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Evaluating a Central Bank's Recent Forecast Failure

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Evaluating a Central Bank's Recent Forecast Failure*

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10 August, 2005

Abstract

Failures are not rare in economic forecasting, probably due to the high incidence of shocks and regime shifts in the economy. Thus, there is a premium on adaptation in the forecast process, in order to avoid sequences of forecast failure. This paper evaluates a sequence of inflation forecasts in the Norges Bank Inflation Report, and we present automatized forecasts which are unaffected by forecast failure. One conclusion is that the Norges Bank fan-charts are too narrow, giving an illusion of very precise forecasts. The automatized forecasts show more adaptation once shocks have occurred than is the case for the official forecasts. On the basis of the evidence, the recent inflation forecast failure appears to have been largely avoidable. The central bank's understanding of the nature of the transmission mechanism and of the strenght and nature of the disinflationly shock that hit the economy appear to have played a major role in the recent forecast failure.

Keywords: *Inflation forecasts, Monetary policy, Forecast uncertainty, Fan-charts, Structural change, Econometric models.*

JEL classification: *C32, C53, E37, E44, E47, E52, E58, E65.*

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1 Introduction

Over the past 10 years, several countries have adopted inflation targeting as a framework for monetary policy. A hallmark of modern and flexible inflation targeting is that the operational target variable is the forecasted rate of inflation, see i.e., Svensson (1997). One argument for this choice of target is to be ahead of events, rather than to react after actual inflation has deviated from target. In this way one might hope to achieve the target by a minimum of costs to the real economy in terms of e.g., unwanted output fluctuations or large fluctuations in the exchange rate. However, as acknowledged by inflation targeting central banks, any inflation forecast is uncertain, and might induce wrong use of policy. Hence, a broad set of issues related to inflation forecasting is of interest for those concerned with the operation and assessment of monetary policy.

A favourable starting point for inflation targeting is when it can be asserted that the central bank's forecasting model is a good approximation to the inflation process in the economy. In this case, forecast uncertainty can be represented by conventional forecast confidence intervals, or by the fan-charts used by today's best practice inflation targeters.[1] The point of the probabilistic forecasts is to convey to the public that the forecasted inflation numbers only will coincide with the actual future rate of inflation on average, and that neighbouring inflation rates are almost as probable. By the same token, conditional on the forecasting model's representation of uncertainty, still other inflation rates are seen to be wholly improbable realizations of the future.

However, the idea about model correctness and stationarity of macroeconomic processes is challenged by the high incidence of failures in economic forecasting, see e.g., Hendry (2001). A characteristic of a forecast failure is that forecast errors turn out to be larger, and more systematic, than what is allowed if the model is correct in the first place. In other words, realizations which the forecasts depict as highly unlikely (e.g., outside the confidence interval computed from the uncertainties due to parameter estimation and lack of fit) have a tendency to materialize too frequently. Hence, as a description of real-life forecasting situations, an assumption about model correctness is untenable and represents a fragile foundation for forecast based interest rate setting, see Bårdsen et al. (2003).

In Norway, the inflation forecast has been the operational target of monetary policy since the spring of 2001. In the framework of flexible inflation targeting, economic forecasts represent the cornerstone for designing a credible policy. Because of its relevance for policy decisions, reviewers of Norwegian monetary policy have emphasized the need to evaluate the forecasts, and to understand why there are large errors from time to time, see Bjørnland et al. (2004).[2] Specifically, the central bank's decision to postpone interest rate cuts in the summer of 2002 has been criticized and has been linked up with the Bank's forecasts of inflation close to target in 2003 and 2004. However, there has been no analysis so far that tries to answer the question of whether the errors were avoidable or not.

In this paper I first review, in section 2, the definition of forecast failure in

[1] See e.g., Ericsson (2001) for a accessible discussion of forecast uncertainty, and its presentation in published forecasts.

[2] Chapter 4.1 and 4.2 in particular.

economics, as well as the likely sources of such failures. This represents a necessary backdrop for an evaluation of forward looking monetary policy. Section 3, shows that the consequences of forecast failure for interest rates depends on the nature of the transmission mechanism as well as on the detailed operational aspects of inflation targeting. Specifically, i) long lags in the transmission mechanism, and ii) gradual interest rate adjustment by the bank, jointly imply that policy decisions are harmed by forecast failure. Since both apply to Norwegian monetary policy. there is indeed good reason to worry about forecast failures and to consider remedies.

In section 4 we discuss some of the features of the forecasting process in Norges Bank, and we then present graphs showing recent forecast performance. In section 5, we provide a set of *automatized* forecasts for the same period, based on an econometric forecasting model. The automatized forecasts represent a 'possible past': they could have been produced by the central bank in real time. The comparison also provides the background for the concluding discussion of why Norges Bank's forecasts have been ridden by significant errors. Interestingly, structural breaks in the Norwegian inflation spiral process do *not* seem to be the most important source of forecast failure in this case. Instead, the evidence points in the direction of the bank's adjustments to the forecasts, or, and this is complementary, that the bank's own model of the transmission mechanism has been biased toward a too rapid return to the inflation target after a shock.

2 Sources of forecast failure

All economic forecasting is based on observed regularities in the current economy and its history. The future is fundamentally uncertain, and in particular it is impossible to use future observations to quantify the parameters of the forecasting mechanism (or rule) being used. History remains the only information available to us when we make statements about the future, or as put by the Norwegian economist Leif Johansens:

> "Forecasting is essentially processing of historical information in order to be able to formulate statement about the future (Johansen (1983, p. 131))

Many would add that economic theory is also part of the information set used by forecasters, which is of course true, but also the theoretical part of the forecasting mechanism is dependent on history, unless one ventures into the use of completely untested theories in the forecasting model.

As already noted, forecast properties are closely linked to the assumptions we make about the forecasting situation. An useful classification, see Clements and Hendry (1999, Ch 1), is:

A The forecasting model coincides with the true inflation process except for stochastic error terms. The parameters of the model are known constants over the forecasting period.

B As in A, but the parameters have to be estimated.

C As in B, but we cannot expect the parameters to remain constant over the forecasting period—structural changes are likely to occur.

D We do not know how well the forecasting model correspond to the inflation mechanism in the forecast period.

A is an idealized description of the assumptions of macroeconomic forecasting. There is still the incumbency of inherent uncertainty represented by the stochastic disturbances—even under A. Situation B represents the situation theoretical expositions of inflation targeting conjure up, see Svensson (1999). The properties of situation A will still hold—even though the inherent uncertainty will increase. If B represents the premise for actual inflation targeting, there would be no forecast failures, nor any ensuing big errors in interest rate setting.

In practice we of do not know what kind of shocks that will hit the economy during the forecast period, which is the focus of situation C. A forecast failure effectively invalidates any claim about a "correct" forecasting mechanism. Upon finding a forecast failure, the issue is therefore whether the mis-specification was detectable or not, at the time of preparing the forecast. In principle, it is quite possible that a model which have been thoroughly tested for mis-specification within sample, nevertheless produces a forecast failure, which is a situation that may occur in situation C.

As discussed by Clements and Hendry (1999), a frequent source of forecast failure is regime shifts in the forecast period, i.e., *after* the preparation of the forecasts. Since there is no way of anticipating them, it is unavoidable that *after forecast* breaks damage forecasts from time to time. Specifically, when assessing inflation targeting over a period of years, we anticipate that the forecasters have done markedly worse than they expected at the time of preparing their forecasts, simply because there is no way of anticipating structural breaks before they occur. The task is then to be able to detect the nature of the regime shift as quickly as possible, in order to avoid repeated unnecessary forecast failure.

However, experience tells us that forecast failures are sometimes due to shocks and parameter changes that have taken place prior to the preparation of the forecast, but which have remained undetected by the forecasters. Failing to pick up a *before forecast* structural break may be due to low statistical power of tests of parameter instability. There are also practical circumstances that complicate and delay the detection of regime shifts. For example, there is usually uncertainty about the quality of the provisional data for the period that initialize the forecasts, making it difficult to assess the significance of a structural change or shock.

Hence both *after* and *before* forecast structural breaks are realistic aspects of real life forecasting situations that deserve the attention of inflation targeters. In particular, one should seek forecasting models and tools which help cultivate an adaptive forecasting process. The literature on forecasting and model evaluation provide several guidelines, see e.g., Hendry (2001) and Granger (1999).

Situation D brings us to a realistic situation, namely one of uncertainty and discord regarding what kind of model that approximates represents reality, in other words the issues of model specification and model evaluation. However, the link between model mis-specification and forecast failure is not always as straight-forward as one would first believe. The complicating factor is again non-stationarity, regime-shifts and structural change. For example, a time series model in terms of the change in the rate of inflation—a dVAR—adapts very quickly to regime shifts, and is immune to *before* forecast structural breaks, even though it is blatantly mis-specified over the historical data period, see Clements and Hendry (1999, Ch 5). In terms of forecasting vocabulary, simple time series models of the change in the rate of inflation have the advantage provides automatic *intercept correction* which makes for robust inflation forecasts. An econometric forecasting model is less adaptable, and in order to avoid forecast failure after a structural break, the model forecasts must be manually intercept corrected.

However, to aid monetary policy, central bank economists need to be able to explain their forecasts with reference to economic theory, in particular the link between the interest rate and inflation. Hence, despite their robustness, time series forecasting tools do not meet the needs of inflation targeters. Inevitably, model choice and detailed specification issues becomes a primary concern for inflation targeters. For example, the specification of the equilibrating mechanism is of importance for the quality of inflation forecasts, see Bårdsen et al. (2002). Conversely, acting *as if* there is only one model available for inflation targeters (currently the New Keynesian Phillips curve has become dominant), and not doing serious empirical work on model specification and evaluation, is a certain recipe for forecast failure.

The classification at the start of this section has focused on model knowledge and structural breaks, but there are of course other sources of forecast failures that are relevant for monetary policy. Three particularly relevant sources are: data revisions, adjustments to model forecasts and the projections of non-modelled variables in the forecasting model. Inflation forecasts and monetary policy decisions are made in "real time", so if important variables are inaccurately measured, inflation forecasts will be harmed by not having access to later revised data. Output-gap based forecasting models are examples of methods that are exposed to real-time data problem: GDP data are often substantially revised, and the almost routine use of the HP filter to construct the output-gap aggravates the problem.

Adjustments to model based forecasts in the form of intercept correction, are usually found to improve forecast quality, as we made clear above. However, opportunistic or speculative adjustments can harmful though. One scenario with some relevance for forecasting in a inflation targeting regime is when the dynamic forecasts are adjusted in a way that affects the estimated and projected long-run mean of inflation. That kind of adjustment, by way of end-point restrictions, amounts to asserting a regime shift in advance of the evidence, but might be rationalized by theories of strong and direct effects of an inflation target on inflations anticipation.

3 Do forecast failures harm policy?

When central banks set interest rates so that the inflation forecasts is in accordance with the inflation target, there is a danger that structural breaks in the monetary policy transmission mechanism will also affect interest rate setting. But in which way, and with what potentially harmful consequences, depends both on the operational aspects of inflation targeting and the nature of the transmission mechanism.

In order to simplify, we omit all other variables than the policy instrument.

Hence, we use the autoregressive distributed lag model:

$$\pi_t = \delta + \alpha\pi_{t-1} + \beta_1 i_t + \beta_2 i_{t-1} + \varepsilon_t, \quad t = 1, 2, 3..., T, \\ -1 < \alpha < 1, \beta_1 + \beta_2 < 0, \tag{1}$$

where π_t denotes the rate of inflation, and i_t is the interest rate. ε_t is stochastic and normally distributed with a constant variance and zero autocorrelation.[3]

Suppose, for simplicity, that the central bank has chosen a 2-period horizon—for the time being we may think of the period as annual. The forecasts are prepared conditional on period T information, so

$$\hat{\pi}_{T+1|T} = \delta + \alpha\pi_T + \beta_1 i_{T+1|T} + \beta_2 i_{T|T} \tag{2}$$

$$\hat{\pi}_{T+2|T} = \delta(1+\alpha) + \alpha^2\pi_T + \alpha\beta_1 i_{T+1|T} + \alpha\beta_2 i_{T|T} + \beta_1 i_{T+2|T} + \beta_2 i_{T+1|T} \tag{3}$$

give the first and second year forecasts. There are two degrees of freedom if the bank chooses to attain the target π^* in period 2, and $i_{T+1|T}$ and/or $i_{T|T}$ can be set to (help) attain other priorities.

For simplicity, set $i_{T+1|T}$ and $i_{T|T}$ to some autonomous level, represented by 0.[4] In this case, the interest rate path becomes

$$\begin{aligned} i_{T|T} &= 0 \\ i_{T+1|T} &= 0 \\ i_{T+2|T} &= \frac{1}{\beta_1}\left\{-\mu + \alpha^2(\mu - \pi_T) + \pi^*\right\} \end{aligned} \tag{4}$$

where μ denotes the long run mean of inflation. Assuming that the parameters are constant over the forecast period, this path will secure that $\pi_{T+2|T}$ is equal to π^* on average. This is the benign stationary case with no regime shifts in the forecast period. On the other hand, if μ increases to a higher level μ' in period $T+1$ and $T+2$, the forecasts $\hat{\pi}_{T+1|T}$ and $\hat{\pi}_{T+2|T}$ will turn out to be too low, and if large enough, the errors will constitute a forecast failure. However, the forecast failure is not too worrying since only only the announced future interest rate $i_{T+2|T}$ is affected. With the 'policy rule' in (4), a future interest rate is planned to be changed in such a way that the inflation target is reached in the second year. Today's interest rate $i_{T|T}$ is not affected, and the planned $i_{T+2|T}$ can always be replaced by $i_{T+2|T+1}$ in the next forecast round. Thus, there seems to be negligible damage on today's policy associated with the poor forecast.

Note that the apparent "policy irrelevance" of forecast failure depends crucially on the transmission mechanism, namely that the transmission of interest rate changes on inflation is sufficiently fast. Formally, unless $\beta_1 < 0$, the interest rate two years ahead cannot be used to bring the forecasted rate of inflation in line with the target. Central banks typically state that they view the transmission as relatively slow: *'Monetary policy influences the economy with long and variable lags'* is

[3] A comprehesnive analysis of the normative aspects of forward-looking interest rate setting, also covering the case of parameter uncertainty (i.e., the case subsumed in situation B above) is given in Svensson (1999).

[4] i.e..,we interpret i_t as the deviation from mean, hence the interest rate in period T and the planned interest rate in $T+1$ are both equal to the mean.

a recurrent formulation. [5] This is probably the main reason for choosing a different operational procedure in practise, namely to move $\hat{\pi}_{T+1|T}$ in the direction of the target by changing the current interest rate, $i_{T|T}$. As a rule, a central bank's policy will therefore be to change the interest rate gradually. In our simplified model, we can represent gradual instrument adjustment by:

$$i_{T+j-1|T} = \gamma i_{T+j|T}, \quad j = 1, 2, ...h, \, 0 \leq \gamma < 1$$

which gives the interest rate path:

$$\begin{aligned} i_{T|T} &= \frac{\gamma^2}{B}\left\{-\mu + \alpha^2(\mu - \pi_T) + \pi^*\right\} \\ i_{T+1|T} &= \frac{\gamma}{B}\left\{-\mu + \alpha^2(\mu - \pi_T) + \pi^*\right\} \\ i_{T+2|T} &= \frac{1}{B}\left\{-\mu + \alpha^2(\mu - \pi_T) + \pi^*\right\} \end{aligned} \tag{5}$$

where $B < 0$ is a function of α, β_1, β_2 and γ. Clearly, with gradual interest rate adjustment, the event of a new mean inflation rate $\mu^{'}$ in period 2 will not only cause a forecast failure, it will also imply that today's interest rate $i_{T|T}$ ought to have been set differently.

In sum, long lags in the transmission mechanism, and "gradualism" in interest rate setting individually and jointly increase the danger that regime-shifts and forecast failures are rolled back to interest rate setting. Of course, in the example, omniscience (also of the future) would have been required to avoid the policy mistake. But the same analysis applies to the avoidable sources of forecast failures, such as for example *before* forecast structural breaks and real-time data measurement problems. Unless the central bank's forecasting system is able adapt to changes in these factors, forecast instigated policy errors become a possibility.

4 Norges Bank's recent inflation forecasts

On 29 March 2001 Norway formally introduced an inflation targeting monetary policy regime. The Central Bank of Norway committed itself to stabilization of inflation at a level around $2.5\frac{1}{2}$ per cent annually. This is in accordance with an international trend during the 1990s, where countries like Canada, New Zealand, Sweden and the United Kingdom changed monetary policy toward explicit inflation targeting.

As we have already seen, in the first years of the new monetary policy regime, the operational target was defined as the forecasted rate of inflation 2 years ahead. Hence, the sight deposit rate is adjusted upward if the forecasted rate is higher than $2\frac{1}{2}$ per cent with unchanged interest rates. If it appears that inflation will be lower than $2\frac{1}{2}$ per cent with unchanged interest rates, the interest rate will be reduced. Gradualism in interest rate setting is official policy.

As has become practice in inflation targeting countries, the forecasted rate is not based on the official CPI but on a trimmed CPI which adjusts for high-frequency

[5] see, http://www.norges-bank.no/english/monetary_policy/in_norway.html#horizon

price components. In Norway, the corrected index is adjusted for the influence of energy prices and indirect taxes (denoted CPI-ATE). Norway's electricity supply is based on hydroelectricity, and the price of electricity contributes significantly to the 12 month growth rate of the headline CPI over the calendar year. Likewise, discretionary changes in indirect tax rates and subsidies show up in the short-term variations in the headline CPI. Since the horizon for monetary policy is 2-3 years, the bank has decided to filter out both these sources of short term variability from its target variable.

Inflation forecasts are published three times a year in the central bank's inflation reports. The details of the process leading up to the published forecast is unknown to the outsider, but reading of the inflation reports shows that (like all professional forecasters) Norges Bank combines several methods of forecasting: surveys, leading indicators, "gut feeling" and guessing, "informal models" and econometric models. The bank's beliefs about the transmission mechanism between policy instrument and inflation, represents a main premise for the forecasts, and secures consistency in the communication of the forecasts from one round of forecasting to the next. For simplicity, we refer to the systematized set of beliefs about the transmission mechanism as the Bank Model—BM for short.

No full account or documentation of BM exists, but some of its main features can be gauged from the rationalization of the forecasts given in the inflation reports, from the governors' speeches and other official statements (several of which are accessible from Norges Bank's internet pages). For example, an integral element of BM is a short run Phillips curve with an output-gap to represent demand pressure, and which also includes explanatory variables representing imported inflation and expectations. Over the forecast horizon, a change in the nominal interest rate affects both the output-gap (through the real interest rate and the real exchange rate), and the rate of change of the price of imports (i.e., in domestic currency). These are the two main interest rate channels in BM. Norges Bank seems to keep an open mind about the nature and strength of a separate expectations channel, although one can detect an inclination to attribute a separate effect to the adoption of inflation targeting as such, and an anticipation that this channels will grow in importance as time passes. After all, stabilization of the public's expectations about the value of money is a *raison d'etre* of inflation targeting.

A main feature of BM has been that the joint contribution of all interest rate channels secures a sufficiently strong and quick transmission of interest rate changes on to inflation to justify a 2 year policy horizon:

> A substantial share of the effects on inflation of an interest rate change will occur within two years. Two years is therefore a reasonable time horizon for achieving the inflation target of $2\frac{1}{2}$ per cent.[6]

As we will see, this view of the transmission mechanism has left its mark on the published inflation forecasts, which typically revert to the target of 2.5% within a

[6] Cited from www.norges-bank.no/english/monetary_policy/in_norway.html.
See also the newspaper article in Aftenposten's 29 May 2001 issue, titled *Inflasjonsmål-hvordan settes renten?*, by Central Bank Governor Svein Gjedrem (English translation available at www.norges-bank.no/english/publications/articles/).

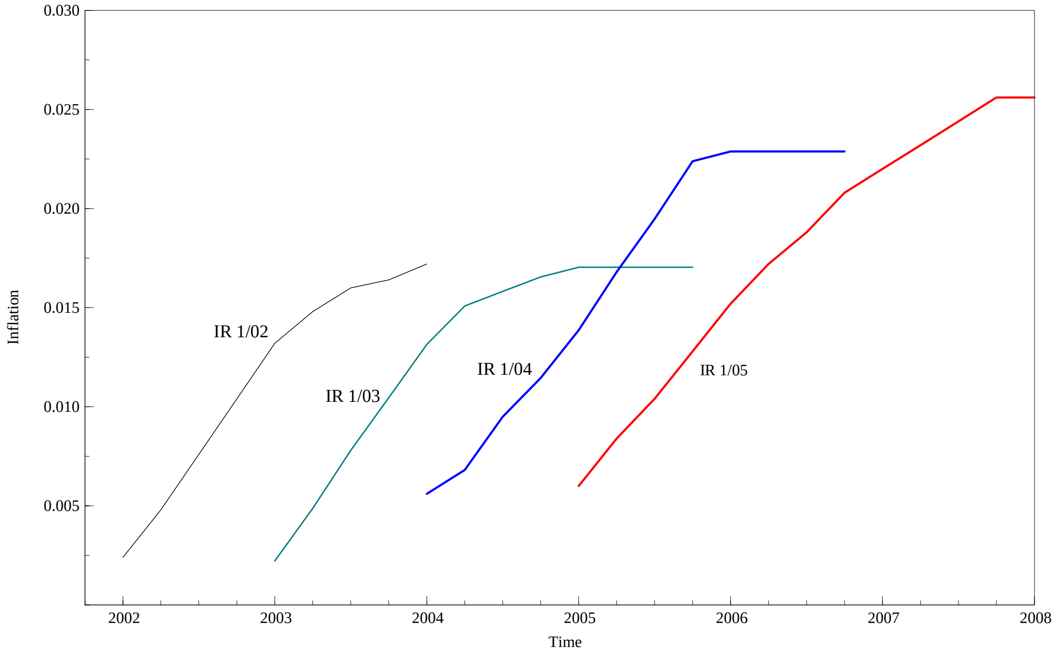

Figure 1: Uncertainty measures of Norges Bank's inflation forecasts in Inflation Reports 1/02, 1/03, 1/04 and 1/05. The lines show the width of the the approximate 90% confidence region (corresponding to the difference between the upper and lower 90% band in the fan-charts, divided by 100), for the 12 month growth rate of CPI-ATE.
Source: Inflation Reports 1/02, 1/03 and 1/04.

2-year forecast horizon. However, in the summer of 2004 Norges Bank announced that the forecast and policy horizon was changed to 1-3 years.[7]

The bank's forecasts are published in fan-charts where the wideness of the bands represents 30%, 60% and 90% probabilities for future inflation rates. Technical details aside, the uncertainty bands serve the same function as conventional forecast confidence intervals from an econometric forecasting model, namely to communicate that the point forecast is the most probable realization, but that other outcomes are almost as likely.

The forecasted uncertainty is particularly relevant when assessing forecast performance. Outcomes that fall within e.g., the 90% band do not constitute forecast failure, whereas outcomes that are not covered by the bands by definition represent forecast failure.

There is a trade-off between the wish to provide useful forecast, and the wish to avoid forecast failure. Forecasts with high information content come with narrow uncertainty bands. Conversely, the wider the uncertainty bands are, the less information about future outcome is communicated by the forecast. A simple indication of the information content of the inflation forecast is therefore to compare the width of the uncertainty bands with the variability of inflation itself (measured by the

[7] http://www.norges-bank.no/english/monetary_policy/in_norway.html#horizon

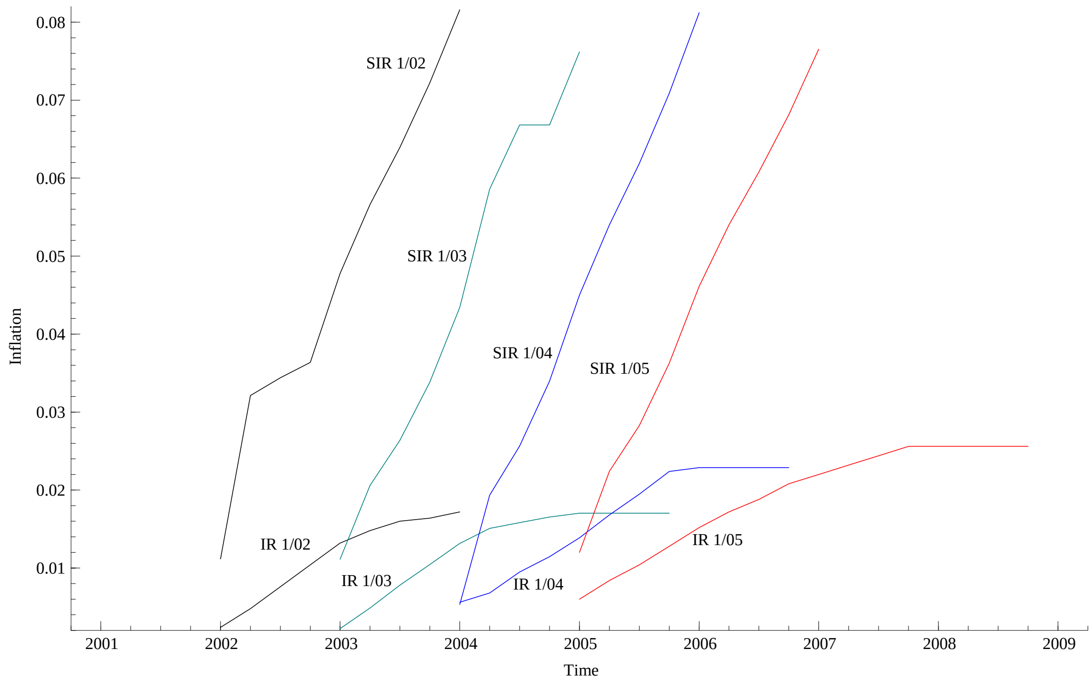

Figure 2: Uncertainty measures of Norwegian and Swedish central bank inflation forecasts. The lines marked SIR 1/02 - SIR 1/05 show the width of the the approximate 90% confidence region for the 12 month growth rate of Swedish CPI, in the Inflation Reports 1/02, 1/03, 1/04 and 1/05. The lines marked IR 1/02 - IR 1/05 are the same curves as in Figure 1, for Norwegian inflation forecasts.
Source: Inflation Reports 1/02, 1/03 and 1/04 from the two central banks.

standard deviation over, say the last 5 or 10 years). If the forecast confidence region is narrow compared to the historical variability, the central bank forecasts can be said to have a *high intended information value*.

Figure 1 shows the future inflation uncertainty spanned by the forecasts in the first issues of the inflations reports of 2002, 2003, 2004 and 2005. There are several features worth commenting in this graph. First, the "near inflation future", for example the 1 to 4 quarters ahead forecasts, have little uncertainty attached to them. In the forecasts stemming from IR 1/02 and IR 1/03, the widths of the uncertainty bands are less than 1% for all the first four predictions, corresponding to an anticipated forecast standard deviation of less than 0.25% even four quarters ahead. Second, the maximum level of uncertainty is reached in two years in the three first IR forecasts covered by the graph. This is consistent with the two year horizon noted above. Again the implied standard deviation of the forecast errors is small, a little more than 0.4% at the end of the forecast horizon.

The low degree of uncertainty both for the 1-quarter ahead forecast and for the end-of-horizon forecasts is difficult to reconcile with Norwegian inflation history. For example, the standard deviation of the rate of inflation itself is 3.4% on a 10 year sample from 1994(1) to 2003(4). In the econometric forecasting equation that we employ in the automatized inflation forecasts in the next section the residual standard error is 0.45%, which is 7 times the 1-period ahead forecast error of IR 1/02 and IR/03, but much lower than the historical variability of inflation though.

A third noteworthy feature of Figure 1 is the larger forecast uncertainty in IR 1/04 inflation forecast than in IR 1/02 and IR 1/03. However, also in this case, the uncertainty bands are narrow compared to the historical variability of inflation, and it is also low compared to what one would expect from econometric modelling of the rate of inflation. Specifically, the 2004(4) confidence interval is only a little above 1%. The final notable feature in Figure 1 is that the uncertainty bound of IR 1/05 reflects a longer horizon of predictability than the earlier Norwegian Inflation reports. The line marked IR 1/05 shows that "maximum uncertainty" is reached at the end of the second year of the forecast horizon, while in the three others IRs the uncertainty bounds stop widening in the third year of the forecast period. This difference reflects the change in the operation of inflation targeting that took place in the summer of 2004. Until then, as cited above, Norges Bank communicated that 2 years was a reasonable time horizon for achieving the inflation target of $2\frac{1}{2}$ per cent, but after the change the official horizon for operational monetary policy in Norway is 1-3 years. It is unlikely that Norges Bank's change of forecasting horizon corresponds to anything underlying or structural in the Norwegian inflation spiral. Instead, the change seems to reflect a recognition that the 2-year horizon represented an overestimation of how fast and how strongly the interest rate affects inflation, i.e., that the central bank had based its policy on the wrong model of the transmission mechanism.[8]

The low degree of uncertainty of Norges Bank's forecasts is a main point so far and it is of interest to compare the Norges Bank uncertainty bounds with the uncertainty bounds published in the Swedish inflation reports, published by Riksbanken. Figure 2 shows that the differences are indeed large. First, the Swedish uncertainty bounds, dubbed SIR in the figure, are much wider than the Norwegian. For the inflation reports of 2002, 2003 and 2005 this is true even for the 1-step ahead forecasts. Second, the Swedish uncertainty bounds increase steeply with the length of the forecast horizon, and there is no levelling off as in the Norges Bank forecasts. These large differences probably reflect different modelling assumptions. Norges Bank's uncertainty bounds are consistent with an assumption of a stationary inflation process, while the Swedish forecast bounds are interpretable as generated by as model that imposes a unit root and thus unlimited inflation persistence. Given the similarities of the two economies' socioeconomic systems, the lack of consensus regarding the nature of the inflation processes in Norway and Sweden is surprising, and the validity of the two assumptions have never really been argued.

We next look at the Norwegian inflation forecasts in more detail, and figure 3 shows seven forecasts from Norges Bank, starting with the IR1/02 forecast and ending with the forecasts published in IR 2/04. The inflation forecasts are reported together with the 90% forecast confidence bounds already discussed. In all panels, the graph of the actual rate of inflation is drawn for the period 2001(1)-2005(1).

All 8 graphs display forecast failure. In IR 2/02, the first four inflation out-

[8]Logically, another possibility is that Norges Bank in the summer of 2004 had reached a different assessment than before about the strength of the exogenous shocks to the domestic inflation spiral, while its model of the transmission mechanism was kept unchanged. However, this interpretation is not supported by the wording of the announcement of the policy change.

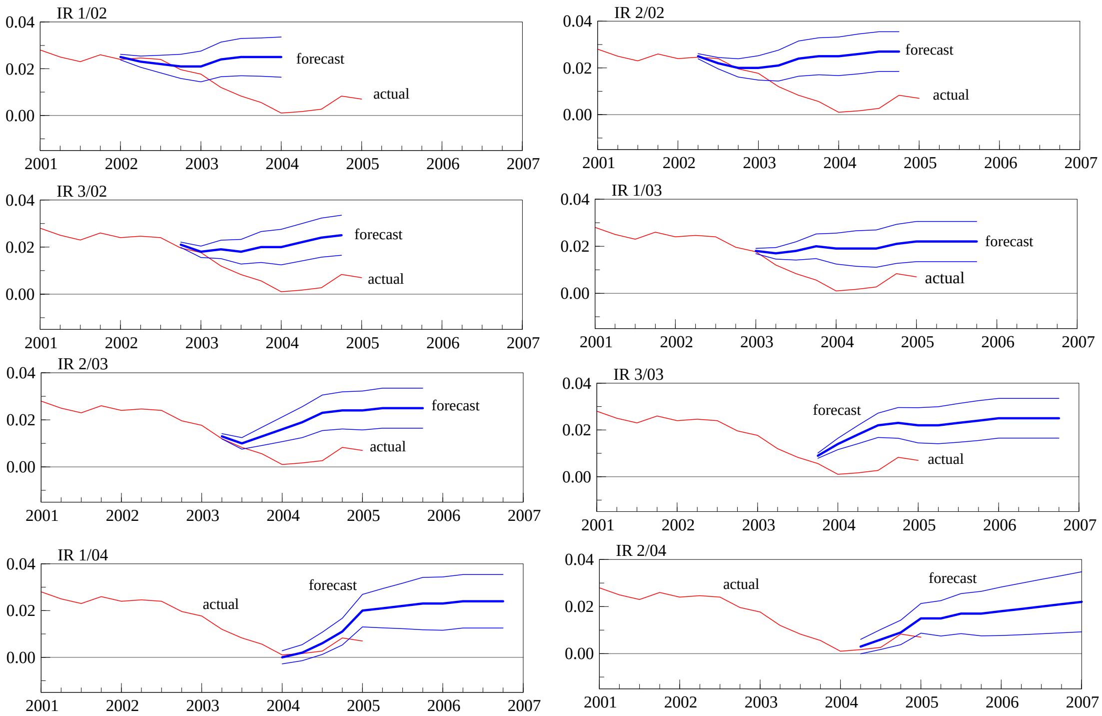

Figure 3: Actual CPI-AET inflation rate and Norges Bank's inflation forecasts (thicker line) and the 90% confidence regions.

comes are covered by the forecast confidence interval, but the continued fall in inflation in 2003 (the second year of the forecast horizon) constitutes a forecast failure. We note that the forecast failure becomes more evident in the two other forecasting rounds in 2002, and all the three forecasts produced in 2003 predicted significantly higher inflation than the actual outcome. Specifically, the forecast confidence interval of IR 3/03 doesn't even cover the actual inflation in the first forecast period.

The IRs from 2002 and 2003 also illustrate the issues raised above about the link between forecast failure and interest rate setting. One often heard response to IR 1/02 for example, is that the failure of the 2003 inflation forecasts is little to worry about, since it simply represents an interest rate path that has subsequently been changed. However, to be valid this viewpoint requires that the IR 1/02 forecast for 2003 was a function only of the *planned* interest rates, i.e., the projected interest rates for the rest of 2002, and for the whole year 2003. If the transmission of interest rate effects takes longer than a one year, the logical implication of the failures of the 2003 forecasts is more worrying: namely that the 7% sight deposit rate which was kept for the whole of 2002 was (far) too high. In the course of 2003 the sight deposit rate was gradually cut from 7% to just below 2%. Hence, one possible interpretation of the extremely poor forecast of the 2003 IRs is that BM overestimated the impact of the change in the instrument on the rate of inflation. Based on the bank's understanding of the Norwegian transmission mechanism, the rate of inflation should have climbed up again—but as the evidence shows, that anticipated reversion did occur.

The seventh panel shows that the forecasted zero rate of inflation for 2004(1) in IR 1/04 turned out to be very accurate. The forecasts were substantially revised from IR 3/04. It is impossible to gauge from available sources whether this is due to permanent changes in BM, and hence in the way Norges Banks understands the economy, or whether it is due to a temporary adjustment to the BM forecast. In any case, the actual rate of inflation is covered by the confidence bands also for the rest of 2004, but the inflation rate of 2005(1) was unexpected based in the forecast one year earlier, and it represents a failure. As can be seen, the reversion of the inflation rate towards the target in the course of two years again turned out to be too optimistic.

Finally, the IR 2/04 forecast clearly incorporates the lengthening of the forecasting and policy horizon that we noted above. The forecasted rate of inflation rises less fast toward the target than in the other IRs. Nevertheless, 2005(1) is a borderline failure. The next section contains an evaluation by way of presenting *ex post* forecasts based on information which were available to the forecasters at the time of preparing the IR forecasts.

5 Automatized inflation forecast

In the introduction, we pointed out that poor forecasts due to *after forecast* structural breaks are unavoidable in economics. Since shocks are unanticipated by definition, large forecast errors in forecasts made before the occurrence of such shocks will always haunt forecasters. Given these facts, there is a premium on having a robust and adaptable forecasting process. Allowing relevant historical shocks to be reflected in forecast uncertainty calculations contributes to robustness in the forecasts, otherwise reported forecast confidence intervals may be too narrow, giving rise to an impression of a high degree of precision in the forecasts. This is of relevance for the evaluation, since the low and stable inflation rates of the late 1990s may have lead forecasters to down-play forecast uncertainty. Yet, as a nominal variable, inflation is subject to frequent changes in mean, exactly the type of shocks that will damage forecasts, see Hendry (2001). Adaptable forecasting mechanisms have the ability to adjust the forecasts when a structural change is in the making, or at the latest, when a forecast failure has manifested itself. Conversely, little adaptable forecasting systems are susceptible to sequences of poor forecasting.

The forecast failures of the previous section also give rise to the question of whether the sequence of poor forecasts was avoidable at the time of preparing the forecasts. This is a complex issue which needs to be analysed from several angles. The most ambitious is to look for the explanation in the forecasting system that actually underlies the bank's forecasts, i.e., the BM and the user determined adjustments. This strategy goes beyond the scope of this paper, and on the face of it seems infeasible given the present degree of documentation of BM, and of the other elements in Norges Banks forecasting process.

Instead we follow an *on-looker's* approach, and set up a forecasting mechanism which features at least two elements which logically must be present in the forecasting process in the central bank: First, all explanatory variables of inflation are themselves forecasted. Hence, our *ex-post* forecasts do not condition on variables that could not have been known also to the forecasters at the time of preparing the different inflation reports. Second, just like in a practical forecasting situation, the forecasts are updated: model parameters are re-estimated as new periods are included in the historical sample, and, more importantly for the forecasts themselves, the initial conditions are changed as we move forward in time.[9] Hence, in our stylized forecasts, the up-dating of the forecasts is automatized. In real life forecasting, of course, the revision of the forecasts from one inflation report to the next is done by forecasting experts and involve both analysis and judgement. The bank's forecasting staff is able to review a range of current economic indicators, and regularly allow that information to influence the published forecasts. In comparison, the econometric forecasts reported below are naive, since no judgemental intercept corrections have been used—they are automatized forecasts.

Turning to the forecasting mechanism itself, it consists of an equation for the rate of inflation (CPI-ATE), and 8 equations which are needed to forecast the following variables: the (logarithm of the) rate of unemployment, productivity growth, the nominal and the real exchange rates, foreign inflation (in foreign currency), domestic and foreign interest rates and oil prices. The theory behind the forecasting equation, and the econometric specification is explained in appendix A.

The set of forecasting equations has been estimated on a quarterly data set which starts in 1981(1). Figure 4 shows the sequence of model forecast that corresponds to Norges Bank's forecasts showed above. We dub them AIRs, *Automatized* IRs that can be used to "shadow" the IR forecasts. The first panel, AIR 1/02 therefore corresponds to the IR 1/02 panel of Figure 3. The forecasted quarters are 2002(1), 2002(2),....,2004(1). In the same way as above, both forecasted and actual inflation (ticker line) are shown, while the confidence regions are shown as error-bars in this graph.

There are three points of difference between AIR 1/02 in Figure 4, and IR 1/02 in Figure 3 worth commenting. First, the confidence bands of the forecasts are wider in AIR 1/02 than in IR 1/02, both for the one and eight quarter ahead forecasts. The scale is the same in the IR and AIR graphs, so the bounds in AIR 1/02 increases to approximately 4%, while IR 1/02 in Figure 3 is approximately 2% at the end of the forecast horizon. The AIR band are only 50% of the Swedish forecast bounds though. Second, even though the second year forecasts in AIR 1/02 show too high inflation, there is a forecasted weak tendency towards lower inflation in 2003. Third, since the second year actual inflation rates are within the corresponding confidence bands, these outcomes do not represent forecast failures in AIR in Figure 4, while their IR counterparts do.

The next panel, labelled AIR 2/02 shows that the conditioning on 2002(1), has little impact on the forecasts for 2002(2), 2002(3),....,2004(1). But in the third panel, marked AIR 3/02, the conditioning on 2002(2) results in much less overprediction of inflation in 2003 and 2004. Clearly, already at the end of 2002, the automatized forecasts for 2003 and 2004 have adapted, in an entirely different way than the official IR forecasts.

The next three panels in Figure 4 show an even more market difference from the Norges Bank forecasts. For example, the poor forecasts of IR 1/03 in Figure

[9] This is because the parameters are relatively constant when we extend the end of sample from 2001(4) to 2003(4).

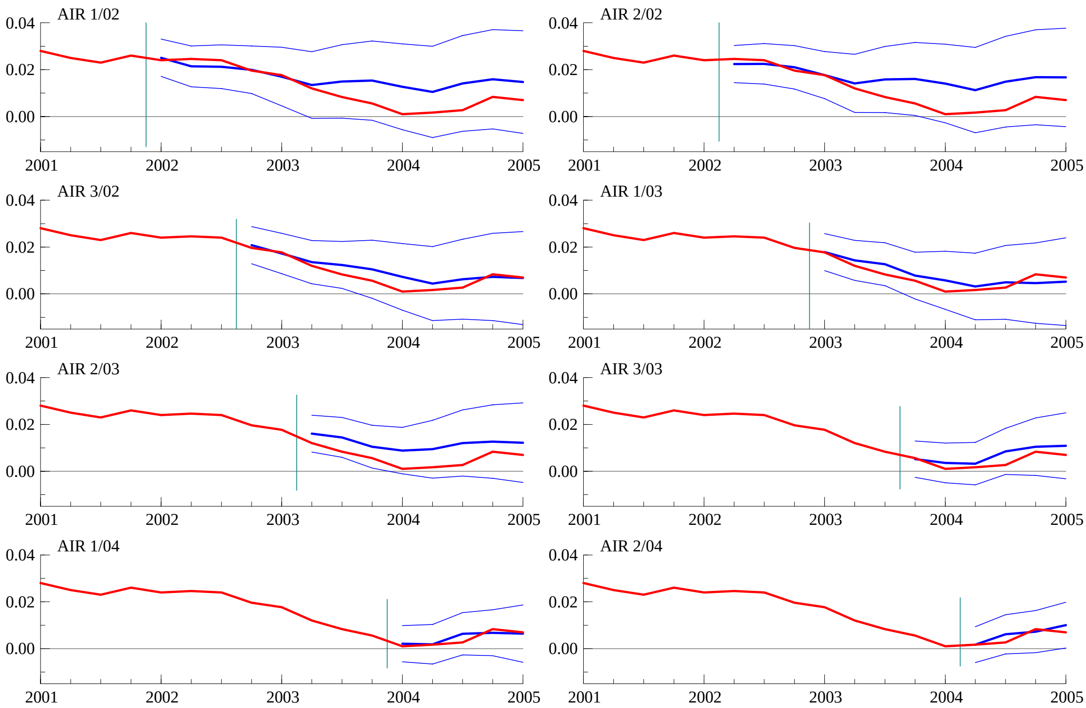

Figure 4: Automatized inflation forecasts. 90% confidence regions are shown as bounds.

3 are replaced by the quite acceptable forecasts dubbed AIR 1/03. Moreover, AIR 3/03 does not show any resemblance with the complete failure of IR 3/03 in Figure 3. Finally, in the same way as in the official forecasts, AIR 1/04 forecasts the inflation rate of 2004(1)-2004(4) quite accurately, but unlike IR 1/04 there is no forecast failure for the first quarter of 2005.

Hence, the conclusion that presents itself is that Norges Bank's recent forecast failure was avoidable. One caveat might be that an important premise for comparison, namely that the econometric forecasts utilize only information that also were within the forecasters' information set, is not fulfilled. In a limited sense that is true—the bank's forecasters did *not* have access to the model used to produce Figure 4. However, in a wider sense, they had both the opportunity and the means, since the model has later been specified using econometric software and data which were available already in 2002 and 2003.[10] Hence, the forecasters could have based their forecasts on a similar, or probably much better, forecasting model. In terms of forecasting history, the forecasts in Figure 4 represent a "possible past".

The fact that the data period available when specifying the model ends in 2004(4), while the official forecast goes back to IR 1/02, does not affect the main principle justifying the forecast comparison. True, having access only to data that ends in 2001(4) could have lead to a false inclusion or exclusion an explanatory variable, but the consequences for the forecasts need not have been detrimental. First, including an irrelevant variable ("overfitting") does not lead to forecast failure. Moreover, the sequential updating of the coefficient estimates means that in each

[10]In fact the dataset used is the databank of the, now defunct RIMINI model.

round of forecasting, the irrelevant variable may be revealed. Falsely excluding a variable which changes in the forecast period will induce forecast failure. But as time passes, and the shift is moved form the forecast period to the estimation period, the hypothesis non-inclusion of such a variable stands a chance of becoming rejected, see Clements and Hendry (2002) for analysis, and Eitrheim et al. (2002) for an example of a major structural break leading to model improvement and better forecasts.

The forecasts of the econometric model, the AIRs, are both more robust, and show more adaptability to shocks than is the case of the recent official forecasts. Robustness comes in a form of confidence regions that are wide compared to the fan-charts of the inflation reports. Being a very simple forecasting system, and since no judgement have been applied to its forecasts, the AIR forecast confidence intervals are probably too wide. In particular, for the first couple of periods ahead, a professional forecaster will usually know more about the inflation-outlook than what is incorporated in an econometric model. This justifies the practice of shrinking the forecast confidence region somewhat, and thus increase the information content of the forecasts. However, care must be taken in order to avoid too narrow bands which will create an illusion of high precision of the forecasts.

6 Conclusions and discussion

In this paper we have taken as our premise that Norges Bank's inflation forecasts are shaped by, and are consistent with, the bank's belief about the transmission mechanism between policy instrument and the rate of inflation—dubbed the Bank Model (BM) above. That same set of beliefs also underlies the interest rates decisions which are made with the purpose of bringing the forecasted rate on inflation in line with the target. Forecast errors are most serious for the evaluation of policy decisions when the transmission mechanism contains non-trivial lags and when interest rates changes are gradual. Both premises seem to be relevant for the operation of inflation targeting in Norway.

The main finding is that all the IRs from 1/02 to 2/04 represent forecast failures, although in varying degree. One conspicuous feature is the complete lack of adaptation of the IR forecasts of 2003. This may reflect an overestimation, written into the central banks forecasting system, of the interest rate effect on the rate of inflation. Or, and this is complementary, the Banks's forecasting system and routines were unable to evaluate precisely enough the strength of the disinflationary shocks that hit the economy during 2003.

We have also shown that automatized inflation forecasts, AIRs, can be used to shadow the IR forecasts. There are no forecast failures for AIRs. Robustness of the AIR forecasts comes in a form of confidence regions that are wide compared to the IRs fan-charts, hence to some extent the IR forecast failures are certainly due to underestimation of forecast error uncertainty. But the underestimation is worrying in itself, since objective measurement of inflation forecast uncertainty is a premise for modern inflation targeting. Moreover, the success of the AIRs is not seemingly, and due to the wider confidence bands. The AIRs also give more accurate point predictions and, despite being automatized, show much more adaptation. Against this backdrop, we conclude that the recent inflation forecast failure was to some extent avoidable.

The no-forecast-failure for AIRs has other implications as well. First, the explanation of IR forecast failure is *not* regime-shifts in the Norwegian inflation process. Our investigation thus provides a counter example to the thesis that the source of forecast failures is "always" deterministic shifts damaging the forecasts from a model that is well specified within sample. Plainly speaking, the failures of the IR forecasts do not appear to be resulting from a model which is a reasonable good approximation to the Norwegian inflation spiral. The systematic forecast errors are instead due to a mistaken model of the transmission mechanism which incorporates the end-point restrictions (2.5% within two years). In 2004 there was a change in the central bank's forecasting system which moved the end point restriction one year out in the policy horizon. This amounts to a structural change in the bank's forecasting model which has no counterpart in the underlying Norwegian inflation spiral.

Forecast failure is not only destructive but represent a potential for improvement, since respecification of models and other changes in the forecasting process may follow in its wake. A potential solution to Norges Banks present quandary is to increase the adaptability of the forecasting process. Forecasting systems with a high degree of adaptability are specified in terms of differences of the variables, but cannot be rationalized using economic analysis, see e.g., Hendry (2001). At the other extreme, forecasts from models that are prescribed from at theory based on stylized assumptions will be unresponsive the type of shocks that cause forecast failure. However, between the two extremes there is a large middle ground where forecasting systems which are based on economic analysis, and which are adaptable enough to avoid *before forecast* structural breaks, can thrive. An econometric model, provided that it is evaluated and updated regularly using both theoretical and statistical standards, combined with judgemental intercept correction, represents one route to achieving an adaptable system for inflation forecasting

A A simple forecasting model

Our preferred approach to inflation modelling is to model the markets that features foremost in the inflation spiral, namely the labour market, the market for foreign exchange and price setting in domestic product markets, using models that are consistent with modern economic theory and which are specified econometrically, see e.g., Sargan (1964), Rowlatt (1992), Bårdsen et al. (2003). However, even a completely aggregated structural model is quite demanding to operate in practice (data input and maintenance), so something less well specified will have to do. In brief, we set up an empirical reduced form model of $\Delta_4 pa_t$ which has interpretable signs on the coefficients of the variables that represent the different markets in the Norwegian inflation spiral. It is a simple reduced form of a incomplete competition model of wage and price dynamics, see Bårdsen and Nymoen (2003).

Since the purpose of the modelling exercise is to forecast the annual growth rate of inflation, we choose the four quarter change in the natural logarithm of CPI-AET as the dependent variable, it is denoted $\Delta_4 pa_t$ in the model reported in equation (6). Of course $\Delta_4 pa_{t-1}$is an excellent predictor of $\Delta_4 pa_t$, but collinearity then hinders estimation of the effects of other explanatory variables, including the effect of the interest rate. In other to reduce the degree of collinearity we instead use

$\Delta_4 pa_{t-4}$ as the autoregressive term, although this will induce some autocorrelation in the residuals.

$$
\begin{aligned}
\Delta_4 pa_t = \; & \underset{(0.002)}{0.018} + \underset{(0.05)}{0.37}\, \Delta_4 pa_{t-4} + \underset{(0.003)}{0.04}\, D_{p,t} \\
& - \underset{(0.003)}{0.012}\, (u-\mu_u)_{t-1} - \underset{(0.004)}{0.010}\, (u-\mu_u)_{t-3} - \underset{(0.004)}{0.018}\, (u-\mu_u)_{t-4} \\
& - \underset{(0.042)}{0.15}\, i_{t-4} + \underset{(0.06)}{0.17}\, i_{*,t-4} + \underset{(0.019)}{0.05}\, (rex-\mu_r)_{t-4} \\
& + \underset{(0.05)}{0.48}\, \Delta_4 p_{*t} - \underset{(0.017)}{0.05}\, \Delta_4 z_t + \underset{(0.015)}{0.02}\, \Delta_4 z_{t-6}
\end{aligned} \tag{6}
$$

$$
\begin{array}{lcllcl}
T = 1981\,(1) - 2000\,(4) = 76 & & & OLS & & \\
\hat{\sigma} & = & 0.45\% & & & \\
\mathsf{F}_{\mathsf{AR}(1-5)}(5,63) & = & 7.95[0.00] & \chi^2_{\mathsf{Forecast}}(16) & = & 7.42[0.96]] \\
\chi^2_{\mathsf{normality}}(2) & = & 2.82[0.24] & \mathsf{F}_{\mathsf{Chow}}(16,68) & = & 0.43[0.97] \\
\mathsf{F}_{\mathsf{x}}(20,44) & = & 1.15[0.3346] & t_{\mathsf{bias}}(15) & = & -0.70[0.49]
\end{array}
$$

Together with $\Delta_4 pa_{t-4}$ on the right hand side we include two deterministic terms: an intercept and a dummy variable $D_{p,t}$, which mops up the inflation effects of a devaluation in may 1986 as well as the cost-push effect of the reduction in the length of the working week in January 1987, see Nymoen (1989). The detailed definition of $D_{p,t}$ is given in section B. Since most of the economic right hand side variables, which we return to shortly, have zero means, the intercept is a raw estimate of the average short run mean of the annual rate of inflation. The estimated 1.8% rate of inflation is perhaps a too high, but the implied long-run mean of 2.9% is not unreasonable for the sample period.

Below the equation we report the residual standard error $\hat{\sigma}$ (in percentage points).[11] As noted in the main text, the estimated residual standard error of 0.45% is much larger than the implied standard deviation of the IR forecast, even 1-step ahead. It represents a kind on intrinsic uncertainty in the AIR forecasts and it determines how wide the forecasts bounds are at the beginning of each AIR period. Hence, $4 \times 0.45\% = 1.8\%$, is close to the width of the first AIR uncertainty bounds in Figure 4. According to the estimated equation, the unconditional standard error is only a little larger, 0.48%. However, that calculation rests on the assumption that all the explanatory variables are deterministic, which they of course are not. As can be seen from Figure 4, the valid AIR confidence bounds increase to about 4%, meaning that a significant share of inflation forecast uncertainty is inherited from the stochastic explanatory variables in equation (6).

The second line of the equation contains four lags of the rate of unemployment, adjusted for the mean μ_u. The unemployment variable is the natural logarithm of the

[11] In the equation, the sample size (number of quartely observations) is denoted by T, and the residual standard error by $\hat{\sigma}$ as noted in the text. In the same column as $\hat{\sigma}$ three residual tests are reported: As indicated by the notation, the normality test is a Chi-square test, while the two other (autoregressive residual autocorrelation, and heteroscedasticity due to squares of the regressors) are F-distributed under their respective null hypotheses. The numbers in brackets are p-values for the respective null hypotheses. In the second column we report constancy ($\mathsf{F}_{\mathsf{Chow}}$) and forecast accuracy tests ($\chi^2_{\mathsf{Forecast}}$ and the Student-t distributed t_{bias}) These diagnostics tests are explained in Doornik and Hendry (2001a).

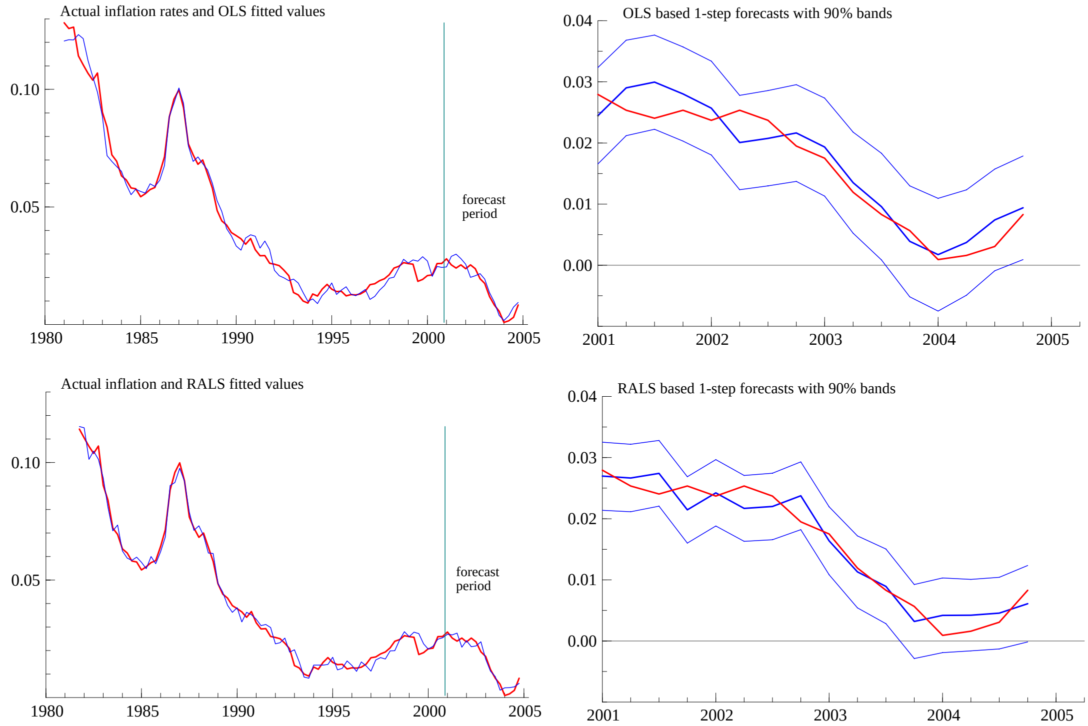

Figure 5: Fit and forecasts of equation (6) and autoregressive least square estimation of the same equation, denoted RALS in the figure

labour force survey rate of unemployment, see section B, and it enters the reduced form inflation equation primarily through wage setting, although it may also act as a proxy for cyclical variation of the mark-up in price setting. Previous research has established empirically the effect of unemployment on wages, both in a Phillips curve framework and in wage equations that can be rationalized from bargaining theory, see Bårdsen et al. (2005, Chapter 3-6) for an overview. The numerically and statistically significant effects in equation (6) are therefore consistent with several existing studies.

The third line in equation (6) represents the inflationary impulses from the market for foreign exchange: Under quite general assumptions, the difference between the interest rate in the domestic, (i_t) and foreign money markets $(i_{*,t})$ affects the nominal exchange rate, see Bårdsen and Nymoen (2005) for an analysis. In equation (6) the interest rate differential manifests itself quite clearly (at the fourth lag) although we have estimated the two coefficients freely in this case. Usually, a real depreciation of the currency, corresponding to a higher rex in the notation of equation (6), will lead to a certain 'internal devaluation' and appears to be picked up by the positive coefficient of the mean adjusted real exchange rate.

In the fourth line of the inflation equation, we first include the direct effects of imported inflation, as measured by $\Delta_4 p_{*,t}$ the annual rate of change in foreign consumer prices, in foreign currency. Finally, the variable $\Delta_4 z_t$ is a measure of the annual rate of productivity growth. The impact effect is negative, consistent with normal cost pricing in domestic product markets. The sixth lag has an (albeit weakly significant) positive coefficient. We believe that this is consistent with the view that manufacturing sector productivity are by and large wage leaders, hence over some period of time, productivity growth in the manufacturing sector may lead to a positive pressure on prices in the service and non-tradables sectors, see Rødseth (2000, Ch 7.6).

As noted above the specification with $\Delta_4 pa_{t-4}$ as the autoregressive term induces autocorrelated residuals. Re-estimation of equation (6) by autoregressive least squares (a third order process is assumed) shows that all coefficients remain significant, with the exception of the coefficient of $\Delta_4 z_{t-6}$, which is non-robust with respect to estimation method. The residual standard error is markedly reduced, from 0.48% to 0.31% and the forecast bands are therefore narrower in the 1-step RALS forecasts in Figure 5. In future use, one possibility is to shrink the uncertainty bands of the AIRs by use of RALS estimation.

The AIRs are based on equation (6) which is sequentially updated by re-estimation, hence for AIR 2/02 the estimation period is 1981(1)-2002(1) and so on. All the stochastic variables in equation (6) are in turn modelled by econometric relationship, so that the AIRs are based on estimation and dynamic simulation of a 9 equation system: There is one equation for each of the 7 explanatory variables in (6), and in addition the annual rate of change in the price of oil is modelled (because it is used in the equation for $\Delta_4 p_{*t}$), and the nominal exchange rate is also modelled in order to forecast the real-exchange rate (rex) within the forecasting system.

B Data definitions and sources

The forecasting model employs seasonally unadjusted data. Unless another source is given, all data are taken from the RIMINI database in Norges Bank (The Central Bank of Norway). The data are seasonally unadjusted. For each RIMINI-variable, the corresponding name in the RIMINI-database is given by an entry [RIMINI: variable name] at the end of the description. The RIMINI identifier is from Rikmodnotat 405, Norges Bank, Research department, 9th December 2002. Each variable's name in the PcGive batch file that generate the forecasting mechanism is also given, with transformation indicated when relevant.

The variables used in the forecasting equation for the rate of inflation are defined as follows:

PA Consumer price index adjusted for the influence of energy prices and indirect taxes, CPI-ATE. 1991=1. [RIMINI: CPIJAE].{PcGive: $cpijae = \ln(CPIJAE)$}.

P Consumer price index (CPI). 1991=1. [RIMINI: CPI].{PcGive: $p = \ln(CPI)$}.

P_* Consumer prices abroad in foreign currency. 1991=1. [RIMINI: PCKONK].{PcGive: $pck = \ln(PCKONK)$}.

E Trade weighted nominal value of the krone based on import-shares of trading countries. [RIMINI: CPIVAL].{PcGive: $v = \ln(CPIVAL)$}.

Z Value added per man hour at factor costs in the Norwegian non-tradables sector, fixed baseyear (1991) prices. Mill. NOK. [RIMINI: ZYI].{PcGive: $zyi = \ln(ZYI)$}.

i Money market interest rate (3 month Euro-krone interest rate). [RIMINI: RS].{PcGive: *RSH*}.

i_* ECU interest rate. For the period 1967(1)-1986(3): Effective interest rate on foreign bonds, NOK-basket weighted. [RIMINI: R.BKUR] For the period 1986(4)-1996(4): ECU weighted effective rate on foreign bonds. [RIMINI: REC/100].{PcGive: RSW}.

U Labour force survey (AKU) rate of unemployment. [RIMINI: UAKU2].{PcGive: $u = \ln(UAKU2)$}.

The logarithm of real effective exchange rate is defined as follows

$$rex = \ln(E) - \ln(P) + \ln(P^*)$$

while the dummy is defined as follows

$$D_{p,t} = 0.25i86q2_t + i86q2_{t-1} + i86q2_{t-2} + i86q2_{t-3} + i86q2_{t-4} + 0.25i86q2_{t-5}.$$

where *i86q2* is 1 in the second quarter of 1986, and is 0 in all other quarters.

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