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Why and How to Assess Inflation-Target Fulfillment

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Abstract

The ex post analysis of inflation-target fulfillment plays an important role in the inflation--targeting framework. The major benefits of ex post analysis are threefold. First, it improves forecast accuracy. Knowledge of the main sources of previous forecast inaccuracies helps to better understand the current state of the economy and prevents a central bank from producing systematically biased forecasts. Second, it elucidates the abilities and limitations of forecasts used in central-bank decision making. Third, it enhances monetary-policy transparency and credibility.

The primary aim of the paper is to propose a methodological framework for assessing inflation-target fulfillment based on partial simulations, as applied in the Czech National Bank. In order to demonstrate the applicability of this framework, we analyze the performance of the bank between 2002 and 2006. We show that inflation targeting in this period might have been negatively affected by biased variables describing external developments.

1. Introduction

Central banks are increasingly focusing their efforts on improving the transparency of monetary policy. This trend is reflected by a growing number of central banks explicitly announcing their quantitative inflation targets, notwithstanding whether they call them selves inflation targeters or not. The existence of explicit target allows a central bank to analyse monetary policy performance. For example, Svensson (1997) notes: „[...] a specified quantitative target [...] provides an ex post measurement of monetary policy performance, namely realized inflation relative to the inflation target."

The major benefits of ex post analysis of inflation target fulfilment are threefold. First, it provides a central bank with a useful tool for a regular check of model accuracy and lack of bias. Second, it strengthens the knowledge of shock transmission in the economy as described by the modeling apparatus among the staff and Board members. Third, publication of a sound analysis of target misses/fulfilment might enhance monetary policy transparency and credibility.

Empirical evidence supports this line of reasoning. For example, Eijffinger and Geraats (2002) include a public evaluation of the target fulfilment in the operational transparency component of their transparency index.[1] A subsequent study by Demertzis and Hallett (2002) used the Eijffinger-Geraats index to estimate the impact of

[1] Beside the public evaluation of target fulfilment (a description of transmission disturbances and the comparison of the outcome with central bank objectives) the operational transparency component includes discussion of control errors in achieving operating targets. From the sample of nine major central banks, only Sveriges Riksbank received a full score in this transparency aspect.

transparency on inflation and output variability. One of their conclusions[2] is that operational transparency significantly reduced inflation variability.

Despite these benefits of doing and disclosing the assessment, a fear exists of being too transparent by disclosing such sensitive information. Some economists (Jensen, 2002) and (Mishkin, 2004) argue that transparency has its own limits and that full transparency is less than optimal. Recognition and public announcements of central bank mistakes might in their opinion shed doubt on future success of the central bank and decrease public confidence in the future fulfilment of the target. Alternatively, it is argued that too much transparency in general may bring too much attention to the central bank signals and crowd out the signals from the private sector – see (Morris, Shin, 2002). Higher transparency then increases rather than decreases the economy's sensitivity to external shocks. On the other hand, some economists argue in favour of full transparency (e.g. Blinder (1998) or Chortareas, Stasavage and Sterne (2002)).

We argue that publishing target fulfilment assessment might, if properly communicated, further enhance a central bank's transparency and credibility. Public disclosure reveals the central bank's ability for self-reflection and its willingness to learn from its past mistakes. If the mistakes are not discussed by the bank, they will be discussed by journalists and analysts using simple methods and with usually less precise and (for the bank) less favourable conclusions. Also, publishing the reasons behind meeting/missing central bank objective makes the central bank accountable to the public and thus solves the dilemma of the limited accountability of an independent central bank. Last, but not least, publishing the analysis may further enhance public knowledge of the target and transmission mechanism of the monetary policy, especially knowledge of the transmission lag between the central bank's measures and their biggest impact on the economy.

Section 2 of this paper provides a reader with a detailed overview of current practice in evaluating target fulfilment in selected "targeting" central banks. In section 3 we propose a methodological framework for the decomposition of inflation deviation from the target into underlying economic factors, based on partial simulations. Section 4 summarizes the historical experience of the Czech National Bank with this particular way of inflation target assessment. Section 5 presents the conclusion.

2. Survey of Current Practice in Target Fulfilment Assessment

In this section we provide an overview of how selected central banks balance the pros and cons of target fulfilment assessment and its public disclosure. The countries in our selection are OECD countries with an explicit target. Out of 19 OECD members with an independent monetary policy framework[3], 17 members have an explicit target and 2 members (Japan and the U.S.) conduct monetary policy without any explicit target. With exception of Danmarks Nationalbank, which has a fixed exchange rate regime against the euro, all central banks with an explicit target focus their attention on inflation. In the rest of this section we describe the assessment of hitt-

[2] They also found that higher operational transparency increases output variability. This is probably due to a transparent central bank's higher emphasis on the primary target, and fully in line with the Jensen (2002) findings.

[3] OECD countries, which are members of the euro area, are treated in this paper as a single country.

ing/missing the target in 16 countries with central banks explicitly targeting inflation, namely at the Reserve Bank of Australia, Bank of Canada, Czech National Bank, European Central Bank[4], Magyar Nemzeti Bank, Central Bank of Iceland, Bank of Korea, Banco de México, Reserve Bank of New Zealand, Norges Bank, National Bank of Poland, Národná Banka Slovenska, Sveriges Riksbank, Swiss National Bank, Central Bank of the Republic of Turkey and the Bank of England.

First we searched through central banks websites for publicly available documents on the issue of target fulfilment and analysed whether these documents describe, in detail, the underlying factors behind the target (non)fulfilment and whether they explicitly contain the evaluation of monetary policy contribution. Second, we sent a questionnaire to each central bank in the sample asking to reveal its internal target fulfilment assessment procedures. Subsequently we compared these two sets of information and analysed how much the internal documents differ from the officially published documents.

Despite the pronounced transparency of central banks operating in inflation targeting regime and despite the key role of inflation target fulfilment in building the credibility record, not every central bank in our sample (as of summer 2006) provides a public analysis of target fulfilment or mentions the role of central bank policy in the outcome (see *Table 1*).

Four central banks in the sample do not regularly and explicitly compare inflationary outcomes with their inflation target (we consider the joined presentation of actual inflation and the inflation target in a single paragraph, table or chart to be an explicit comparison) or, in the case of the European Central Bank, with its definition of price stability. In the case of the Narodná Banka Slovenska, the absence of the comparison probably stems from the short history of inflation targeting, which was adopted in December 2004 with the first target set for December 2005. Aside from these four, the central banks confront inflation with the target verbally, graphically, or numerically. In a majority of banks, this comparison is published both in their core annual (Annual Report) and quarterly (Inflation Report, Monthly Bulletin, etc.) publications.

Table 1 shows that if a central bank decides to compare actual inflation with the target, it also provides the analysis of the underlying factors behind the inflation outcome. A strong tendency seems to exist among the banks to explain the deviation from the target, if it is unveiled. This finding is intuitive since the detailed explanation allows the bank to sustain inflation target credibility by blaming the deviation from the target fully or partially on factors that are outside the monetary policy control. A specific procedure exists in the Bank of England, which only provides a public explanation of the deviation from the target when inflation deviates from the target range by more than 1 percentage point. The first (and so far only) letter was sent in April 2007.

Interestingly, after excluding the Bank of England, only six banks in our sample provide a full description of factors behind meeting/missing the target including a discussion of monetary policy contribution. These are the Bank of Canada, Bank of England, Czech National Bank, Magyar Nemzeti Bank, Norges Bank, National Bank

[4] Although ECB officially does not consider itself an inflation targeter, its definition of price stability fulfils the features of an inflation target – see (Kieler, 2003).

TABLE 1 Publicly Disclosed Analysis of Inflation Target Fulfilment

Country	Central bank	Explicit comparison of inflation with target	Analysis of underlying factors in the outcome	Explicit role of monetary policy in the outcome
Australia	Reserve Bank of Australia	no	yes (SMP)	no
Canada	Bank of Canada	yes (MPR + AR)	yes (MPR + AR)	yes (AR)
Czech Republic	Czech National Bank	yes (IR + AR)	yes (IR + AR)	yes (IR)
Euro area	European Central Bank	no	yes (MB)	no
Hungary	Magyar Nemzeti Bank	yes (IR + AR)	yes (AR)	yes (AR)
Iceland	Central Bank of Iceland	yes (MB + AR)	yes (MB + AR)	yes[a]
Korea	Bank of Korea	yes (MPR + AR)	yes (MPR + AR)	no
Mexico	Banco de México	yes (IR)	yes (IR)	no
New Zealand	Reserve Bank of New Zealand	yes (MPS + AR)	yes (MPS)	no[b]
Norway	Norges Bank	yes (MPR + AR)	yes (MPR[c] + AR)	yes (MPR[c] + AR)
Poland	National Bank of Poland	yes (IR + AR)	yes (IR + AR)	yes (IR)
Slovak Republic	Národná Banka Slovenska	no	no	no
Sweden	Sveriges Riksbank	yes (MPR[d] + AR)	yes (MPR[d] + AR)	yes (MPR[d] + AR)
Switzerland	Swiss National Bank	no	no	no
Turkey	Central Bank of the Republic of Turkey	yes (AR)	yes (AR)	no
United Kingdom	Bank of England	yes (IR + AR)	yes[e]	yes[e]

Abbreviations: AR = Annual Report, IR = Inflation Report/Report on Inflation, MB = Monthly Bulletin/Monetary Bulletin, MPR = Monetary Policy Report, MPS = Monetary Policy Statement, SMP = Statement on Monetary Policy

Notes: [a] If inflation moves beyond the tolerance limit (currently ± 1.5 percentage point), the Central Bank of Iceland is obliged to send a report to the government, explaining the reasons for the deviation from the target.

[b] Role of moentary policy mentioned occassionally (i.e. Drew and Orr (1999)).

[c] published annually in spring issue of Economic Bulletin and February/March issue of MPR

[d] annually in first MPR issue

[e] If inflation moves away from the target by more than 1 percentage point, Governor of the Bank is obliged to write an open letter to the Chancellor explaining the reasons behind target missing.

Source: Central banks' websites, author's survey

of Poland and the Sveriges Riksbank. Surprisingly, the Reserve Bank of New Zealand, despite its high degree of monetary policy transparency does not include an explicit discussion of monetary policy contribution to target fulfilment in its regular publications.

For some central banks, the cons of revealing the target fulfilment assessment to the public might exceed its pros. It is then reasonable to conduct the assessment for internal purposes only. In that case, outsiders can hardly find out whether such an analysis is being made and what the main sources of target (non)fulfilment are.

To unveil the internal assessment procedures, we sent out a questionnaire to the central banks in our sample, asking them to reveal their internal target fulfilment assessment procedures. Eleven out of 16 central banks have responded (a response rate of 69 %).[5] Given the confidentiality of the survey answers we will hereafter only discuss a summary of the main findings from the survey without citing any particular banks.

Surprisingly, from the 11 banks which sent back the questionnaire, only two claim that they do not disclose the target fulfilment analysis to the public in its full length. Notably, these two banks use sophisticated modelling techniques for the decomposition of the overall deviation from the inflation target into its separate underlying factors. These banks do not publish all the technical details of the computation and the exact results of the simulations, but a verbal description of the main results, primarily for sake of clarity.

If evaluated, the contribution of the central bank monetary policy to the target fulfilment is disclosed to the public. However, it must be said that the publicly disclosed evaluation of the past monetary policy is usually written in a rather general manner, without any explicit judgement on the soundness of the past monetary policy.

Roughly half of the responding central banks employ a modeling technique in the target fulfilment assessment, the other half relies rather on expert judgement. If a macroeconomic model is used in the assessment, it is in most cases the core model used for building the central bank forecast. The main advantages of the application of the same model for both tasks are the mutual consistency of the assessment with the forecast and the possibility to use the results of the assessment immediately for forecast improvement. Indeed, all the banks which use the same modeling technique for both assessment and forecasting use the results of the assessment as feedback into the forecast and whenever the assessment reveals a systematic bias, a review of the model assumptions is initiated.

On the other hand, the close link between the forecast and assessment implies that usually the same staff prepares both the assessment of the target fulfilment and the forecast. This is the case in the majority of the central banks in our sample, especially in the banks which use sophisticated modeling techniques. Then, incentives to do some "prejudiced" window dressing might emerge. For example, the staff may either intentionally or unintentionally distort the analysis in such a manner as to undervalue the forecast error (for example, by attributing missing the target primarily to vis major – external development). But there are ways this problem can be reduced. For example, a rewards scheme, based on the improvement of forecast accuracy (not on the forecast accuracy itself) might be implemented.

3. How to Assess Target Fulfilment

In this section we describe the methodology of the evaluation of target fulfilment as applied in the CNB. This methodology is based on partial simulations of a core macroeconomic model. The CNB's core model is a New Keynesian model with forward looking expectations and endogenous monetary policy, more details on the CNB's model can be found in (Coats, Laxton, Rose, 2003).

The use of a model with a monetary policy reaction function provides a consistent framework, which accounts for active monetary policy. On the other hand it

[5] Here I would like to thank all the respondents for valuable feedback, namely: Michal Brzoza-Brzezina from the National Bank of Poland, Philippine Cour-Thimann from the European Central Bank, Guy Debelle from the Reserve Bank of Australia, Gill Hammond from the Bank of England, Per Jansson from the Sveriges Riksbank, Per Espen Lilleås from the Bank of Norway, Sharon McCaw from the Bank of New Zealand, John Murray from the Bank of Canada, Thorarinn Petursson from the Central Bank of Iceland and Ernesto Sepulveda-Villarreal from the Banco de México.

makes the analysis more difficult. If monetary policy reacts to exogenous shocks, the inflation forecast stays near the inflation target in the longer-term horizon regardless of the deviations in other variables. This prohibits us from simulating the impact of one variable's deviation on inflation, because all simulations end up with inflation on target. However, the effect of different assumptions can be seen in the monetary policy instrument – interest rates. There are two plausible ways for dealing with this complication.

We can "switch off" the reaction function and keep interest rates fixed for some period of time. With such a passive policy, the effect of deviation in a given variable on inflation is not offset by the central bank's reaction. Alternatively we can simply evaluate the impact of the deviation in a given variable on the interest rate trajectory instead of its impact on inflation. Since either way has its shortcomings we analyse both of them in the following text, starting with the transitory switching off of the reaction function.

In both approaches, the purpose of simulations is to explain the difference between the actual inflation and the inflation target:

$$\pi_t - \pi_t^{target} \tag{1}$$

where π_t stands for the actual inflation and π_t^{target} for the inflation target.[6] In a flexible targeting framework, the central bank does not have to fully offset the inflationary impact of an economic shock. Hence, part of the difference (1) might be explained either by calling escape clauses into effect or by smoothing the interest rate trajectory. Both explanations should be already incorporated in the forecast upon the central bank, decided *n*-time periods ago, when the central bank was influencing inflation in time *t*:

$$\pi_t - \pi_t^{target} = \pi_t - E_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) + \varepsilon^{escape\_clauses} + \varepsilon^{smoothing} \tag{2}$$

where $E_{t-n}\pi_t$ stands for the inflation forecast, made *n*-time periods ago, a time horizon corresponding to the lag in the monetary policy transmission. x denotes exogenous variables (from model perspective input variables), ir interest rates and the E_{t-n} operator their expected behaviour. $\varepsilon^{escape\_clauses}$ specifies the intentional missing of the target as ex ante explained by escape clauses and $\varepsilon^{smoothing}$ as the intentional missing of the target explained by interest rate smoothing. Values of $\varepsilon^{escape\_clauses}$ and $\varepsilon^{smoothing}$ are known at the time when the forecast is being made and the equation (2) should always hold for consistency reasons. This becomes evident when we subtract the actual inflation from both sides of the equation (2) and rewrite:

$$\varepsilon^{escape\_clauses} + \varepsilon^{smoothing} = E_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) - \pi_t^{target} \tag{2´}$$

We can analyse these two factors of missing the target in more depth either jointly or separately. If we opt for the separate analysis, we can obtain the contribution of the escape clause application by running the simulation with the assump-

[6] Here we assume that the inflation target is either a point target or a range target with a midpoint. If the target is set as a range without a midpoint, it is reasonable to use the middle of a range as a benchmark.

tion that the central bank reacts to overall inflation development and not to a part of it, as in the case of the escape clause application. The contribution of smoothing is then easily obtained as a complement.

Having described intentional target missing, we can go further and break down the right-hand side of equation (2), unexplained by escape clauses and smoothing, as follows:

$$\pi_t - E_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) = \pi_t - E'_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) + \varepsilon^{model\_change} \qquad (3)$$

where $E'_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir)$ stands for the inflation forecast, as if it were made in time *t-n* using the latest model specification, i.e. using today's knowledge of the functioning of the economy, but with the original forecast's assumptions on exogenous variables and nominal interest rates. Equation (3) then compares the missing of the target using the historical model specification and the missing of the target when the latest model specification is applied. $\varepsilon^{model\_change}$ stands for the part of the missing of the target explained by the changes in the model specification and improvements in the understanding of the economy since the original forecast formulation.

Again, equation (3) can be rewritten into:

$$\varepsilon^{model\_change} = E'_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) - E_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) \qquad (3')$$

The right-hand side of the equation (3), unexplained by the model specification improvement, can be further decomposed into:

$$\pi_t - E'_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) = \pi_t - E'_{t-n}\pi_t(x, E_{t-n}ir) + \varepsilon^{exogenous} \qquad (4)$$

where *x* denotes the actual development of the exogenous variables in the model and $\varepsilon^{exogenous}$ the part of the missing of the target assigned to the deviation of actual exogenous variables´ development from the original assumptions of the forecast. Again, for the purpose of better visualisation we rewrite the equation (4) into:

$$\varepsilon^{exogenous} = E'_{t-n}\pi_t(x, E_{t-n}ir) - E'_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir) \qquad (4')$$

The simulation $E'_{t-n}\pi_t(x, E_{t-n}ir)$ is done using the present model specification, the actual exogenous variable development and the original interest rate trajectory.

Subsequently, the right-hand side of the equation (4), unexplained by the deviation of actual exogenous variables from the assumptions, can be rewritten into:

$$\pi_t - E'_{t-n}\pi_t(x, E_{t-n}ir) = \pi_t - E'_{t-n}\pi_t(x, ir) + \varepsilon^{monetary\_policy} \qquad (5)$$

where *ir* stands for the actual development of interest rates and $\varepsilon^{monetary\_policy}$ for the part of missing the target explained by the deviation of the actual interest rate development from the original recommendation of the model. Rewriting the equation (5) we get:

$$\varepsilon^{monetary\_policy} = E'_{t-n}\pi_t(x, ir) - E'_{t-n}\pi_t(x, E_{t-n}ir) \qquad (5')$$

The simulation $E'_{t-n}\pi_t(x,ir)$ is obtained by running the simulation with the latest model specification, the actual exogenous variables´ development and the actual interest rate development.

Finally, the right-hand side of equation (5), unexplained by the deviation of actual interest rates development from the assumptions, is labelled as model inaccuracy:

$$\varepsilon^{model\_inaccuracy} = \pi_t - E'_{t-n}\pi_t(x,ir) \tag{6}$$

More precisely, $\varepsilon^{model\_inaccurancy}$ is the part of the missing of the target, unexplained by previous simulations. This term captures both the inaccuracy of the present model, the inaccuracy of the simulations and the inaccuracy of the data.

It must be said that the approach of partial simulations presented here is conditional on several simplifying assumptions. First, we assume that historical data, as published for example by the statistical office, are perfect measures of reality. Second, we treat historically observed shocks as expected in simulations. Third, we consider the latest version of the model as the best available description of reality. We should carefully bear these assumptions in mind especially when interpreting the last part of the missing of the target as defined by equation (6).

Solving equations (2) to (6) we get:

$$\begin{aligned}\pi_t - \pi_t^{target} &= \varepsilon^{escape\_clauses} + \varepsilon^{smoothing} + \varepsilon^{model\_change} + \\ &+ \varepsilon^{exogenous} + \varepsilon^{monetary\_policy} + \varepsilon^{model\_inaccurancy}\end{aligned} \tag{7}$$

While the first two terms on the right-hand side describe the intentional missing of the target, the remaining terms should be considered as the unintentional missing of the target. The aim of the central bank should be to minimize the extent of the unintentional missing of the target, i.e. the values of $\varepsilon^{model\_change}$, $\varepsilon^{exogenous}$, $\varepsilon^{monetary\_policy}$ and $\varepsilon^{model\_inaccurancy}$.

Some central banks, including the CNB, when forecasting exogenous variables mechanically draw on the consensual forecasts of independent economists. In that case, the central bank is not directly responsible for the $\varepsilon^{exogenous}$ term, and the forecasting team should only be held responsible for $\varepsilon^{model\_change}$ and $\varepsilon^{model\_inaccurancy}$. $\varepsilon^{model\_change}$ is the disclosed part of the model inaccuracy, while $\varepsilon^{model\_inaccurancy}$ is the undisclosed part. It is reasonable to assume that the forecasting team gradually improves the forecasting techniques, so non-zero values of $\varepsilon^{model\_change}$ consequently reduce the values of $\varepsilon^{model\_inaccurancy}$. If the forecast was based on the internally made assumptions regarding exogenous variables, the forecasting team should also be responsible for the value of $\varepsilon^{exogenous}$.

It is the role of the decision-making body of the central bank (monetary policy committee, banking board) to identify the risks of the forecast and to choose the $\varepsilon^{monetary\_policy}$ that offsets the inaccuracy of the forecast and minimizes the overall sum of $\varepsilon^{model\_change}$, $\varepsilon^{exogenous}$, $\varepsilon^{monetary\_policy}$ and $\varepsilon^{model\_inaccurancy}$, i.e. the future

unintentional deviation of inflation from the target. In an ideal case, the decision--making body should fully compensate for forecast inaccuracy:

$$\varepsilon^{monetary\_policy} = -(\varepsilon^{model\_change} + \varepsilon^{exogenous} + \varepsilon^{model\_inaccurancy}) \quad (8)$$

However, equation (8) does not hold if the decision maker has changed the perception of optimal interest rate smoothing or the perception and application of escape clauses since the original forecast completion. To differentiate between the effect of risk assessment and the effects of changes in monetary policy behaviour, one must carefully read the minutes from the decision body's meetings and identify the overall risk assessment.

A similar approach might be adopted in central banks that use, in their decision--making, models with exogenous monetary policy, which are based on the assumption of unchanged interest rates or interest rates fixed on a predefined trajectory.[7] Assuming fixed interest rates, the forecast is usually outside the inflation target in the monetary policy horizon. Writing from an ex post perspective:

$$\pi_t - \pi_t^{target} = \pi_t - E_{t-n}\pi_t(\overline{ir}, E_{t-n}x) + \varepsilon^{fixed\_ir} \quad (9)$$

where $E_{t-n}\pi_t(\overline{ir}, E_{t-n}x)$ stands for the inflation forecast, based on the assumption of interest rates fixed on a predefined trajectory $\overline{ir}$ and ε^{fixed_ir} stands for the divergence of the forecast from the target, caused by non-reactive monetary policy. In this case, the monetary authority must decide not only the bias in the inflation forecast caused by model inaccuracy and by exogenous variable development, but also on the bias in the forecast caused by adhering to the assumption of fixed interest rates, ε^{fixed_ir}:

$$\varepsilon^{monetary\_policy} = -(\varepsilon^{fixed\_ir} + \varepsilon^{model\_change} + \varepsilon^{exogenous} + \varepsilon^{model\_inaccurancy}) \quad (10)$$

The aforementioned procedure of target assessment with a temporarily switched-off reaction function or with exogenous monetary policy is rather tricky. Besides vulnerability to the Lucas critique,[8] exogenising the interest rate trajectory brings additional complications to our analysis. It is obvious that the economy will diverge from a reasonable path without the stabilising effect of monetary policy. As a consequence, some simulations might result in large deviations from the steady state and might be difficult to interpret. These arguments lead us to recommend the use of a model with endogenous monetary policy and a target fulfilment analysis based on simulations with a switched-on reaction function. In this approach, the impact of each factor on the target fulfilment is derived from a comparison of the implied interest rates.

Following the same logic as in equations (2)–(6) in the previous approach, we can break down the difference between the actual interest rates and the interest rates consistent with the target fulfilment in the following way:

$$ir - E_{t-n}ir^{inflation\_in\_target}\ (E_{t-n}x) = ir - E_{t-n}ir(E_{t-n}x) + \eta^{escape\_clauses} + \eta^{smoothing} \quad (11)$$

[7] For example, forecasts of the Bank of England and the ECB are based on interest rate trajectories derived from the market yield curves.

[8] In fact we use a different model with the same coefficient values.

or, if rewritten:

$$\eta^{escape\_clauses} + \eta^{smoothing} = E_{t-n}ir(E_{t-n}x) - E_{t-n}ir^{inflation\_in\_target}(E_{t-n}x) \qquad (11')$$

where *ir* denotes the actual development of interest rates, $E_{t-n}ir^{inflation\ in\ target}(E_{t-n}x)$ refers to the interest rate trajectory which will keep inflation in the target, given the expected development of exogenous variables *x*. Similarly to (2), we can break down the first two components of the right-hand side of equation (11), unexplained by escape clauses and smoothing, as follows:

$$ir - E_{t-n}ir(E_{t-n}x) = ir - E'_{t-n}ir(E_{t-n}x) + \eta^{model\_change} \qquad (12)$$

or:

$$\eta^{model\_change} = E'_{t-n}ir(E_{t-n}x) - E_{t-n}ir(E_{t-n}x) \qquad (12')$$

Further breakdown will disclose the impact of the deviation of the actual exogenous variables´ development from the original assumptions of the forecast:

$$ir - E'_{t-n}ir(E_{t-n}x) = ir - E'_{t-n}ir(x) + \eta^{exogenous} \qquad (13)$$

or:

$$\eta^{exogenous} = E'_{t-n}ir(x) - E'_{t-n}ir(E_{t-n}x) \qquad (13')$$

And finally, the right-hand side of the equation (13), unexplained by the deviation of the actual exogenous variables´ development from the original assumptions of the forecast, is labelled model inaccuracy:

$$\eta^{model\_inaccuracy} = ir - E'_{t-n}ir(x) \qquad (14)$$

In contrast to (6), the model inaccuracy term in equation (14) also contains inaccuracy in forecasting monetary policy reaction, which is not treated separately from other endogenous variables in simulations with a switched-on reaction function.

It is easily seen that the sum of error terms in equations (11)–(14) is equal to the total deviation of actual interest rates from the trajectory consistent with target fulfilment:

$$\begin{aligned} ir - E_{t-n}ir^{inflation\_in\_target}(E_{t-n}x) &= \eta^{escape\_clauses} + \eta^{smoothing} + \\ &+ \eta^{model\_change} + \eta^{exogenous} + \eta^{model\_inaccurancy} \end{aligned} \qquad (15)$$

The main shortcoming of the approach based upon a switched-on reaction function is the impossibility to determine the extent in which the decision-making body anticipated the model inaccuracy and the contribution of the risk assessment to the inflation outcome. Another problem stems from the necessity to analyse the whole trajectory of interest rates from period *t-n* to period *t* (mainly due to interest rate smoothing, which melts the central bank reaction into several quarters).

In section 4, we show an example of the target fulfilment assessment based on the switched-on reaction function approach, as applied in the Czech National Bank.

4. Example of the Target Fulfilment Assessment – CNB's Historical Record

The Czech National Bank started assessing inflation target fulfilment with the introduction of inflation targeting in 1998. Until 2001, targets were only set for year-end and the inflation target fulfilment assessment was made on an annual basis and published each year in the January Inflation Report. Starting from 2002, a continuous target has been introduced and inflation target assessment has become an integral part of every issue of the Inflation Report (chapter II.2 of the Report).

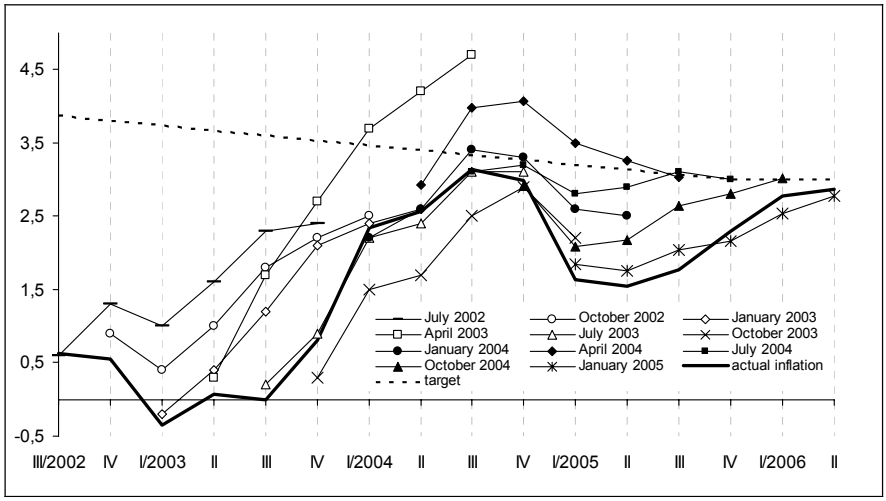
Until July 2002, the CNB forecast was based on the assumption of constant interest rates and expert judgement played a key role in shaping the forecast. As a consequence, the inflation target fulfilment assessment was mostly judgemental until the third quarter of 2003 (the October 2003 Inflation Report).[9] Starting from the January 2004 Inflation Report, the regular assessment stands upon simulations of the model with endogenous monetary policy.

Eleven assessments were made from January 2004 to July 2006 using the approach described in section 3 with a switched-on reaction function. As previously discussed, in this approach we discuss interest rate residuals rather than inflation residuals. In all assessments, the following effects were identified: (i) the intentional missing of the target ($\eta^{escape\_clauses} + \eta^{smoothing}$), (ii) the effect of the external environment ($\eta^{exogenous}$), (iii) the effect of model change (η^{model_change}) and (iv) the effect of model inaccuracy ($\eta^{model\_inaccurancy}$). Starting from the first quarter of 2004, the assessment has been extended for (v) the effect of regulated prices and changes in consumption taxes (lets denote this effect by $\eta^{regulated\_prices}$), and finally, starting from the second quarter of 2005 the assessment also includes (vi) the effect of the deviation of the fiscal impulse from the original assumptions of the forecast (lets denote this by $\eta^{fiscal\_impulse}$).

Figure 1 and 2 shows the inflation and interest rates forecasts from the CNB's model with endogenous monetary policy together with the actual outcomes. Although the forecasts are in practice made for an infinite horizon, only the first six quarters which correspond to the monetary policy horizon of the CNB are depicted in the charts. Several observations can be made from *Figure 1*. First, the actual inflation was in the majority of the forecasts below the forecasted values. Out of eleven forecasts in the sample, three (July 2003, January 2004, January 2005) almost matched the ex post outcomes and one (October 2003) stood below the actual inflation for the significant part of the forecast. This finding is consistent with the series of negative exogenous shocks in the sample period (the prolonged recession in Germany, low pace of price deregulation, exceptionally good harvest in 2004 and 2005), whose disinflationary impact on the inflation was only partially offset by the unexpectedly high oil prices. The second observation is that, with the only exception of the April 2003 forecast, inflation forecasts tend to return to the inflation target in the longer horizon. This reflects the nature of the forecasts with endogenous monetary policy, which in a sufficiently long time horizon pushes the inflation forecast close to the target. Only the April 2003 forecast significantly departed from this rule in the moneta-

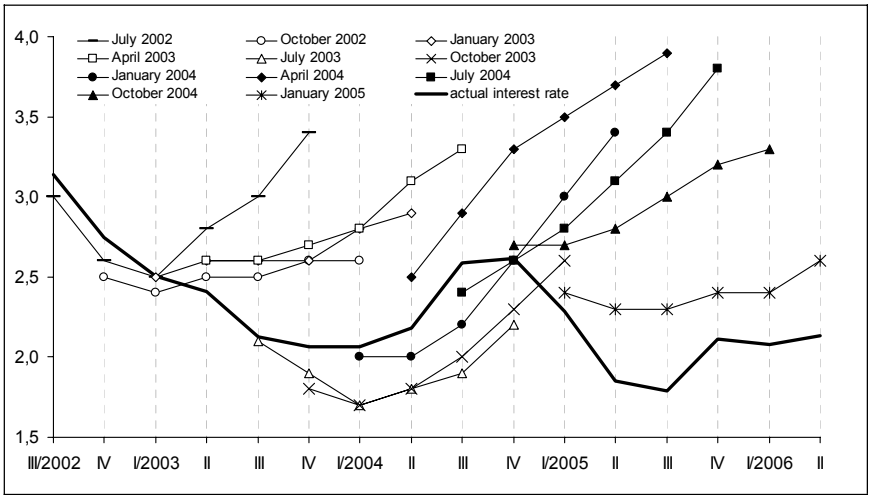
[9] The monetary policy horizon of the CNB is between twelve and eighteen months.

FIGURE 1 CNB's Forecasts for CPI, July 2002–January 2005



Source: CNB Inflation Reports

FIGURE 2 CNB's Forecasts for Short-term Interest Rates, July 2002–January 2005

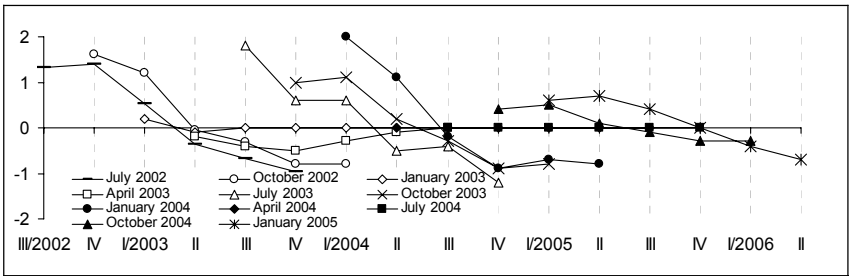


Source: CNB Inflation Reports

ry policy horizon because of the temporary effect of expected adjustments in consumption taxes, which were treated by escape clauses.

The interest rate forecasts, presented in *Figure 2*, provide a similar picture. The majority of forecasts exceeded the outcome in the longer horizon. Forecasts between July 2003 and January 2004 break this rule, which in the case of the October 2003 forecast intuitively corresponds to the bias in the inflation forecast. From a policy-maker perspective interest rate forecasts, as opposed to the inflation forecasts, are most important in the short-term horizon, where they have an immediate effect on

FIGURE 3 $\eta^{escape\_clauses} + \eta^{smoothing}$ Values



Source: CNB calculations

the decision-making. In the short-term horizon the accuracy of interest rate forecasts is significantly higher than in the longer-term horizon. This can be partially explained by interest rate smoothing and partially by the self-fulfilment of the interest rate assumption. In the sample, CNB's banking board usually followed the forecast recommendation, with October 2002, April 2003, October 2003 and April 2004 exceptions.

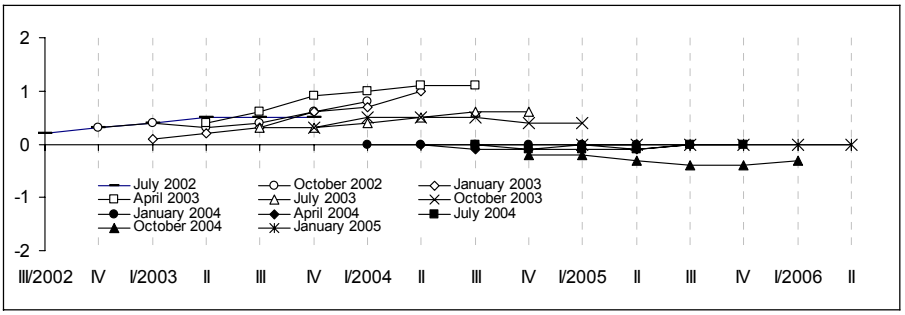
The second observation in *Figure 2*, parallel to the second finding in the previous chart, is that the interest rate path is usually upward-sloping in the longer horizon. This is a result of model assumption that in the sufficiently distant future interest rates will converge to their equilibrium values (defined as the equilibrium real interest rate plus the inflation target, approximately 5 % in the sample) and initial interest rates uniformly lying below their long-run equilibrium values in the sample period.

The charts above may serve as a good illustration of the basic features of the CNB's forecasts and as a first insight into the economic development in the analysed period, but they cannot tell us which particular factor made reality deviate from the forecast and whether the modeling apparatus is sufficiently accurate or not. Based on these figures, it is impossible to judge whether the forecasting techniques or monetary policy can be improved and in which direction. In order to reach answers to these questions we provide, in the following paragraphs, the results of the partial simulations prepared in the sample period.

Figures 3–8 depict the values of $\eta^{escape\_clauses} + \eta^{smoothing}$, η^{model_change}, $\eta^{exogenous}$, $\eta^{regulated\_prices}$, $\eta^{fiscal\_impulse}$ and $\eta^{model\_inaccurancy}$. As mentioned earlier, $\eta^{regulated\_prices}$ values are available since the 2004 Q1 assessment and $\eta^{fiscal\_impulse}$ values since the 2005 Q2 assessment.

Figure 3 shows that CNB quite often does not aim exactly at the middle of the inflation target in the monetary policy horizon (the situation corresponding to the zero line). Within the sample, three inflation forecasts (January 2003, April 2004 and July 2004) stood on the target. Consistent with this, the interest rate trajectory in these forecasts was the same as the interest rate trajectory necessary for achieving the target, i.e. the $\eta^{escape\_clauses} + \eta^{smoothing}$ residual was zero. In the rest of forecasts, either the smoothing of interest rates or ex ante escape clauses made the CNB deviate interest rates from the trajectory consistent with inflation target fulfilment.[10] In most forecasts, meeting the target would require a lower initial interest rate than the sug-

FIGURE 4 η^{model_change} Values



Source: CNB calculations

gested baseline scenario (positive residuals in *Figure 3*). However, after already three quarters a more aggressive rule pushes interest rates above the original forecast in order to compensate for the previous easing of the monetary policy. The April 2003 forecast was the only forecast predicting inflation above the target in the monetary policy horizon (see *Figure 1*). In this case, meeting the target would require higher interest rates for all six quarters.

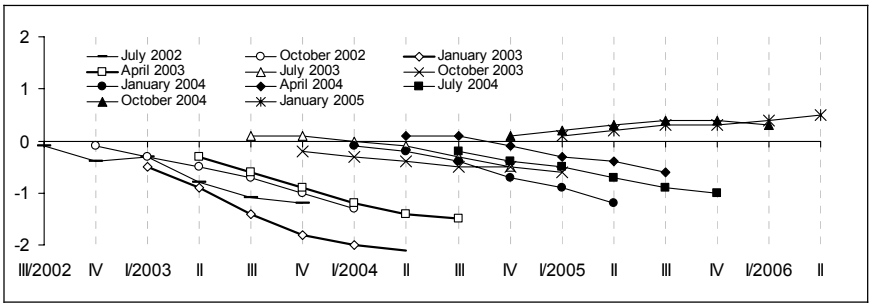
Figure 4 captures the effects of changes in the model specification. Since the introduction of the New Keynesian model with endogenous monetary policy in summer 2002, several improvements in the modelling techniques have been made.[11] These changes acted in the direction of higher inflation and interest rates with the only exception of the October 2004 forecast assessment, based on the model specification as in January 2006.

The effect of the external environment is depicted in *Figure 5*. The interest rate trajectory with ex post knowledge of external developments lies uniformly below the interest rate forecasts based on ex ante expectation until the July 2004 forecast. This reflects the disinflationary effect of the external environment (especially of foreign demand as represented by the German output gap) on the Czech economy between 2002 and 2004. However, the inflationary effects of the pronounced rise of oil prices in 2005 and 2006 outweighed the weak foreign demand in the October 2004 and January 2005 forecast. *Figure 5* exhibits the average highest absolute values from *Figures 3–8*, implying that external factors explain the biggest part of inflation

[10] Theoretically, an infinite number of interest rate trajectories exist which would lead to the inflation forecast at the target. In our simulations we have derived the hypothetical interest rate trajectories by increasing the aggressiveness of the reaction function, i.e. by increasing the weight on inflation in the reaction function and, if necessary, also by lowering the smoothing parameter.

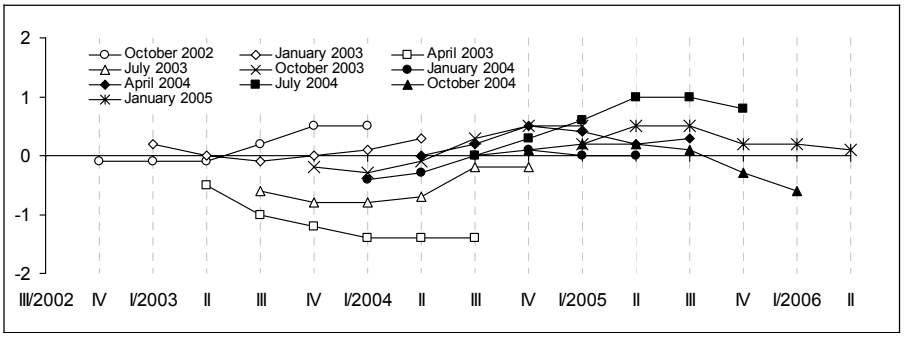
[11] The most important adjustments have been abandoning the assumption of the price rigidity of some items of the consumer basket in April 2003 and the gradual lowering of the estimated rate of equilibrium appreciation of the Czech crown's exchange rate in July and October 2003 and January 2004. In the January 2005 and in the 2006 forecasts the equilibrium appreciation was increased. The other changes to the model, including the break-up of the single Phillips curve into two separate equations for food prices and core inflation in October 2002, the recalibration of the central bank's reaction function in April 2003, the inclusion of the EUR/USD exchange rate in the import price equation in April 2004, the decomposition of equilibrium exchange rate appreciation between tradables and non-tradables in October 2005 and the change in the proxy for energy prices in April 2006 had a negligible impact on the model behaviour.

FIGURE 5 $\eta^{exogenous}$ Values



Source: CNB calculations

FIGURE 6 $\eta^{regulated\_prices}$ Values



Source: CNB calculations

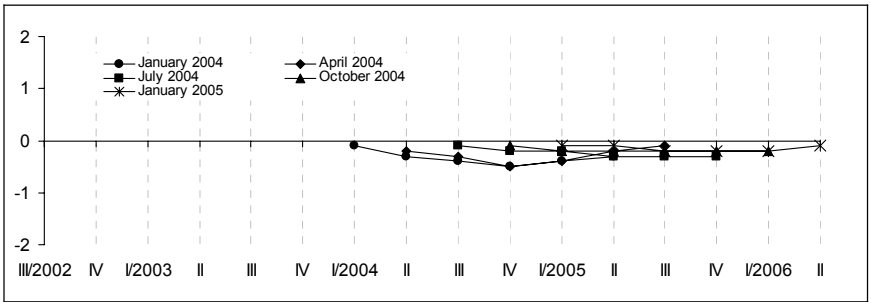
deviation from the target. This finding clearly illustrates the vulnerability of the Czech economy to external developments.

The effect of the deviation of regulated prices and adjustments in taxes from the original assumptions is presented in *Figure 6*. Although some of the forecasts in the sample predicted a significantly different development of administrative prices than subsequently turned up (noticeable in the April 2003 forecast), the average deviation of the forecasts is close to zero. One should note here that these simulations include both the primary and secondary effects of regulated prices changes (if their contribution to overall inflation is "normal"[12]) and only the secondary effects of tax changes. Primary effects of tax changes and the "abnormal" contribution of regulated prices to inflation are included in the simulation of escape clause effects.

Figure 7 shows the effect of the deviation of the fiscal impulse from the original assumptions. Only five forecasts are depicted in this chart because this factor was not treated separately until the January 2004 forecast (before that it was included in the model inaccuracy effect). Having this limited number of observations it is difficult to identify any systematic pattern. However, all observations have been in the negative region, i.e. the CNB tended to overestimate the fiscal impulse in its fore

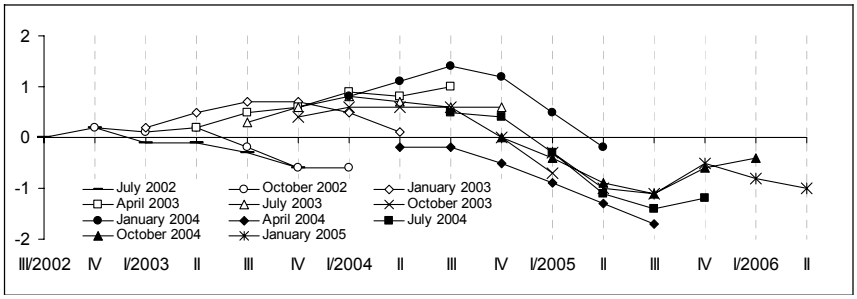
[12] The contribution of 1–1.5 percentage points to y-o-y inflation was considered to be "normal."

FIGURE 7 $\eta^{fiscal\_impulse}$ Values



Source: CNB calculations

FIGURE 8 $\eta^{model\_inaccurancy}$ Values



Source: CNB calculations

casts. This might look like a sign of central bank vigilance, but the real reason is more prosaic. The Czech government systematically overestimated its budget deficits in the sample period and central bank forecasts, despite some discounting of official budget plans, have been influenced in the direction of higher fiscal impulses.

Finally, *Figure 8* captures the remaining residuals of the forecasts, unexplained by previous simulations. Among these, a prominent role should be assigned to the central bank reaction function residual, as discussed in section 3. The banking board might disagree with the forecast message and might assign asymmetric risks to the baseline scenario of the forecast. In an ideal case, this risk identification will anticipate the future deviation of the economy from the forecast, so the deviation of interest rates from the forecast will keep the inflation in line with the forecast. However, the identified risks are only rarely fully realised in the anticipated extent and it would be useful to distinguish between ex post appropriate risk identification (corresponding to model inaccuracy) and ex post inappropriate risk identification (interest changes beyond model inaccuracy). But as we mentioned in section 3, this is not possible using simulation with a switched-on reaction function. Hence, we have to limit our discussion of *Figure 8* to the overall bias of the model, including the effect of risk assessment.

Although residuals in *Figure 8* are on average balanced, three specific periods might be identified. For the first two forecasts, the residuals are balanced and

close to zero. In the second period, beginning with the January 2003 forecast, the residuals lie significantly above the zero line, i.e. the actual interest rates were higher than the model would suggest, based on the perfect knowledge of all relevant information. Starting from the April 2004 forecast the sign of residuals turned around and became mostly negative. The differences between the residuals in these three periods might be either the result of a shift in the risk evaluation, changes in the forecasting techniques that were not captured in the previous simulations[13] or the result of changes in the functioning of the economy.

Whereas it is impossible in our approach to discriminate between the last two hypotheses, we can try to verify the first hypothesis by looking at the overall balance of the risks, as recorded in the minutes from the decision-making meeting, and by comparing this finding with the actual setting of interest rates. In the first period, risks were slightly disinflationary (the July 2002 forecast) or balanced (the October 2002 forecast). Risks in the second period were predominantly inflationary (the January 2003, October 2003 and January 2004 forecasts), the July 2003 forecast was assessed as balanced and the April 2003 forecast as disinflationary. On the contrary, risks in the third period were mostly biased in the disinflationary direction (the April 2004, January 2005 forecasts), the balanced risks were identified for the July 2004 and October 2004 forecasts. Based on this information we can conclude that the bias in the residuals in each specific period corresponds to the overall direction of the risks, as identified by the board. We can conclude that the residuals in *Figure 8* are at least partially influenced by the bias in the risk assessment.

To sum up, our analysis based on the partial simulations shows that a large part of missing the target in the period under review came from a deviation in the input variables (predominantly from the external environment). We also show that in the context of the model with endogenous monetary policy, some part of the model inaccuracy, as expressed by the deviation of the actual interest rates from the recommendation of the model with full knowledge, might be assigned to the risk assessment of the board.

5. Conclusions

The assessment of target fulfilment is an essential part of a monetary policy framework with an explicit target. It prevents a central bank from producing systematically biased forecasts, deepens the central bank staff's and board members' understanding of the abilities and limitations of the forecast and enhances monetary policy transparency and credibility. We argue in favour of publishing the analysis.

Indeed, our survey shows that the majority of central banks armed with an explicit inflation target provide the public with detailed ex post analyses of inflation target fulfilment, either on a regular or irregular basis. However, some central banks still do not even compare inflation outcomes with the target.

Subsequently we propose a possible approach to identifying the underlying reasons behind hitting/missing the inflation target based on partial simulations of the reduced-form model. We distinguish between models with endogenous and exogenous monetary policy and propose procedures for quantifying the contribution of

[13] These might include, for example, shifts in the expert judgement, which strongly affects forecast in the nearest quarter.

risk assessment to the outcome. The procedure with endogenous monetary policy is applied to the Czech National Bank's forecasts between 2002 and 2005.

In this period, inflation forecasts and interest rate forecasts were biased upwards and inflation was most of time below the target. A detailed assessment of the inflation target fulfilment reveals that a large part of the bias in the forecasts might be assigned to the bias in variables describing external development and that some short-lived deviations of interest rates from the model recommendation might be explained by the board's asymmetric risk assessment.

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