An empirical evaluation of inflation forecast based monetary policy – the case of Sweden

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Abstract: In this paper we take a few steps towards evaluating some aspects of monetary policy under *inflation forecast targeting*, and while it is confined to Sweden we believe the results may be of wider interest. We use regression analysis to evaluate some aspects of the Riksbank's inflation forecasts and policy. While the methodology is simple, it allows us to address questions from a different perspective than in much of the literature. Our main results are that the information available appears to be efficiently incorporated into the inflation forecasts, but that the forecast revisions are "too slow", resulting in persistence in the forecast errors, which are in the same direction over several years. We find that the constant interest rate assumption is problematic. Moreover, there are some evidences of underestimation of the inflation effects of foreign inflation in the short run (one year) and that of the exchange rate in the longer run (two years). We also observe smaller inflation target deviations over time. Finally, we find results consistent with the conventional wisdom that monetary policy has most effects on the 1-2 year horizon.

1. Introduction

The arguments for making central banks independent with clear mandates for price stability have had considerable influence on economic policy and macroeconomic development in recent years. Many countries have changed their laws and institutions in line with suggestions from the academic literature. Today we stand with several years of experience of inflation targeting gained from independent central banks.

In this paper we investigate some aspects of the monetary policy pursued by Sveriges Riksbank. While confined to the Riksbank's experience, we believe there are wider lessons applicable outside of Sweden, in particular concerning the framework of *inflation forecast targeting*. In brief, the principle guiding inflation forecast targeting at the Riksbank is as follows: it is the inflation forecast, conditional on an assumption of unchanged repo rate (the normal steering instrument of the bank) over the forecast

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horizon that determines the course of monetary policy. If the forecast one to two years ahead is below the target of two percent inflation, the repo rate should normally be lowered and vice-versa.[1]

It is important to evaluate monetary policy for a number of reasons. First of all, with operational independence for central banks there should also be public accountability. For example, how well has the goal of price stability been achieved? Secondly, an evaluation may also be of help to the central bank aiming to improve future monetary policy.

The inquiry in this paper is focused on two types of questions for monetary policy. The first is to what extent the Riksbank's inflation forecasts efficiently utilises the information available at the time of the forecast. More specifically, we investigate if information dated *at the time of the decision* can explain any of the systematic difference between the forecast and the eventual outcome. Presumably the forecast error is an important explanation of why *actual* inflation deviates from the *target* inflation rate of two percent – once the assumption of constant repo rate is accounted for.

The second question concerns monetary policy in a slightly broader sense. We investigate various empirical features of the inflation targeting regime. How much of the forecast error can be attributed to the technical assumption of the constant repo rate? To what extent has policy – that actually deviates from constant repo rate – lead to smaller deviations from the inflation target? Do the empirical results point to some ways in which monetary policy could have been better in the sense of having inflation more stable around the target of two percent? What if anything can be said about the speed of forecast revisions in the right direction?

Ours is of course not the first study on this topic. There are several studies that aim at evaluating independent inflation targeting central banks.[2] Our study utilises econometric techniques that are tailor-made for the framework in which policy is conducted, making it easy to interpret and to relate to the performance objective of

[1] For more details about various aspects of the Riksbank's framework, see for example Heikensten and Vredin (2002) or the box "Monetary policy and simple rules" in Inflation Report 2002:1.
[2] See Svensson (2001), Svensson, Houg, Solheim and Steigum (2002), Jansson, Vredin (2001) and Berg, Jansson and Vredin (2003). For cross country evaluations, see e.g. Corbo, Landerretche and Schmidt-Hebbel (2001) and Bernanke, Laubach, Mishkin and Posen (1999). For an evaluation of US monetary

the Riksbank. In addition, our econometric framework allows us to address the questions outlined above from a different perspective than usual in the literature.

Central banks performance is of course also discussed outside the academic literature. Often there will be political structures that deal with this. In Sweden, the Governor of the Riksbank appears in a sub-committee of parliament twice a year to explain and defend the bank's performance. In order to assist the parliament in its evaluation, the Riksbank publishes a text in its inflation report detailing the conduct of monetary policy and the arguments that underpinned it.[3] Alas, the investigative capability of the parliament is limited and independent academic studies as well as inquires by journalists remain important.[4]

The rest of this paper is outlined as follows. In the next section we discuss the model rationale for our specification; the third section discusses the empirical results, the fourth explores some issues for the conduct of monetary policy and the final section concludes. Tables of results and details about the data as well as model based derivation of the regressions that underpins the analysis are in the appendix.

2. A framework for evaluating the Riksbank's inflation forecasts and policy.

Our econometric specification can be derived from a traditional backward looking model with a quadratic loss function assigned to the central bank, see the appendix for details (TBW). The intuition for the setup is that since monetary policy is based on the *inflation forecast* it should contain (most of) the information we need. Moreover, the forecast errors should therefore contain information about the size and direction of potential policy errors. Of course, we have to control for the technical assumption of constant repo rate over the forecast horizon, an issue discussed more below.

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policy see Rotemberg and Woodford (1997).

[3] Since 1999 the first Inflation Report of the year contains an appendix where monetary policy in recent years is assessed.

[4] The audit committee of the Swedish parliament published an evaluation of the Riksbank recently. The evaluation focused on other things than the conduct of monetary policy. The (Swedish) National Institute of Economic Research published an evaluation of the Riksbank in 2002 (Penningpolitiken 1999-2001, Occasional paper No.1, available in Swedish only), but no further evaluations are planned so far.

The notion that the inflation forecast errors contain information about monetary policy is central to our setup. Admittedly, inflation forecast errors can occur for other reasons unrelated to policy. There are always going to be unpredictable shocks in the economy which will affect future inflation. Moreover, it might be the case that the forecast error – and the consequent policy response – was the result of having the "wrong" model or that the transmission mechanism in the economy has changed over time.[5] Orphanides (1999) provides an important example of how central bank misperceptions about the economy can lead to policy errors. We will not be able to distinguish between the latter two explanations, but we will be able to investigate *systematic* deviations that depart from white noise errors.

The econometric specification

In our setup we posit a simple linear relation between the forecast errors, information at the time of decision and monetary policy. In a regression framework this yields two basic econometric equations

$$(1)\quad \pi_{t+4} - \pi_{t+4|t} = \alpha_t + \beta x_t + \delta r_{t-1} + \omega_1 \Theta_t^1 + R(L)\varepsilon_{t+4}$$
$$(2)\quad \pi_{t+8} - \pi_{t+8|t} = \alpha_t + \beta x_t + \delta r_{t-1} + \omega_2 \Theta_t^2 + R(L)\varepsilon_{t+8},$$

where the frequency is quarterly, π_t is the yearly CPI-inflation rate, α_t is a potentially time varying intercept, x_t is a set of variables *known* at time t (i.e. real time unrevised data) and r_{t-1} is the repo rate determined at the previous adjustment date; Θ_t^i is a measure of monetary policy over the forecast horizon. In some specifications Θ_t^i will be pre-determined (an issue discussed more below).

We make the standard assumption about ε_t being uncorrelated with the exogenous variables. What this implies in our specification is that monetary policy is presumed not to react to temporary shocks to inflation.[6] The information set x_t is presumed to contain all the relevant information for monetary policy, including shocks on which monetary policy may react.

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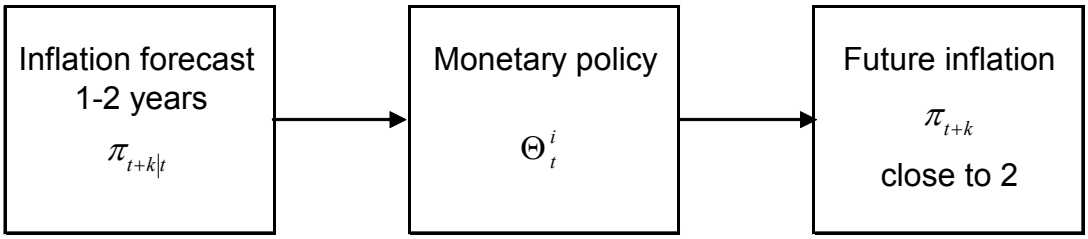
[5] Our analysis is similar to that of Andersen and Wascher (2001), who analyse OECD forecasts.
[6] See Heikensten, Lars (1999).

Econometric specification of monetary policy

The econometric setup is also guided by a view of the monetary transmission mechanism, as depicted in diagram 1. The diagram shows a highly stylized view of monetary policy, but which suffices for our purposes: as stated by the Riksbank, its decision rule for monetary policy is that if the inflation forecast $\pi_{t+k|t}$, conditional on constant repo rate, is above the target of two percent, then the repo rate should normally be raised; and conversely if the forecast is below the target – in order to bring inflation in line with the target.

Although this last point may be rather obvious, it has implications for our specification. In particular, $\pi_{t+k|t}$ can be viewed as pre-determined in the sense that it is clearly not affected by future monetary policy in the regressions so that the only remaining term on the LHS that is affected by the variables on the RHS is π_{t+k}. Concerning the timing in the specification, the choice of a forecast evaluation with 4 and 8 quarters horizon, is set to coincide with the monetary policy lag assumed by the Riksbank.

Diagram 1. Simple schematic summary of inflation forecast targeting.



A central implication of the inflation forecast targeting regime is that there *should* be systematic differences between actual and forecasted inflation, but that this difference should disappear once we control for the fact that policy typically deviates from the constant repo rate assumption. In other words, if the central bank utilises available information efficiently β and δ in (1) and (2) should be zero – or at least insignificantly different from zero in the statistical sense. If systematic forecast errors still remain, then it stands to reason that a more "efficient" policy would have led to inflation being closer to the target. The magnitude and pattern of the estimation residuals may give an indication of how much better the policy could have been. The notion of a "more efficient" policy, however, should not be taken to imply that society

somehow would have been better off. That is of course an important question but which we cannot address in our framework.

The role of the lagged repo rate r_{t-1}

If the Riksbank correctly evaluates the inflation effects of holding the repo rate constant, then δ in forecast error equations (1) and (2) should be zero. If the Riksbank's inflation forecast partly ignores the constant repo rate assumption by including some unconditional elements (that incorporate forecasted repo rate developments) then this will result in a negative δ.

The negative δ can be illustrated by the following example.[7] Suppose the Riksbank makes a forecast that implies a high future inflation that leads to an *expected* increase of the repo rate. Since the repo rate increase was expected, there is no reason for the external institutions to revise their (unconditional) inflation forecasts. However, the Riksbank's inflation forecast should be revised downwards since the repo rate now is assumed to be constant at a higher level, which should dampen future inflation compared to the forecast under constant repo rate. But if the Riksbank's inflation forecast is heavily influenced by for example external unconditional forecasts this can lead to the downward revision being too small. Hence, an increase of the repo rate will in this example be associated with $\delta < 0$. A positive δ, on the other hand, can be interpreted as the Riksbank's inflation forecast overreacting to changes in the constant repo rate assumption.

Controlling for the assumption of the constant repo rate

In order to discuss various ways of approaching the issue of the constant repo assumption, we first need to make a few definitions. Let

$$(3)\quad \Omega_t^1 \equiv \sum_{i=1}^{4}\left(\overline{r}_{t+i} - r_{t-1}\right)/4, \qquad \Omega_t^2 \equiv \sum_{i=5}^{8}\left(\overline{r}_{t+i} - r_{t-1}\right)/4,$$

where $\overline{r}_t$ is the average observed repo rate in the quarter concerned and r_{t-1} is the assumed constant level of the repo rate. Thus, they measure the difference between the actual repo rate and that implied by the constant repo rate assumption for the first

[7] Here we presume that there the transmission mechanism works normally, i.e. an upward adjustment of

year and for the second year of the forecast horizon respectively. Also, define the corresponding expressions

$$(4)\quad A_t^1 \equiv \sum_{i=1}^{4}\left(\hat{r}_{t+i|t} - r_{t-1}\right)/4, \qquad A_t^2 \equiv \sum_{i=5}^{8}\left(\hat{r}_{t+i|t} - r_{t-1}\right)/4$$

where $\hat{r}_{t+i|t}$ is the market repo rate expected by the market. These measures allow us to construct the following alternative measures of monetary policy in the regressions (1) and (2):

$$(5)\quad \omega_1 \Theta_t^1 = \begin{cases} \chi\Omega_t^1 & \text{Case 1} \\ \chi\Omega_t^1 + \psi A_t^2 & \text{Case 2} \\ \phi A_t^1 & \text{Case 3} \\ \phi A_t^1 + \psi A_t^2 & \text{Case 4} \end{cases}, \text{ and } \omega_2 \Theta_t^2 = \begin{cases} \chi\Omega_t^1 + \psi\Omega_t^2 & \text{Case 5} \\ \chi A_t^1 + \psi A_t^2 & \text{Case 6} \end{cases}.$$

We tackle the assumption of constant repo rate in two ways. First, we compute what might be labelled an *ex post* measure of the difference between actual monetary policy and the constant repo rate assumption. More specifically, we consider cases 1, 2 and 5. When these are substituted into the regressions in (1) and (2) we get time t regressions but which include future inflation on the LHS and future monetary policy on the right. In this way, we attempt to empirically control for the effects of monetary policy.

Cases 1 and 5 are straightforward in that they just include the actual future repo rate. Case 2 also includes a term for expected monetary policy for the period after one year. The rationale for this term is that the assumption of constant repo may influence one year forecast errors via effects from the long-term interest rates.[8] Overall, we should expect the coefficient on Θ_t to be negative and significant on 1-2 years horizon but small and insignificant on 1 year horizon if the conventional wisdom about the lag of monetary policy is correct. One reason for a small (and potentially) positive effect on the inflation rate is the presence of the so called interest rate expenditure costs that can contribute to a positive inflation effect in some circumstances.[9]

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the constant repo rate assumption will dampen future inflation.

[8] In the Riksbank's forecasting process, the repo rate is assumed to be constant only during the forecast period of about 8 quarter and thereafter it returns to the path according to market expectations.

[9] See the box "House mortgage Interest Costs" in the Inflation Report 1998:1, page 22.

The second way of controlling for the assumption constant repo rate concerns the variables A_t^1 and A_t^2, an approach that might be labelled the *ex ante* method. They reflect how much the constant repo rate assumption deviates from the future repo rate path *expected by the market*, which is of course a path much more likely than that of constant repo rate.

Serial correlation in the residuals

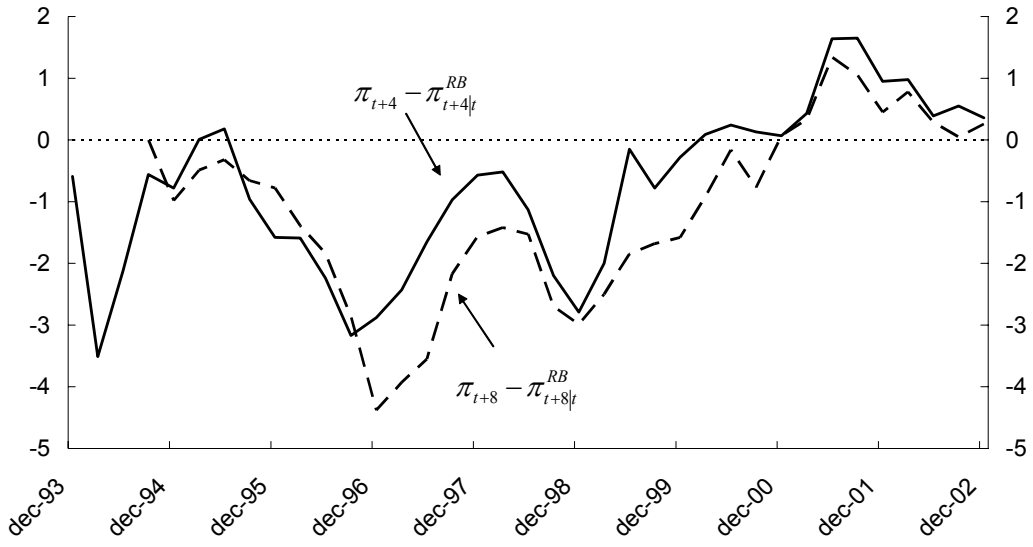
Finally, a separate issue is that we may expect to obtain serial correlation in the error terms – both autoregressive and moving average. Moving average terms will arise from including yearly changes (in particular the inflation forecast errors) in a quarterly frequency as there will then be data overlap. Autoregressive errors can also arise for example when the forecast is revised too slowly as warranted by the data. This is an issue we will return to below when we turn to interpreting the effectiveness of monetary policy. To safeguard our conclusions from problems with serial correlation in the error term we focus on the specifications with ARMA errors.

3. Forecast evaluation

The empirical results

In this section we discuss the empirical results. The above considerations tie down some aspects of the specification, but leave a number of issues open. Which variables should be included in the information set x_t? Levels or differences? In this section we briefly discuss these issues before turning to the results.

Diagram 2. Inflation forecast errors.



Note: The forecast errors are presented at the time of the inflation outcome.

Diagram 2 shows the forecasting errors of the Riksbank, i.e. $\pi_{t+4} - \pi_{t+4|t}$ and $\pi_{t+8} - \pi_{t+8|t}$, over the time period concerned. It illustrates some features that the regressions need to capture. First of all, there was a systematic overprediction of inflation for a large part of the sample. But during the last three years the errors have been in the other direction. Although in econometric terms this underprediction is still rather short, it is important for the modelling process. It is clear that the strong autocorrelation of the forecast errors cannot be attributed to overlapping observations only. We handle the systematic features in the forecast errors by trying alternatives such as dummy variables, persistent economic variables and ARMA type estimation residuals. Secondly the swings in the forecast error may have become smaller, although the time period on which to base such a conclusion is still rather short.

The specification of the information set x_t

In principle, many variables may be included in x_t. Indeed, most of the information set that is used in a forecasting round would qualify. In practice, we are constrained by having rather few observations (less than 35). We therefore need to keep the number of variables included in x_t fairly limited. The variables we have chosen to be included

in x_t are the lags of the domestic CPI-inflation rate, the OECD inflation rate, the change in trade weighted exchange rate TCW and the annual unrevised change in GDP (measures of the output gap have not been published). We have tried other variables as well in a large number of regressions. But the variables chosen represent the features that we have found to be most important for inflation forecasts.[10]

Results consistent with central bank conventional wisdom

Table B1 in the appendix shows several different regression specifications for equation (1). Many of the variables included in x_t are not significant and change signs but collectively they explain much of the deviation of the forecast error. It is clear that there is much multicollinearity in the regressions, but we do not view this as a problem for our purposes. The major finding is that virtually none of the variables in x_t have robustly non-zero effects, thus indicating that the available information in this sense has been efficiently incorporated into the forecasts.[11]

Also important for our purposes are the results on Ω_t^1 and r_{t-1}. The effect of monetary policy on the inflation forecast error after four quarters is small and insignificant. This supports the notion, often contended by central banks, that only a little part of the effect from monetary policy appears on such a short horizon. This result appears robust to the specifications we have tried, as long as the term r_{t-1} is included.

What about the effects on the two year horizon as represented by the regression (2)? The explanatory power of these regressions in table B2 is somewhat higher than those in table B1, which is also consistent with the conventional wisdom of monetary policy transmission mechanism. Note that the terms capturing monetary policy have "switched" roles in this regression as compared to (1): here Ω_t^2 should be small as it represents the effects after only four quarters and Ω_t^1 representing the effect of policy on the eight quarter horizon should be negative. Notably, this is roughly what happens

[10] As for the question of levels or differences, yearly change or quarterly, we have been agnostic wherever economic theory does not provide strong suggestions. In those cases, we have tried several permutations and ended up with the ones that pass the econometric diagnostic tests and/or that have the best fit.

[11] The inflation rate in the OECD area may constitute an exception to this in that it sometimes enters significantly in the regressions, perhaps indicating an underestimation of the short run inflationary

and, moreover, the results are robust: Ω_t^1 is significantly different from zero and robustly negative, whereas Ω_t^2 is smaller and (with one exception) insignificant.

When the constant repo rate assumption is evaluated from an ex ante perspective we obtain a positive effect on 4-quarters forecast errors (Eq. (1d)), that is positive but small and insignificant. In the 8-quarters forecast error equation (Eq. (2d)) the effects are small and insignificant, but the total effect of A_t^1 and A_t^2 is negative. The effects may be somewhat blurred by the fact that much of the variation in A_t^1 and A_t^2 stem from the pre-1996 period when interest rates were heavily affected by credibility problems.[12] A_t^2 has a negative impact when it is added to the 4-quarters forecast error equation (Eqs. (1e) and (1f)), which indicates that the assumption that the repo rate is held constant below the expected repo rate path beyond the forecast horizon has positive effects on the forecasts, e.g. via its effect on longer interest rates.

As regards the other terms captured by x_t, similar to the findings in the table, there are no clear patterns. The TCW-exchange rate has many times been weaker than forecasts by the Riksbank (and others). The coefficient on the exchange rate is often positive and sometimes significant and fairly stable for the two year horizon. Our tentative interpretation of this result is that the Riksbank's view concerning the krona's development systematically has been too strong. When the krona depreciates a rather pronounced appreciation of the krona has been forecasted whereas the actual development of the krona has been weaker, which in turn has lead to positive inflation forecast errors.

4. An empirical evaluation of monetary policy

In the previous section we analysed the forecast errors when controlling for the assumption of the constant repo rate. In this section we build on that setup in order to pose some questions for the conduct of monetary policy in Sweden. We will not be able to assess monetary policy from a welfare theoretic perspective; for that, a different approach is needed. Also we do not specifically discuss the issue of target fulfillment,

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effects from global price developments.

[12] See Dillen and Hopkins (1998) for an analysis of Swedish interest rates and credibility problems.

as this is already well documented in the inflation reports. But we will attempt to shed some light on the extent to which policy has reduced target fluctuations and the extent to which the assumption of constant repo actually appears implemented in the Riksbank's forecasts. In other words, we approach issues that more concern the consistency of the pursued monetary policy in relation to the inflation forecasts.

For this purpose, let us define the following two variables,

(6) $$z^{RB}_{t+8|t} \equiv \pi_{t+8} - \pi^{RB}_{t+8|t} - \hat{\chi}\Omega^1_t - \hat{\psi}\Omega^2_t$$

(7) $$w^{RB}_{t+8|t} \equiv \pi_{t+8} - 2 - \hat{\chi}\Omega^1_t - \hat{\psi}\Omega^2_t$$

where $\hat{\chi}$ and $\hat{\psi}$ are estimated coefficients from the previous section. The first expression $z^{RB}_{t+8|t}$ is simply the inflation forecast error "corrected" for the constant repo rate assumption; the second expression $w^{RB}_{t+8|t}$ denotes deviations from the target with a correction for the actual monetary policy pursued. Note that both expressions are conditioned on the repo rate prevailing the time one period before.

Hypotheses for the conduct of monetary policy

The expressions in 6 and 7 allow us to discuss forecast deviations and target deviations due to the conduct of monetary policy. In particular we are interested in examining the following two hypotheses:

(i) $E\left[\left|z^{RB}_{t+8|t}\right|\right] < E\left[\left|\pi_{t+8} - \pi^{RB}_{t+8|t}\right|\right]$

(ii) $E\left[\left|w^{RB}_{t+8|t}\right|\right] > E\left[\left|\pi_{t+8} - 2\right|\right]$

The first hypothesis states that the inflation forecast errors should be smaller when corrected for the constant repo rate assumption; the second states says that the conduct of monetary policy should lead to smaller target deviations than otherwise. Clearly the hypotheses are sensitive to the parameters $\hat{\chi}$ and $\hat{\psi}$, and below we comment briefly on this robustness issue. In what follows the analysis is based mainly on parameters we believe are representative of the most realistic values (eq. 2b in table B2 in the appendix).

Table 1. Some statistics for forecast errors and target deviations

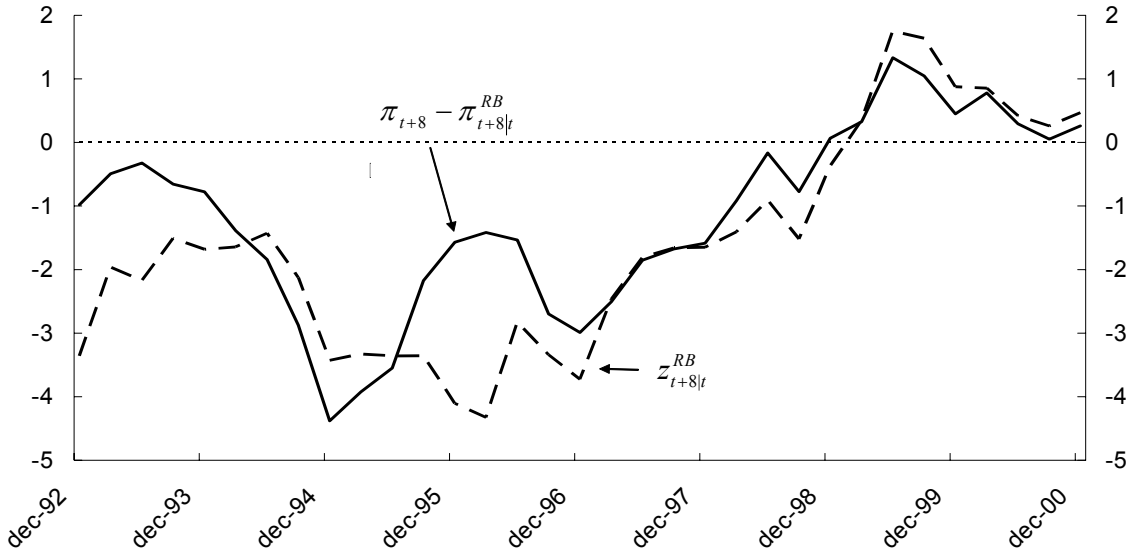
	$z_{t+8\|t}^{RB}$	$\pi_{t+8} - \pi_{t+8\|t}^{RB}$	$w_{t+8\|t}^{RB}$	$\pi_{t+8} - 2$
Mean 92:4-00:4	-1,60	-1,16	-0,97	-0,53
Abs mean 92:4-00:4	2,00	1,44	1,35	1,01
Mean 92:4-96:4	-2,80	-1,97	-1,53	-0,70
Abs mean 92:4-96:4	2,80	1,97	1,53	1,14
Mean 97:1-00-4	-0,32	-0,30	-0,37	-0,35
Abs mean 97:1-00:4	1,15	0,88	1,16	0,88

Note: The statistics shown in the table are based on coefficients from eq 2b in Appendix ($\hat{\chi} = -0{,}79$ and $\hat{\psi} = -0{,}09$).

Are the adjusted forecast errors smaller? - Hypothesis 1

From diagram 3 as well as table 1 we see that hypothesis 1 does not hold: the forecast errors are larger when corrected for the assumption of constant repo rate, a finding similar to that in a study by the National Institute for Economic Research (see footnote 4). To a large extent this is due to the developments during the period 1992:4-1996:4, during which inflation forecasts were above the target but the actual inflation outcomes were below target, implying quite substantial negative forecast errors, see diagram 3.

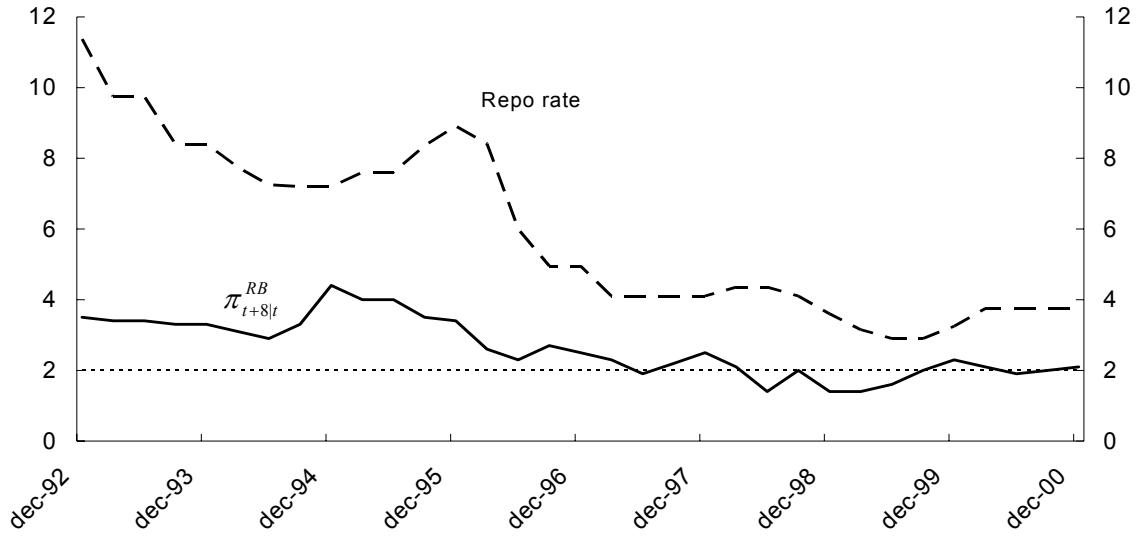
Diagram 3. Inflation forecast errors with/without adjustment for constant repo.



From diagram 4 we see that the decline in the inflation rate occurred during a trend decline in the repo level so that monetary policy tended to be quite a bit more expansionary relative to the assumed constant level of the repo rate. During this time

Swedish economic policy had substantial credibility gains (from a bad initial level) that led to disinflationary effects via lower inflation expectations and a stronger exchange rate as well as a general fall of interest rates. The rapid fall in the inflation rate came as a surprise to many – if not most – forecasters. But even if we examine the post 1996 period only, there is still no support for hypothesis 1.

Diagram 4. The repo rate and 8- quarter ahead forecasts.



What possible explanations can account for this? One possibility is of course that we are unable to control for the effects of the constant repo rate with the techniques discussed in section 2. While this explanation should not be ruled out, another possibility is that the inflation forecast conditional on constant repo rate in reality contains many elements of a non-constant repo rate. As discussed in section 2, the negative estimate of δ gives some support to the notion that the constant repo rate assumption is not fully implemented in the forecasts.

Other indications that this is the case is found more directly from the forecasts published in the inflation reports. For example, the wage forecast of about 4 percent per year that has been made in a number of inflation reports appears low if the repo rate in fact were to be held constant over the forecast horizon. Not least the experience from the 1980:s when wage increases in nominal terms were quite high suggests what may happen when monetary policy is too loose to prevent high nominal wage increases, but which ultimately lead to wage-price spirals erasing virtually all real

wage growth.[13] Moreover, the study by Blix et al (2002) found that the Riksbank had almost the best wage forecasts for Sweden during 1993-2001, a result that is hard to reconcile with those forecasts being based on constant repo rate while the other institutions have unconditional forecasts.

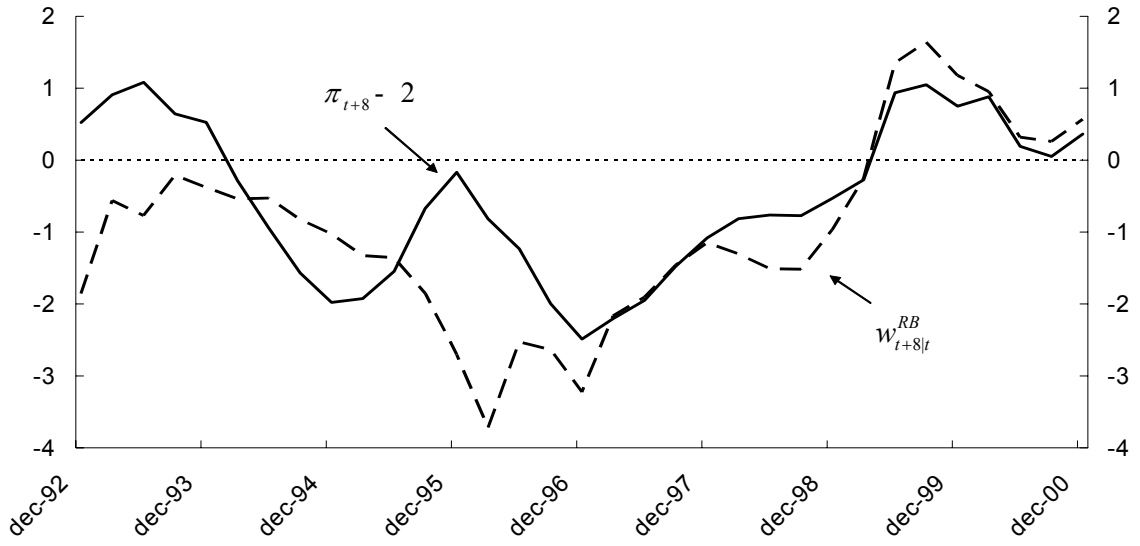
Has monetary policy reduced target deviations? – Hypothesis 2

Monetary policy is indeed associated with reduced target deviations. This can be seen from diagram 5 and table 1, and holds true for almost all parameter estimates in the previous section. On average monetary policy has reduced target deviations by about 25 percent. In terms of sum of squared deviations, which is closely related to the objective function often used in the academic literature, the reduction has been around 45 percent on average.

In our framework, monetary policy is credited with all of this reduction in target deviations, but it is clear that there may be other sources at work as well. For example, the downward trend in Swedish inflation occurs during a time when world inflation also has gradually become lower, thereby making the exogenous circumstances more favourable for a low inflation regime in a small open economy such as Sweden. Even taking this into account, the conquest of Swedish inflation with the associated reduction in volatility is a remarkable achievement. Inflation has come down from an average of about eight percent during 1970-93 to an average around the target level of two percent after 1993.

[13] Though monetary policy inaction was not the only issue that lead to the poor macroeconomic performance during the 1980:s and early 1990:s, see for example Lindbeck et al(1994).

Diagram 5. Inflation target deviations.

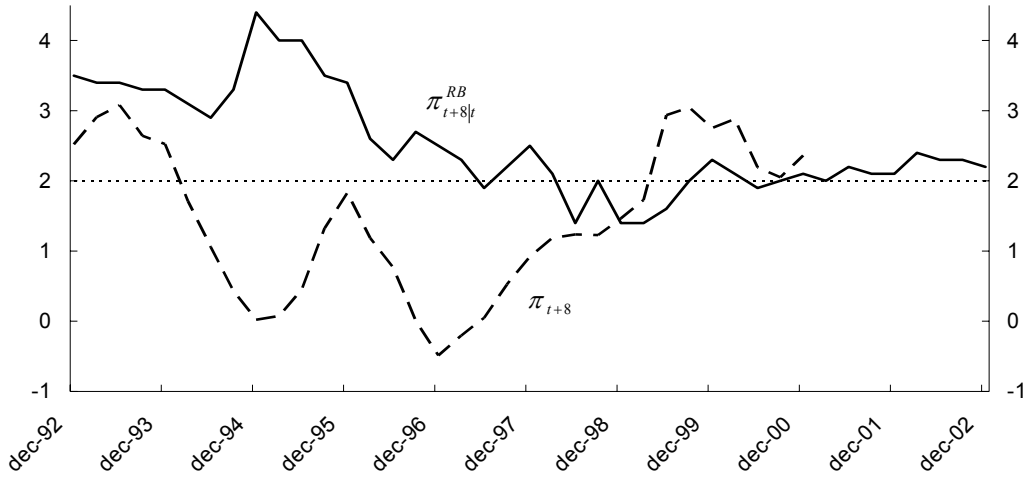


Overall, the stable inflation forecasts in the latter part of the 90's have led a policy with fairly small movements in the repo rate, especially compared to the period before. This is consistent with the inflation targeting regime: small movements in the inflation forecasts under the assumption of constant repo rate should lead to fairly small changes in monetary policy.

Sluggishness in forecast revisions and implications for policy

What are the causes behind the patterns for target and forecast deviations? Here we can make a few tentative remarks. It appears that observed target deviations are caused mainly by forecast errors rather than bad responses to forecasts. This is suggested by diagram 6, which shows that the swings in the inflation forecasts are an order of magnitude smaller than the swings in the inflation outcomes.

Diagram 6. Inflation forecasts and outcomes.



Note: The inflation outcome is illustrated with an 8 quarter time lag to fit accordingly with the forecast.

It is also suggested by the strong correlation between inflation and target deviations, especially in the post-1996 period as seen from table 2. In large part this correlation stems from the Riksbank's inflation forecasts being *fairly close* to its target of two percent during the second half of the sample.

Table 2. Correlations between the time series

sample	$w^{RB}_{t+8\|t} / \pi_{t+8}$ - 2	$\pi_{t+8} - \pi^{RB}_{t+8\|t} / \pi_{t+8}$ - 2
92:4-00:4	0,69	0,83
92:4-96:4	0,44	0,89
97:1-00:4	0,96	0,95

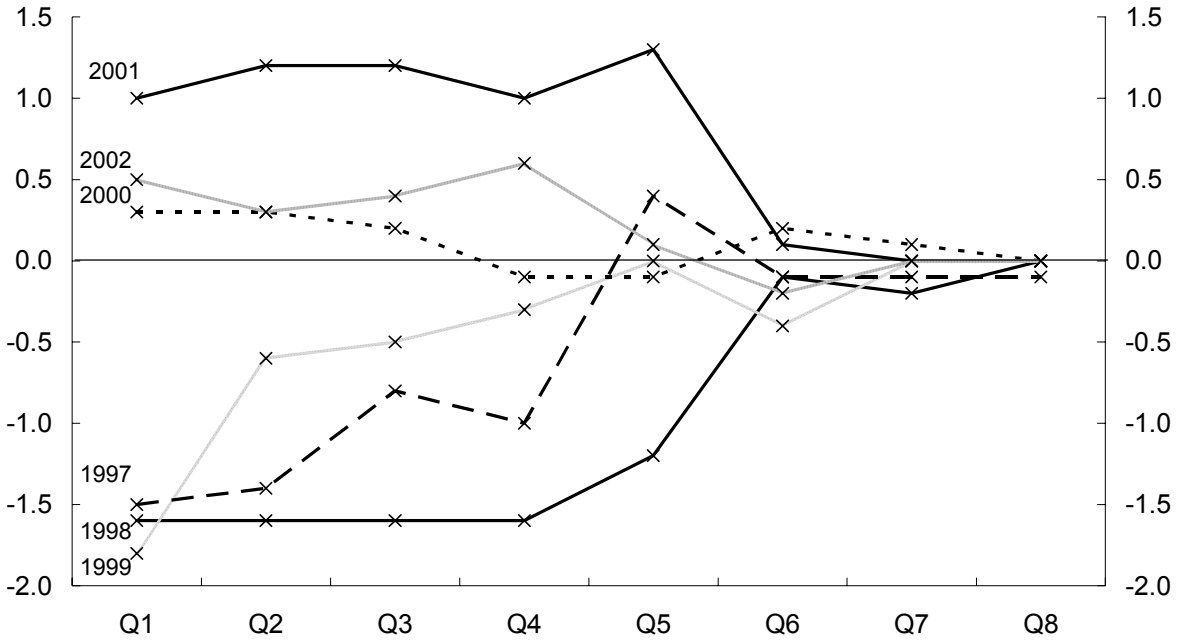
Note: The parameters used are those that are specified in the note to table 1.

Another pattern that emerges is the persistent serial correlation in the forecast errors in considerable excess to what can be explained by overlapping observations discussed in section 2. This can arise from several sources, for example the shocks in the economy may be serially correlated. The most likely explanation, however, is that forecast revisions have been "too" slow or overly cautious. In part this is suggested by (lags of) the estimation errors $\hat{\varepsilon}_t$ in the regressions being positive and significant when included as a RHS variables in many of the regressions (see table B2 in the

appendix). Also, this is suggested by diagram 7 which shows that for the most part it takes 3-4 quarters before the forecasts start converging to the actual outcome.

Even if more rapid revisions may have given better forecasts, this does *not* imply that policy would necessarily have been better in terms of goal fulfilment. Though important, this question cannot be answered in our simple framework and requires a more fully developed model.

Diagram 7. Evolution of inflation forecast errors for 1997-2002.



Note: Each line represents the forecast error for a particular year tracked over time based on comparing the yearly average outcome with its corresponding forecast, i.e. $\pi_i - \hat{\pi}_{i,t}$ where hat denotes forecast, i the year and t the quarter the forecast was published. Thus, Q1 is the first quarter a forecast was made for the year i and we track the forecast for that year until the final outcome is known and the forecast error thus zero. The vertical line illustrates the point when inflation outcomes for the year in question begin to be known: in Q6 one-fourth of the inflation outcome is known and so on.

Diagram 7 raises some other issues about the patterns in the inflation forecasts. On a side note, there is a curious tendency for the three forecast paths with more modest errors to make a revision in the *wrong* direction at the time when four quarters remain before the outcome becomes known. More importantly is the question whether or not the forecasts have improved during the years of accumulated experience with inflation targeting. With the exception of forecasts for the year 2001, an exceptional year with

large supply shocks, this appears to be the case.[14] But this conclusion is clearly sensitive to the forecast errors for 1998. What about evidence for upward bias in inflation forecasts, a critique sometimes leveled against central banks? Diagram 7 shows that there have been long periods of both over- and underestimation of forecasts. The period 1998-2002 is fairly balanced, but the years prior to 1998 (for which less forecasting detail is available) inflation was overestimated for several years, see diagram 2 in section 3. Overall, there have been more years for which inflation has been overestimated than underestimated. What is also striking is the long persistence in the periods of over –and underestimation: overestimation during 1993-1999 and underestimation during 2000-2002

5. Summary

In this paper we have used the framework of inflation forecast targeting as a starting point for an econometric specification that investigates forecasting performance and some aspects of the conduct of monetary policy.

Using this framework we obtain several results about the forecasts and their relation to policy. We find that information available at the time of the forecast appears to have been used efficiently. In particular, we cannot find a robust relation between information at the time of the forecast and the future inflation forecast error. Although information appears to have been used efficiently, we find that forecast revisions are "too slow" in the sense that the forecast errors are quite persistent, often of the same sign over several years.

As regards monetary policy, we find that controlling for this assumption of constant repo rate yields slightly larger forecast errors, indicating that this assumption may not be wholly implemented in the Riksbank's forecasts. Moreover, we find that inflation target deviations are smaller since the inception of inflation targeting regime, for which monetary policy is likely most responsible. Finally, our estimates of the effects of monetary policy are consistent with the conventional wisdom that monetary policy has most effects on the 1-2 year horizon.

[14] See the inflation reports 2002:1 and 2003:1 for discussions of these supply shocks.

The analysis in the paper raises some issues that could be investigated in future research. Some of these require models that can incorporate important tradeoffs in the conduct of policy for the central bank that are often not discussed in the academic literature. An example of such a trade-off concerns when the economy is potentially approaching a turning point, say about to enter into an expansionary phase. The central bank may need to tighten policy well before the turning point: but too much tightening could be damaging for the growth of economy, particularly when there is considerable uncertainty about the timing of the turning point. What is then the optimal degree of caution in forecast revisions and in monetary policy? How much can we improve forecasts by less conservative revisions? And what are the economic costs of basing policy on such forecasts if they turn out to be in the wrong direction? These kinds of tradeoffs would be useful to explore in a sufficiently rich macro model.

6. Appendix A: a note on the data

This appendix briefly outlines the construction of the variables used in the paper. The data comes from the Statistical Central Bureau (Statistics Sweden) and the Riksbank. Unless otherwise stated we use quarterly data over a sample period of 1992:2-2002:4.

At the time of the forecast, *(t),* there is generally information available up to the quarter of *(t-1),* regarding CPI inflation and TCW exchange rate. These are represented in the information set x_t with one lag. GDP, on the other hand, tends to be available only after a two quarter lag. In general, our guiding principle in the construction of the data is to use only information that was available at the time of the forecast; that is, we use unrevised data and take care with the timing of the data.

- C_2. A time varying intercept.

$$\text{Eq(2)}\ C_2\begin{cases}1992:4-1998:4=0\\1999:1-2001:4=1\end{cases}\quad \text{Eq(3)}\ C_2\begin{cases}1992:4-1998:3=0\\1998:4-2000:4=1\end{cases}$$

Forecast errors in CPI.

In the first years of the inflation targeting regime, 1992-1998, the Riksbank did not produce complete paths for inflation. We have had to construct rolling four- and eight- quarter ahead inflation forecasts approximated on forecasts of the December

inflation.[15] We did this in the following way. The first two quarters of a particular calendar year, say 1993, are assumed to proxy the four-quarter ahead forecasts; the next-year forecasts, say for 1994, made in last two quarters of the previous year are again assumed to proxy the four quarter forecasts. The same procedure goes for the eight quarter ahead forecasts. From the fourth quarter of 1998, the Riksbank published "proper" 4- and 8 quarter forecasts.

-**ERROR4(-5)**. Is the forecast error four quarters ahead lagged five quarters. It can also be regarded as the latest observed forecast error when it is based on the inflation outcome t-1.

A note on the variable represented in the information set x_t.

Here we briefly describe the variables included in the regressions.

- **SW_CPI**. Annual CPI- inflation rate.
- **SW_GDP**. Real time unrevised data of the annual change in Swedish GDP.
- **OECD_CPI**. Annual OECD 19 CPI inflation rate.
- **TCW_CH**. Two different approaches are used: Quarterly percentage change and annually percentage change of trade weighted exchange rate (TCW)- index. When included in the regression we take the average of the latest four observations in order to allow for the possibility that it is exchange rate movements over the whole past year which may trigger price changes on consumer goods.

Monetary policy variables

- **Reporate (R_{t-1}).** [16] The observed repo rate level is defined by the so called *"stop-date"* of the forecast, i.e. the date from which the forecast for publication purpose is locked. Because forecast are published on a quarterly basis, repo rate changes can occur in the same quarter but after the forecast is made. We have attempted to carefully date the forecasts to ensure that we use the constant repo rate implicit in the forecast. When constructing Ω, the variable r_{t+k} is the *quarterly average repo* rate at quarter *t+k*. When constructing A, the variable $r^m_{t+k|t}$ is a constructed time series over the markets

[15] These calendar year forecasts are the same as the ones published in Berg, Jansson and Vredin (forthcoming).
[16] Until second quarter of 1994 the mariginal rate is used.

expectations of the future repo rate at each forecast date. A continuously compounded 12 and 24 month rate is used as a proxy for the intended path for the repo rate. To avoid the impact from temporary market movements, we define $r^{m}_{t+k|t}$ as the average expectation *the firs*t *month* of the quarter of the forecast.

7. Appendix B: Tables of regression results

Table B1. Regression specifications for equation (1)

Variable	Eq (1)	Eq (1a)	Eq (1b)	Eq (1c)	Eq (1d)	Eq (1e)	Eq (1f)
AR(1)		0.59	0.72	0.54	0.58	0.54	0.59
		0.181	*0.191*	*0.189*	*0.170*	*0.193*	0.179
MA(1)		0.63	0.39	0.65	0.66	0.64	0.57
		0.170	*0.247*	*0.169*	*0.170*	*0.179*	0.198
C_1	-0,02	-0,68		-0,51	-0,98	-0,47	-0,10
	1.146	*1.637*		1.456	1.498	1.488	1.484
C_2	1.53						
	0.47						
R(-1)	-0.32	-0.54	-0.64	-0.58	-0.48	-0.57	-0.45
	0.156	*0.257*	*0.433*	*0.236*	*0.212*	*0.245*	0.210
SW_CPI (-1)	0.19	-0.02	-0.49	-0.06	-0.03	-0.06	-0.13
	0.229	*0.199*	*0.394*	*0.179*	0.201	*0.183*	0.190
SW_GDP(-2)	-0.12	-0.01	0.03	0.02	-0.01	-0.01	-0.04
	0.112	*0.073*	*0.085*	*0.069*	0.077	*0.073*	0.080
OECD_CPI(-1)	0.20	1.35	1.06	1.32	1.35	1.30	1.05
	0.535	*0.634*	*0.758*	*0.585*	0.629	*0.600*	0.608
TCW_CH(-1)	-0.05	-0.02	-0.08	0.04	0.03	0.04	0.04
	0.110	*0.110*	*0.145*	*0.040*	*0.111*	*0.043*	0.039
Ω_1	0.16	-0.07	-0.32	-0.11		-0.09	
	0.175	*0.316*	*0.450*	*0.294*		*0.376*	
A1					0.07		0.60
					0.249		0.499
A_2						-0.02	-0.43
						0.196	0.325
ERROR4(-5)			0.17				
			0.273				
n-k	36-8	35-9	31-10	35-9	35-9	35-10	35-10
adj R2	**0.57**	**0.77**	**0.79**	**0.77**	**0.77**	**0.76**	**0.78**
DW	0.77	1.88	2.07	1.86	1.87	1.86	1.82
B-G LM	20.8/0.00*	5.6/0.23	0.9/0.92	3.8/0.44	5.2/0.27	4.4/0.36	3.4/0.47
ARCH LM	6.5/0.17	3.4/0.49	2.1/0.72	3.1/0.54	2.5/0.65	3.1/0.54	3.8/0.44
White heteroskedasticity	17.5/0.18	13.9/0.31	16.1/0.30	13.6/0.33	12.1/0.44	14.0/0.45	13.9/0.46
Jarque Bera	0.1/0.93	0.55/0.76	0.9/0.65	0.4/0.83	0.5/0.77	0.3/0.84	0.2/0.91
Chow b.p 1999:1		0.8/0.64	3.6/0.02**	1.2/0.34	1.1/0.43	0.9/0.54	0.8/0.63

Note: Standard errors are denoted in italics. *, ** Denotes significance at 1% and 5% level respectively.
Note: Eq1 is the basic regression regarding forecast errors 4 quarters ahead as described in the text with C_2 added with a shift at 1999:1. TCW is in quarterly change.
Eq (1a) is same as eq(1) with added ARMA(1.1) term but C_2 excluded.
Eq (1b) is same as eq (1a) with added forecast error lagged 5 (latest observed forecast error).
Eq (1c) is same as eq (1a) with TCW in yearly change.
Eq (1d) is same as eq (1a) but Ω_1 is replaced with A1 .
Eq (1e) is same as (1a) with added A_2.
Eq (1f) is same as (1d) with added A_2.

Table B2. Regression specifications for equation (2).

Variable	Eq (2)	Eq (2a)	Eq (2b)	Eq (2c)	Eq (2d)
AR(1)		0.85	0.06	0.83	0.95
		0.167	*0.269*	*0.218*	*0.083*
MA(1)		0.20	-1.00	0.19	0.18
		0.269	*0.175*	*0.290*	*0.239*
C_1	-1.46	1.03	0.85	3.79	-0.91
	0.980	*2.939*	*1.076*	*4.78*	*4.670*
C_2	2.10				
	0.157				
R(-1)	-0.21	-0.62	0.48	-1.19	0.16
	0.157	*0.636*	*0.230*	*1.134*	*0.270*
SW_CPI (-1)	-0.11	-0.21	-1.08	-0.13	-0.24
	0.165	*0.192*	*0.375*	*0.183*	*0.197*
SW_GDP(-2)	0.06	-0.04	0.01	-0.09	-0.06
	0.090	*0.075*	*0.139*	*0.072*	*0.084*
OECD_CPI(-1)	0.26	0.53	-0.59	0.28	0.57
	0.533	*0.676*	*0.453*	*0.651*	*0.721*
TCW_CH(-1)	0.27	0.15	0.30	0.09	0.14
	0.086	*0.109*	*0.080*	*0.056*	*0.102*
Ω_1	-0.78	-0.79	-1.31	-0.82	
	0.150	*0.320*	*0.197*	*0.380*	
Ω_2	0.13	-0.09	1.00	-0.60	
	0.156	*0.408*	*0.242*	*0.779*	
A1					0.03
					0.578
A_2					-0.20
					0.363
ERROR4(-5)			1.19		
			0.227		
n-k	32-9	31-10	27-11	31-10	31-10
adj R2	**0.81**	**0.84**	**0.92**	**0.85**	**0.82**
DW	1.36	1.98	1.84	1.96	1.99
B-G LM	6.6/0.16	4.5/0.34	7.7/0.10	7.1/0.13	0.6/0.96
ARCH LM	2.7/0.62	1.2/0.88	9.7/0.05**	2.6/0.68	3.5/0.48
White heteroskedasticity	22.6/0.09	8.5/0.86	22.0/0.14	7.1/0.93	8.8/0.84
Jarque Bera	0.4/0.81	5.0/0.08	1.1/0.59	1.7/0.42	0.09/0.96

Note: Standard errors are denoted in italics. *, ** Denotes significance at 1% and 5% level respectively.. Due to adjustment of endpoints when including ar(1) terms the sample after 1998:4 is too short to enable Chow Breakpoint test.

Note: Eq2 is the basic regression regarding forecast errors 8 quarters ahead as described in the text with C_2 added with a shift at 1998:4. TCW is in quarterly change.

Eq (2a) is same as eq (2) with added ARMA(1.1) term. But C_2 excluded.

Eq (2b) is same as eq (2a) with added forecast error 4 quarters ahead lagged 5 (latest observed forecast error).

Eq (2c) is same as eq (2a) with TCW in yearly change.

Eq (2d) is same as eq (2a) but Ω_1 and Ω_2 is replaced with A1 and A_2.

Appendix C. Forecasts errors, misspecification and the constant interest rate assumption

TBW.

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