in line with the target at the two year horizon, the November forecast shows a drop in the inflation projection during the last year of the targeting horizon. In late 1998, the policy makers became increasingly concerned with this trend³ and consequently, the interest rate was lowered by a total of 1.25 percentage points which consequently increased the inflation forecast at the end of the two-year horizon.

³In principle, without having any new information available.



Source: Bank of England Inflation Report

Figure 1: Constant-interest-rate inflation projections by the Bank of England

There is, however, an important aspect with the method, often not explicitly acknowledged by the inflation targeting central bank, relating to the fact that constant-interest-rate projections are not the best forecast of the expected development of the interest rate. This is understood by realizing that the rationally expected interest rate path within the targeting horizon is determined by subsequent inflation forecasts made for the period after the then prevailing targeting horizon. An example may clarify this even further. Consider a central bank pursuing a CII-targeting strategy and sets the interest rate at the level which, if held constant in two years, brings the inflation forecast on target. Furthermore, assume that the one-year inflation forecast is above target, while the three-year forecast is below target. When one year elapses and no new information arrives, the CB will nevertheless not stick to its constant-interest-rate assumption. As the two-year inflation forecast now is below target, the central bank will lower the interest rate to the new level that ensures that the two-year inflation forecast is on target. The change in the interest rate reveals that the premise of the constancy of the interest rate one year previously, was not valid, even if no new information arrived. The constant-interest-rate assumption can therefore be seen merely as an assumption made in deriving policy. Rational agents will understand that CII-targeting does not imply constant interest rates in the forecast horizon but instead base their expectations upon the policy implications of this strategy. The interest rate will change within the forecast horizon, not only due to new information, but also because the bank's inflation target moves forward in time. If forward-looking variables play an important part in the monetary transmission mechanism, failing to take account of this may produce distorted forecasts and inappropriate policy responses.

The remaining of the paper is organized as follows. Section 2 presents the method that allows us

to compute the rationally expected future development of variables in models with forward-looking variables when the central bank is pursuing CII-targeting. At the end of this section we provide some criticism of the backward induction method of Svensson (1999a) and contrast it to our method. In section 3 we use a small closed-economy model to address issues pertaining to the optimal forecast horizon and the general performance of the CII-targeting framework. Section 4 concludes.

2 Constant-interest-rate forecast targeting

Targeting inflation by constant-interest-rate forecasts implies a procedure of responding systematically to the state of the economy. A method of constructing such forecasts and analyzing the performance of the economy under forecast targeting obviously needs to take this into account. This is in particular due to the behaviour of forward-looking agents. Such agents will use all available information about the systematicity of policy in deriving expectations about future variables - not on announced interest rate developments that are not likely to be followed. This section presents a general method of analyzing models with forward-looking behaviour in the context of CII-targeting where agents are rational and use information efficiently.

Most dynamic models can be expressed in a general state-space form corresponding to

$$\begin{bmatrix} x_{1,t+1} \\ x_{2,t+1|t} \end{bmatrix} = A \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + B i_t + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}, \quad (3)$$

where $x_{1,t}$ is a vector of backward-looking variables; $x_{2,t}$ is a vector of forward-looking variables, e.g., the exchange rate or other financial prices; i_t is a vector of exogenous control variables, e.g., the policy instrument - here assumed to be the short interest rate; A and B are matrices of model parameters and ε is a vector of shocks, serially and contemporaneously uncorrelated with zero expectations.

The general h -period-ahead forecast can be written after repeated substitutions in (3), as

$$\begin{bmatrix} x_{1,t+h|t} \\ x_{2,t+h|t} \end{bmatrix} = A^h \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + \sum_{j=0}^{h-1} A^j B i_{t+h-1-j|t}, \quad (4)$$

where $x_{1,t}$ is known and determined but $x_{2,t}$ remains to be determined. Assume that the four-quarter inflation rate can be written as a linear function of the state variables, $\bar{\pi}_t = K \begin{bmatrix} x_{1,t} & x_{2,t} \end{bmatrix}'$ where K is appropriately defined. Then the h -period ahead forecast can similarly be written as $\bar{\pi}_{t+h|t} = K \begin{bmatrix} x_{1,t+h|t} & x_{2,t+h|t} \end{bmatrix}'$, and by using (4),

$$\bar{\pi}_{t+h|t} = K A^h \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + K \sum_{j=0}^{h-1} A^j B i_{t+h-1-j|t}, \quad (5)$$

where the forecast depends on the present state of the economy and the expected policy over the targeting horizon.

The CII-targeting policy is derived by considering the forecast of inflation given a constant interest rate over the targeting horizon, i.e., $i_{t+j|t}(\bar{i}) = i_t$ for $h-1 \geq j \geq 0$. This interest rate path condition can be inserted into (5), yielding

$$\bar{\pi}_{t+h|t}(\bar{i}) = KA^h \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + K \sum_{j=0}^{h-1} A^j B i_t, \quad (6)$$

which is the *constant-interest-rate inflation forecast* conditional on $x_{2,t}$ and the interest rate, i_t . The inflation forecast is related to the state of the economy today and the prevailing interest rate. In order to explore what restrictions CII-targeting imply for policy, combine (6) with (2), for simplicity assuming that the inflation target is normalized to zero, $\bar{\pi}^* = 0$, and obtain

$$\begin{aligned} i_t &= - \left(K \sum_{j=0}^{h-1} A^j B \right)^{-1} KA^h \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} \\ &\equiv F \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix}. \end{aligned} \quad (7)$$

Given that $-\left(K \sum_{j=0}^{h-1} A^j B\right)^{-1}$ exists, (7) will be the interest rate rule. This is, however, not a true reaction function since it requires a response to forward-looking variables which again depend on future expected policy. Hence (7) is only an equilibrium condition. In order to arrive at the true reaction function we first need to express the forward-looking variables as functions of the predetermined variables.

The evolution of the model subject to this particular rule can be examined by substituting the instrument rule (7) into (3), i.e.,

$$\begin{aligned} \begin{bmatrix} x_{1,t+1} \\ x_{2,t+1|t} \end{bmatrix} &= (A + BF) \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix} \\ &= \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}, \end{aligned} \quad (8)$$

which has a unique, stable solution if, and only if, the number of stable eigenvalues in $G = (A + BF)$ is equal to the number of forward-looking variables in x_2 (Blanchard and Kahn (1980)).

To proceed, we need to determine the values for the forward-looking variables, $x_{2,t}$. The solution to these can be expressed as a linear function of all the predetermined variables in the state vector, i.e.,

$$x_{2,t} = Hx_{1,t}, \quad (9)$$

where H so far is undetermined. This has the implication that $x_{2,t+1|t} = Hx_{1,t+1|t}$. From this information and (8) we get two equations for $x_{2,t+1|t}$,

$$\begin{aligned} x_{2,t+1|t} &= H[G_{11} + G_{12}H]x_{1t}, \\ x_{2,t+1|t} &= [G_{21} + G_{22}H]x_{1t}, \end{aligned} \quad (10)$$

which both have the same solution if H obeys the following system of quadratic equations,

$$H[G_{11} + G_{12}H] = [G_{21} + G_{22}H]. \quad (11)$$

The equations in (11) can be solved for example by the method presented in Klein (1999).

Inserting the interest rate rule (7) and the solutions to the forward-looking variables in (9) into (6) yields,

$$\begin{bmatrix} x_{1,t+h|t}(\tilde{i}) \\ x_{2,t+h|t}(\tilde{i}) \end{bmatrix} = \left[A^h + \sum_{j=0}^{h-1} A^j BF \right] \begin{bmatrix} x_{1,t} \\ Hx_{1,t} \end{bmatrix} \quad (12)$$

which is the *constant-interest-rate forecast* of the model conditional only on predetermined variables.

As noted above, F relates the interest rate not only to the predetermined variables but also to the forward-looking variables. In order to arrive at the reaction function of the central bank, partition F as $F = \begin{bmatrix} f_{x_1} & f_{x_2} \end{bmatrix}$ where f_{x_1} and f_{x_2} correspond to the response to the instrument from the predetermined variables and the forward-looking variables, respectively. (7) can then be written as

$$\begin{aligned} i_t &= \begin{bmatrix} f_{x_1} & f_{x_2} \end{bmatrix} \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} \\ &= (f_{x_1} + f_{x_2}H)x_{1,t} \\ &\equiv fx_{1,t} \end{aligned} \quad (13)$$

where we have used (9). (13) is the true reaction function - relating the interest rate only to the predetermined variables.

It is now straightforward to construct the *policy-consistent rational forecasts* in the model which are based upon the reaction function of (13). Iterate on (8) to the appropriate horizon, take expectations and use (9) in order to get,

$$\begin{bmatrix} x_{1,t+h|t} \\ x_{2,t+h|t} \end{bmatrix} = \begin{bmatrix} (G_{11} + G_{12}H)^h \\ H(G_{11} + G_{12}H)^h \end{bmatrix} x_{1,t}.$$

The policy-consistent inflation forecast is then given by the fact that $\bar{\pi}_{t+h|t} = K \begin{bmatrix} x_{1,t+h|t} \\ x_{2,t+h|t} \end{bmatrix}'$, i.e.,

$$\bar{\pi}_{t+h|t} = K \begin{bmatrix} (G_{11} + G_{12}H)^h \\ H(G_{11} + G_{12}H)^h \end{bmatrix} x_{1,t}, \quad (14)$$

which concludes the description of the policy procedure.

A comment: Constructing conditional forecasts by backward induction

Svensson (1998, appendix A) presents an alternative method that constructs forecasts in forward-looking models when the instrument is state-independent, e.g., a constant-interest-rate path within the targeting horizon (or some other definite horizon) or an arbitrary time-dependent reaction function. Such state-independent policies will not generally produce a rational expectations equilibrium since the probability distribution of the variables is not well defined. However, beyond the targeting horizon, the Svensson procedure assumes that policy will return to a state-dependent policy that will yield a unique rational expectation solution of the forward-looking variables in the model. Then, by backward induction from the end of the targeting horizon, the values of the forward-looking variables are derived for the whole targeting period. The model can then be solved forward to yield the expectation of the predetermined variables in the targeting period. It is, however, important to stress that this forecast is not consistent with CII-targeting as derived above. The difference pertains to the assumption that under backward induction, the private agents' expectations are conditional upon a constant-interest-rate within the targeting horizon. The agents literally believe that the interest rate will stay constant for h -periods ahead (irrespective of the new h -period forecast pending next period) and that policy will then return to *some* state-dependent policy. This is different from CII-targeting, as defined in section 2 from the following perspectives:

- Since the length of the targeting horizon stays constant, CII-targeting means that the interest rate is changed within the targeting horizon depending on, e.g., the two-year-ahead inflation forecast. Rational agents will realize this and determine the forward-looking variables in accordance with this - not on the policy assumption of constant interest rates.
- The procedure does not specify consistent restrictions on the particular policy that is assumed to be implemented after the expiration of the targeting period.
- If CII-targeting has been announced by the central bank, why should the agents in the model believe that the policy framework will change in the time subsequent to the targeting horizon? If this policy change is not expected, why should the rational expectation solution to the forward-looking variables in the period following the targeting horizon have any meaning?

To formally see that the backward induction method yields a different policy than CII-targeting as described above, assume that policy is assumed to return to CII-targeting in the period after the forecast horizon. Furthermore, CII-targeting is implemented at the start of the targeting horizon. If we

now can show that backward induction yields a different solution to the forward looking variables than derived above, we have proved that the methods differ.

Assuming CII-targeting in the period after this horizon yields the same solution to the forward-looking variables, i.e.,

$$x_{2,t+h|t} = Hx_{1,t+h|t}, \quad (15)$$

The policy maker implements the interest rate at time t that is consistent with CII-targeting, i.e., $i_t = FX_t$ given that this rate will prevail in the whole forecast period, i.e., $i_{t+h-1|t} = i_{t+h-j|t} = FX_t$ for $j \leq h$. The forecast in our general model can then be written from (12) as

$$\begin{bmatrix} x_{1,t+h|t}(\bar{i}) \\ x_{2,t+h|t}(\bar{i}) \end{bmatrix} = \begin{bmatrix} G_{11}^* & G_{12}^* \\ G_{21}^* & G_{22}^* \end{bmatrix} \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix},$$

where $\begin{bmatrix} G_{11}^* & G_{12}^* \\ G_{21}^* & G_{22}^* \end{bmatrix} = \left[A^h + \sum_{i=0}^{h-1} A^i BF \right]$ and partitioned according to the state vector.

The solution to the forward-looking variables can then be derived by means of backward induction assuming (15) at the end of the targeting period, according to

$$\begin{bmatrix} x_{1,t+h|t}(\bar{i}) \\ Hx_{1,t+h|t}(\bar{i}) \end{bmatrix} = \begin{bmatrix} G_{11}^* & G_{12}^* \\ G_{21}^* & G_{22}^* \end{bmatrix} \begin{bmatrix} x_{1,t} \\ H^*x_{1,t} \end{bmatrix}.$$

The expected values of the forward-looking variables are then give by,

$$\begin{aligned} x_{2,t+h|t} &= (G_{21}^* + G_{21}^* H^*) x_{1,t}, \\ x_{2,t+h|t} &= H (G_{11}^* + G_{12}^* H^*) x_{1,t}, \end{aligned}$$

which yields the same solution if, and only if, H^* obeys

$$H (G_{11}^* + G_{12}^* H^*) = (G_{21}^* + G_{22}^* H^*), \quad (16)$$

which compared with (11) shows that for $h > 1$, $H^* \neq H$ since $G^* \neq G$. However, for $h = 1$, $H^* = H$ since $G^* = G$. *For horizons longer than one period, the procedures yield different solutions.*

The implied interest rate will differ from the one obtained under CII-targeting, i.e.,

$$\begin{aligned} i &= F \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} \\ &= F \begin{bmatrix} x_{1,t} \\ H^*x_{1,t} \end{bmatrix} \\ &= \begin{bmatrix} f_{x_1} & f_{x_2} \end{bmatrix} \begin{bmatrix} x_{1,t} \\ H^*x_{1,t} \end{bmatrix} \\ &= (f_{x_1} + f_{x_2} H^*) x_{1,t} \\ &= f^* x_{1,t} \neq f x_{1,t} \end{aligned}$$

There is certainly nothing that prevents the central bank from actually implementing this policy. We must, however, due to policy consistency reasons, assume that there is no difference in how policy was formulated within (f^*) and beyond ($\tilde{f}$) the targeting horizon. The vector f^* (and the corresponding H^*) is a function of the assumption of policy beyond the targeting horizon, i.e.,

$$f^* = \varphi(\tilde{f}),$$

and the policy consistency requirement would then be the fixed-point at $\tilde{f} = f^*$ with a corresponding $\tilde{H} = H^*$. The appendix presents an iterative procedure which, given convergence, derives this fixed-point. However, in the particular model presented in the next section, convergence is not achieved. Whether this is an indication of a fundamental problem related to the backward induction method or problems pertaining to the particular model is an open issue. The backward induction method is due to this reason not explored in the policy section of this paper.

The fundamental difference between the methods pertains to their treatment of the forward-looking variables⁴. Under CII-targeting, the present rational expectations solutions for these variables at the start of the targeting period, $x_{2,0}$, are used in deriving the constant-interest-rate forecast of inflation. However, within the targeting period, this value is taken as predetermined and the values of the forward-looking variables are derived contingent on the constant-interest-rate assumption - not the rational expectations path of the interest rate. CII-targeting can therefore be criticized for not treating the forward-looking variables in an internally consistent manner when deriving the constant-interest-rate forecast. The Svensson procedure, however, derives the forward-looking variables based upon the assumption that the constant-interest-rate path is actually believed by the private agents to be implemented in the targeting period. Whereas this implies a forecast that is internally consistent with the policy assumption, it is externally inconsistent with the operation and updating of policy inherent in this type of policy.

3 Policy analysis

For illustrational purposes policy analysis will be conducted within a simple macroeconomic model explaining inflation and output deviations from potential output,

$$\pi_{t+1} = \alpha\pi_{t+2|t} + (1 - \alpha)\pi_t + \gamma y_t + \epsilon_{t+1}, \quad (17)$$

$$y_{t+1} = \rho_0 y_t + \rho_1 y_{t-1} - \beta(\tilde{i}_t - \bar{\pi}_t) + \eta_{t+1}, \quad (18)$$

⁴I am indebted to Lars Svensson for this remark.

where π_t is the quarterly change in the logarithm of the consumer price index measured in annual percentage units, y_t is the percentage deviations of the logarithm of output from the logarithm of potential output; $\bar{\pi}_t$ is the four quarter inflation rate, i.e., $\frac{1}{4} \sum_{j=0}^3 \pi_{t-j}$; $\tilde{i}_t$ is the four-quarter moving average of the quarterly averaged annual interest rate, i.e., $\frac{1}{4} \sum_{j=0}^3 i_{t-j}$; ϵ and η are serially and mutually uncorrelated shocks. (17) is a Phillips curve relationship reflecting aggregate supply in the economy. (18) is the aggregate demand relationship which relates the nominal interest rate to the output-gap. The model is close to the model estimated by Rudebusch and Svensson (1999) for the US-economy. It differs⁵ from this by considering partly forward-looking expectations in the Phillips curve. A partly forward-looking, partly backward-looking form is consistent with the Fuhrer and Moore (1995) model in which overlapping nominal wage contracts are set in response to the prevailing and future expected relative real wage development in addition to pressure in the labour market. Our model treats the inflation rate as a predetermined variable which effectively prevents it from reacting to any new contemporaneous information. This differs from the treatment of inflation in the Fuhrer and Moore model. We believe that this formulation is more in line with the evidence from VAR studies⁶. This literature emphasizes the sluggishness and lagged response of inflation to a monetary shock.

The model can be set up in a general state space form according to (3) where

$$x_{1,t} = \begin{bmatrix} \pi_t & \pi_{t-1} & \pi_{t-2} & \pi_{t-3} & y_t & y_{t-1} & i_{t-1} & i_{t-2} & i_{t-3} \end{bmatrix}'$$

is the vector of the predetermined variables and $x_{2,t} = [\pi_{t+1|t}]$ is the vector of the forward-looking variable. i_t is the instrument of the monetary policy maker, assumed to be the short rate interest rate. $\varepsilon = \begin{bmatrix} \epsilon & 0 & 0 & 0 & \eta & 0 & 0 & 0 & 0 \end{bmatrix}'$ is a vector of disturbance terms. A and B are matrices containing the parameters of the model, i.e.,

$$A = \begin{bmatrix} e_{10} \\ e_1 \\ e_2 \\ e_3 \\ A_5 \\ e_5 \\ \bar{0} \\ e_7 \\ e_8 \\ A_{10} \end{bmatrix}, B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ -\frac{\beta}{4} \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

where e_j denotes a row vector with a unity element at column j and with the rest of the elements set

⁵The Rudebusch & Svensson model is an entirely backward-looking model with 4 lags of inflation in the Phillips curve.

⁶See Walsh (1998), chapter 1 for a textbook treatment and overview.

equal to zero; $\bar{0}$ is a row of zeros; and finally,

$$\begin{aligned} A_5 &= \begin{bmatrix} \frac{\beta}{4} & \frac{\beta}{4} & \frac{\beta}{4} & \frac{\beta}{4} & \rho_0 & \rho_1 & -\frac{\beta}{4} & -\frac{\beta}{4} & -\frac{\beta}{4} & 0 \end{bmatrix} \\ A_{10} &= \begin{bmatrix} -\frac{(1-\alpha)}{\alpha} & 0 & 0 & 0 & \frac{-\gamma}{\alpha} & 0 & 0 & 0 & 0 & \frac{1}{\alpha} \end{bmatrix} \end{aligned}$$

Rudebusch and Svensson provide reasonable coefficient estimates for the model, which we use as our benchmark values; $\gamma = .14$, $\rho_0 = 1.16$, $\rho_1 = -.25$ and $\beta = .1$. The estimated standard deviations of the disturbance terms are $\sigma_\epsilon = 1.009$ and $\sigma_\eta = .819$. α will be subject to some sensitivity analysis and $\alpha \in \{.05, .25, .5\}$ is considered. Our benchmark value is set at $\alpha = .25$ to reflect some degree of forward-lookingness in the price and wage setting processes close to the estimate provided by Fuhrer (1997) for the US economy.

The CII-targeting central bank obviously needs to decide on a specific forecast horizon. This decision should reflect a number of aspects, i.e., monetary policy lags, a horizon that facilitates communication with the public and, probably most importantly, the macroeconomic outcome with respect to both nominal and real stability. Table 1 shows the implied interest rate reaction functions corresponding to (13) for different targeting horizons and different degrees of forward-looking inflation behaviour - from almost an entirely backward-looking process ($\alpha = .05$) to moderately forward-looking ($\alpha = .25$) and finally a strongly forward-looking inflation process ($\alpha = .5$).⁷

First note that with an almost completely backward-looking inflation process our targeting procedure fails to achieve a stable economic development at any targeting horizon. The implied interest rate rule generally assigns too small reaction coefficient in front of the inflation terms in order to raise the interest rate sufficiently so as to influence the real interest rate into affecting aggregate demand in a stabilizing way. Consider as an example a shock to inflation. For targeting horizons between four and seven quarters, the nominal interest rate is raised less than the rise in the inflation rate. This leads to a decline in the real interest rate which has an expansionary effect. In subsequent quarters, the positive responses to lagged inflation are off set by the responses to lagged interest rates (the absolute values of the coefficients are equal) since these are treated symmetrically in the model. The result is instability. For targeting horizons beyond seven quarters, the nominal interest rate responds one-to-one to inflation

⁷Computation of the eigenvalues of the system corresponding to each horizon shows that there are no unstable eigenvalues in the system. Since there is one forward-looking variable in the system, there is one unstable eigenvalue too few (Blanchard and Kahn (1980)). There are therefore many potential rational expectation solutions to the model. Here we restrict ourselves to consider only the fundamental solution or that obtained from the minimum state variable criterion (McCallum (1983)).

$$i_t = f_1\pi_t + f_2\pi_{t-1} + f_3\pi_{t-2} + f_4\pi_{t-3} + f_5y_t + f_6y_{t-1} + f_7i_{t-1} + f_8i_{t-2} + f_9i_{t-3}$$

	h	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9
$\alpha = .05$	4*	-.52	.51	.37	.19	6.90	-1.91	-.51	-.37	-.19
	5*	-.38	.13	.08	.03	1.08	-.34	-.13	-.08	-.03
	6*	.45	.04	.03	.01	.55	-.13	-.04	-.03	-.13
	7*	.93	.06	.04	.02	.91	-.21	-.06	-.04	-.02
	8*	1.00	.06	.04	.02	.98	-.23	-.06	-.04	-.02
	10*	1.00	.06	.04	.02	.98	-.23	-.06	-.04	-.02
	12*	1.00	.06	.04	.02	.98	-.23	-.06	-.04	-.02
$\alpha = .25$	4	17.24	.88	.77	.47	21.81	-4.69	-.88	-.77	-.47
	5	3.90	.53	.38	.20	7.83	-1.95	-.53	-.38	-.20
	6	1.73	.29	.19	.09	3.62	-.93	-.29	-.19	-.09
	7	1.12	.15	.10	.05	2.00	-.50	-.15	-.10	-.05
	8*	.84	.09	.06	.03	1.30	-.32	-.09	-.06	-.03
	10*	.58	.05	.04	.02	.83	-.20	-.05	-.04	-.02
	12*	.96	.09	.06	.03	1.36	-.32	-.09	-.06	-.03
$\alpha = .5$	4	6.17	.98	.89	.54	23.11	-5.41	-.98	-.89	-.54
	5	2.23	.72	.53	.27	10.47	-2.73	-.72	-.53	-.27
	6	1.56	.49	.33	.16	6.18	-1.64	-.49	-.33	-.16
	7	1.31	.35	.23	.11	4.31	-1.12	-.35	-.23	-.11
	8	1.15	.26	.17	.09	3.45	-.88	-.26	-.17	-.09
	10	.92	.19	.13	.07	2.73	-.69	-.19	-.13	-.07
	12	.81	.17	.12	.06	2.43	-.61	-.17	-.12	-.06

Table 1: Interest rate reaction functions. A * denotes an unstable rule.

leaving the real interest rate unaffected. The inflation rate then becomes non-stationary. Reactions to the output gap are positive but not strong enough for any horizons to imply stability.

When the inflation process is moderately forward-looking as in our benchmark case, the implied reaction functions are more likely to achieve stability, since interest rate responses are generally stronger at least at shorter targeting horizons above three quarters. The policy responses are now strong enough to raise the real interest rate and therefore achieve stability. Output gaps responses are also generally stronger. A targeting horizon of seven quarters implies a reaction function that is reasonably close to the rule suggested by Taylor (1993). The sum of the coefficients in front of the inflation terms sum to 1.42 and in front of the output gap terms to 1.5. These values correspond to the Taylor coefficients of 1.5 and 0.5. A stronger output gap reaction is however compensated by negative reactions to the past interest rate which make the impact response stronger than the prolonged response compared to the simple structure of the Taylor rule. Extending the targeting horizon generally makes the responses weaker and above 7 quarters the interest rate reaction coefficient responses are too small in order to produce a stable equilibrium.

An extensively forward-looking Phillips curve ($\alpha = .5$) makes inflation even more dependent on the expected future developments in the determinants of inflation, i.e. the output gap development. In our model, the output gap causes inflation and controlling this gap is hence of great importance for achieving stability. When inflation is forward-looking it discounts future output deviation from the natural level into the short-run inflation development, which gives a stronger effect upon the inflation forecast at the prevailing targeting horizon. CII-targeting thus implies a reaction function that reacts strongly to the output gap and hence achieves better nominal and real stability.

3.1 Dynamic responses

Figure 2 displays the response of inflation to an output shock using the benchmark degree of forward-lookingness in the inflation process ($\alpha = .25$) and a targeting horizon of six quarters. In panel A the policy-consistent response of inflation is plotted as a solid line and shows the expected development of inflation after the initial shock. The dashed lines are the constant-interest-rate forecasts made in each quarter.

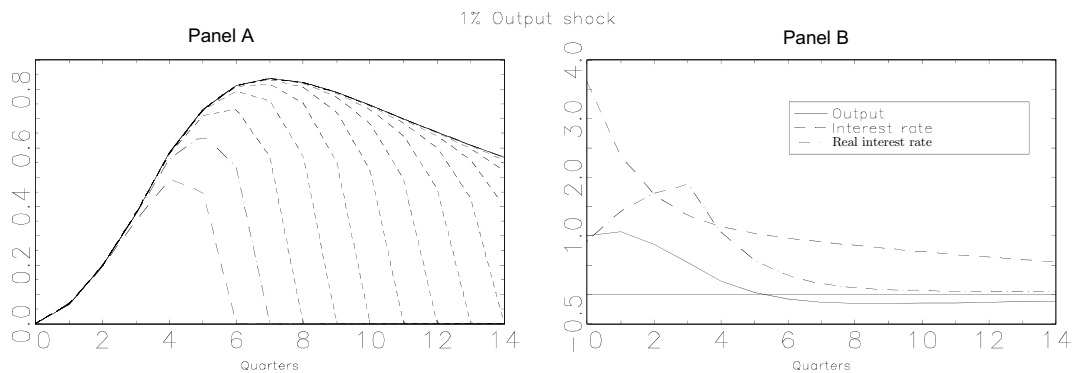


Figure 2: Panel A shows the evolution of the policy-consistent four-quarter inflation response (solid line) and the constant-interest-rate four-quarter inflation response to an output shock with a targeting horizon of $h = 6$. Panel B shows the corresponding output, nominal and real interest rate responses.

The impulse responses suggest that the expected development of inflation follows a considerably smoother path than the constant-interest-rate forecasts indicate. As time passes, the new forecast horizons require a loosening of monetary policy and the interest rate drops. The responses to the output gap, the nominal interest rate and the real interest rate⁸ are displayed in panel B. The output gap is closed five quarters after the initial shock and then remains negative for a rather long period in

⁸The real interest rate is defined here as $\tilde{i}_t - \tilde{\pi}_t$, i.e., the four-quarter moving average of the difference between the nominal interest rate and the inflation rate.

order to lower inflation. The four-quarter moving real interest rate is at its peak 3 quarters after the impact and then declines monotonically towards its equilibrium value. Inflation picks up slowly after the output shock impact and reaches its peak after 7 quarters.

Figure 3 shows the same panels with respect to an inflation shock.

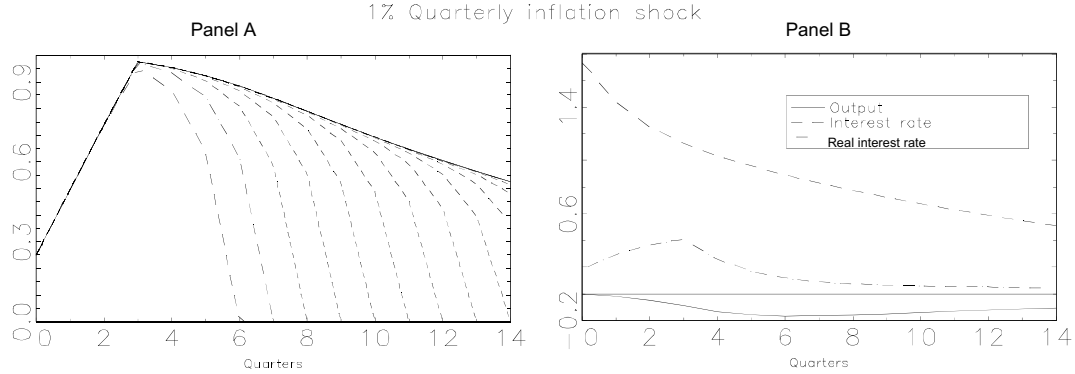


Figure 3: Panel A shows the policy-consistent and the constant-interest-rate responses to an inflation shock. In panel B, the corresponding responses to output, nominal and real interest rates are plotted.

The shock to inflation is met with a nominal interest rate increase which subsequently has an impact on the four-quarter real interest rate and hence aggregate demand. However, the lag structure of the model implies that it takes time to have an important effect on inflation. Inflation therefore picks up rather rapidly and only after three quarters the negative output gap is starting to show an effect on inflation.

3.2 The optimal forecast horizon

In this section we first consider what the optimal choice of the length of the forecast horizon is and try to inquire what it may depend upon. We then compare the CII-targeting strategy with optimally chosen forecast horizon to the discretionary optimum where the CB is allowed to minimize its loss function under discretion.

We postulate that the central bank has a particular quadratic periodic loss function with the four-quarter inflation rate as the main argument and the output gap and the change in the interest rate as additional arguments, i.e.,

$$L_t(\lambda, \nu) = (\bar{\pi}_t - \pi^*)^2 + \lambda y_t^2 + \nu (i_t - i_{t-1})^2,$$

where λ and ν measure the relative importance of output stabilization and interest rate smoothing in the loss function. This periodic loss function can be seen to reflect a concern for nominal, real and financial

stability respectively, or merely an approximation to a more complex loss function. The optimal horizon is therefore the one that minimized the expectation of this periodic loss function intertemporally, i.e.,

$$h = \arg \min_{\{i_{t+s}\}_{s=0}^{\infty}} E_t \sum_{s=0}^{\infty} L_{t+s}(\lambda, \nu)$$

Table 2 shows the standard deviations in percent of some key variables ($\bar{\pi}, y, \Delta i$) in columns 3,4 and 5 at different targeting horizons. In this paper we use a particular value assigned to the importance of interest smoothing with $\nu = .25$ throughout but vary the degree to which output stabilization is important to the monetary policy maker. Columns 6-8 show the losses expected under different assumptions about this degree. The last column shows the standard deviations of the policy-consistent forecast of the four-quarter inflation rate at the appropriate horizon.

h		$\bar{\pi}$	y	Δi	$L(0, .25)$	$L(.5, .25)$	$L(1, .25)$	$\bar{\pi}_{t+h t}$
$\alpha = .05$	any	unstable						
$\alpha = .25$	≤ 3	unstable						
	4	1.48	1.72	43.45	474.3	475.7	477.2	.26
	5	2.44	2.60	9.19	27.1	30.4	33.8	.79
	6	3.94	4.04	3.68	18.9	27.1	35.3	1.94
	7	8.35	8.40	2.02	70.7	106.0	141.2	5.68
	≥ 8	unstable						
$\alpha = .5$	≤ 3	unstable						
	4	.93	1.25	39.19	384.7	385.5	386.3	.070
	5	1.28	1.55	12.62	41.4	42.6	43.8	.097
	6	1.69	1.92	6.37	13.0	14.8	16.7	.104
	7	2.14	2.36	4.15	8.9	11.7	14.4	.076
	8	2.61	2.81	3.24	9.4	13.4	17.4	.020
	10	4.08	4.24	2.48	18.2	27.2	36.2	.288
	12	8.04	8.14	2.17	65.8	98.9	132.0	.838
	≥ 14	unstable						

Table 2: Loss and percentage standard deviations

The most important result from this exercise seems to be that the choice of targeting horizon is a choice between having low nominal and real variability at a reasonably short horizon or having smoother interest rate movements at longer horizons. Hence, our (simple) model does not suggest that the choice of targeting horizon needs to include any considerations about a possible trade-off between nominal and real stability for $\alpha = \{.25, .5\}$. A shorter horizon (up to a certain point) involves both better inflation and output stabilization. However, a horizon shorter than a year produces instability. In order to get the constant-interest-rate forecast on target at this short horizon, output needs to be excessively volatile which requires an increasingly strong use of the interest rate - implying exploding cycles.

The variability of the policy-consistent forecast of inflation addresses a potential important issue pertaining to CII-targeting - to what degree one should expect inflation to return to the target level at the end of the given targeting horizon. A low number is convenient because it implies that the targeting horizon will be more in line with 'having inflation back to target at the end of the targeting horizon' - which may be more compatible with the more general view of a targeting horizon: the time in which inflation is expected to have returned to target. Unfortunately, the results do not seem to point in any clear direction. When $\alpha = .25$ a targeting horizon of 4 quarters offers the lowest variability of inflation at the end of the horizon, whereas for a more forward-looking inflation process with $\alpha = .5$, the corresponding horizon is 8 quarters. These results are also sensitive to the assumptions made about the distributions of the error-terms in the model.

Measured by expected losses, the optimal targeting horizon is between five and seven quarters. Whereas a more forward-looking inflation process tends to lengthen the optimal horizon, the degree to which the CB explicitly cares about output stabilization (as measured by λ) has only a minor shortening effect on the horizon. The latter point is the easiest to explain. As a shorter horizon tends to increase both nominal and real stability, placing a higher weight on any of these arguments relative to the interest rate smoothing argument will imply a shortening of the optimal horizon. A more forward-looking Phillips curve means, as noted above, that inflation is to a larger degree dependent on the expected future development in the output gap. An expected future positive output gap in the future will then more strongly affect inflation today. The (persistent) output gap will therefore be a stronger indicator of inflationary pressure and responding to it produces a better outcome for inflation and output. This is exactly what happens under CII-targeting: As the constant-interest-rate forecast of inflation now is more strongly determined by the output gap, CII-targeting implies stronger reactions to exactly this indicator. In other words, a forward-looking inflation process benefits the central bank that wants inflation quickly to return to its target level since future expectations of inflation now determine next period inflation to a larger degree. This *expectations channel of monetary policy* has a stronger impact the more forward-looking the inflation process is. Fuhrer (1997) stresses that an argument for having partly forward-looking elements in the Phillips curve is that it produces more stable (and realistic) inflation dynamics than an entirely backward-looking inflation process does. Such effects would also benefit and be exploited by the inflation targeter.

As is illustrated by figure 4, a more forward-looking inflation process contributes to stability but the length of the targeting horizon to instability, i.e., a backward-looking process commands a shorter targeting horizon in order to induce stability.

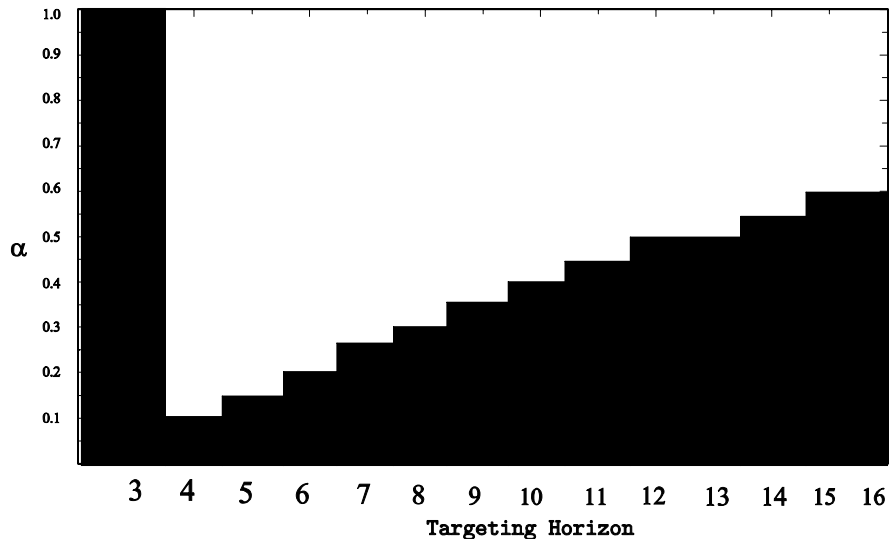


Figure 4: Stability area - the black area shows the region of instability.

Table 3 shows the comparable losses under discretionary optimization which denotes the best rational expectations equilibrium attainable with a time-consistent policy⁹. The optimal discretionary policy may be viewed as a benchmark for comparing different strategies in a specific model.

Minimized losses	L(0,.25)	L(.5,.25)	L(1,.25)
$\alpha = .25$	10.38 (18.9)	14.39 (27.1)	18.12 (33.8)
$\alpha = .5$	7.24 (8.9)	9.86 (11.7)	12.25 (14.4)

Table 3: Losses obtained under discretionary optimization and CII-targeting (in parentheses) under the optimal choice for the targeting horizon

The numbers in the parentheses restate the comparable losses obtained by following CII-targeting at the best targeting horizon. As is evident from the table, CII-targeting compares relatively unfavorably to discretionary optimization when the inflation process is only moderately forward-looking (first row). This is true irrespective of the degree to which losses depend on output stabilization. Losses are almost twice as large for all specifications of the loss function. The comparison is much more favorably when the inflation process is more forward-looking (second row). Absolute losses drop as the expectations channel now plays a stronger role which has a stabilizing effect on output and inflation. It should, however, be noted that the relatively improved performance of the CII-targeting strategy is presumably not only a result of the CII-targeting strategy having a better influence of expectations formation and model stability, but also because the discretionary optimization policy is constrained to have a time-

⁹See Backus and Driffill (1986) for how this equilibrium is calculated in an dynamic model with forward-looking variables.

consistent development which removes the policy maker's ability to favorably affect future expectations - an ability that is crucial in influencing the outcome with a forward-looking inflation process.

The analysis suggests that the main reason for having an extended targeting horizon reflects an unwillingness on the part of the central bank to change the interest rate frequently and in large steps. This *interest rate smoothing* argument could reflect a concern for financial stability but also reasons more closely related to the practise of monetary policy itself, e.g., reflecting uncertainty (Brainard (1967); Rudebusch (1998)), a strategy for controlling forward-looking variables (Woodford (1999)) or simply to have actual policy reflecting to some degree the policy assumption of a constant interest rate inherent in CII-targeting.

4 Concluding remarks

Constant-interest-rate targeting is an intuitive way of implementing inflation targeting. It simplifies communication with the public and provides strong arguments for interest rate adjustments. However, its macroeconomic outcomes can be questioned as its generally performs much poorer than the discretionary optimum.

The paper stresses three main points which may be labeled as technical, logical and economical. The logical point pertains to the idea that a fixed targeting horizon does not necessarily imply that inflation will return to its target by the end of any given horizon unless the targeting horizon coincides with the shortest lag at which the interest rate affects inflation (in which case CII-targeting corresponds to minimizing a quadratic loss function with inflation as its only argument). As time passes, the end of the forecast horizon moves forward in time and the corresponding inflation target follows suit. The return of inflation to target is therefore postponed into the future. This form of "time-inconsistency" in the CII-targeting framework is potentially a threat to the credibility of the central bank in its pursuit of providing a nominal anchor for the economy.

As rational forward-looking agents realize this, a method for analyzing constant-interest-rate forecast targeting necessarily needs to take account of this. This is the technical point of the article.

Within a small model of the US economy, analysis shows that the optimal targeting horizon is between five and seven quarters - somewhat shorter than the two-year horizon utilized by most inflation targeting CBs. Furthermore, we show that if the central bank values interest rate smoothing, it is likely to choose a long forecast horizon which is achieved at the cost of both more real and nominal instability. The usual trade-off between nominal and real stability does not seem to be an issue in the

choice of the forecast horizon as both form of stability moves together and in the same direction within the CII-targeting framework. A shorter forecast horizon than a year, however, results in the model being unstable.

The analysis has been conducted within a small model for a closed economy. Leitemo (1999) extends the model into an open-economy version with a tradeable and a non-tradeable sector and arrives at similar conclusions: an extended targeting horizon allows the central bank to smooth interest rate behaviour at the cost of higher output and inflation variability. This indicates that the third main economical point in this paper may be reasonably robust.

Appendix

A A procedure for constructing consistent forecast through backward induction

Assume that the CB actually implemented the Svensson procedure. It would need to address the problem of having the same policy within the targeting period and beyond the targeting period. Arguably, the central bank could proceed by accepting that the forward looking variables were determined according to backward induction so that

$$\tilde{x}_{2,t} = H^* x_{1,t}$$

is some adjusted measurement of the forward looking variables, sufficient for their forecast, and which acted as the true representation of these variables. This forecast could, however, not rely on an arbitrary assumption about the policy prevailing in the time following the forecast period. In order to be consistent, this policy must be equivalent to the one in the forecast period. Assume that this policy is,

$$i_t = \tilde{F}_j X_t$$

where $\tilde{F}$ so far is unspecified. This linear policy rule will have a corresponding linear solution to the forward looking variables¹⁰ (Blanchard and Kahn (1980)), denoted by

$$x_{2t} = \tilde{H}_j x_{1t}$$

and from (16) we can obtain H_j^* from backward induction and is given from the following set of equations,

$$\tilde{H}_j (G_{11}^* + G_{12}^* H_j^*) = (G_{21}^* + G_{22}^* H_j^*)$$

where G^* is defined as before: $G^* = \left[A^h + \sum_{i=0}^{h-1} A^i B \tilde{F}_j \right]$.

In order to update $\tilde{F}_j$, observe that

$$\pi_{t+h|t}(\tilde{i}, H^*) = K A^h \begin{bmatrix} I \\ H_j^* \end{bmatrix} x_{1t} + K \sum_{j=0}^{h-1} A^j B i_t$$

¹⁰Given that the Blanchard-Kahn condition is satisfied: $A + B\tilde{F}$ has as many unstable eigenvalues as forward looking variables.

and given the policy target, $\pi_{t+h|t}(\bar{i}, H^*) = 0$, the instrument reaction function would be,

$$\begin{aligned} i_t &= - \left(K \sum_{j=0}^{h-1} A^j B \right)^{-1} A^h \begin{bmatrix} I \\ H_j^* \end{bmatrix} x_{1t} \\ &= \tilde{f}_{j+1} x_{1t} \end{aligned}$$

and $\tilde{F}_{j+1} = \begin{bmatrix} \tilde{f}_{j+1} & 0 \end{bmatrix} \cdot \tilde{H}_{j+1}$ can now be recomputed and iterative procedure starts over again. If this procedure converges and the Blanchard-Kahn conditions are satisfied, we know that there exists a solution to the policy rule and a corresponding solution for the forward-looking variables.

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