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Why and How to Assess Inflation Target Fulfilment

Jan Filáček [*]

Abstract

The ex post analysis of inflation target fulfilment plays an important role in an inflation targeting framework. The major benefits of ex post analysis are threefold. First, it might improve the forecast accuracy. Second, it helps central bank staff and board members to understand the capabilities and limitations of the forecasts used in their decision-making. Third, it enhances monetary policy transparency and credibility. The primary aim of this paper is to propose a methodological framework for inflation target fulfilment assessment based on partial simulations, as applied in the Czech National Bank. In order to demonstrate the applicability of this framework we analyse the performance of the Czech National Bank between 2002 and 2006. We show that a large part of the inflation target misses in this period can be assigned to bias in the variables describing external developments.

JEL Codes: E47, E58.
Keywords: Central bank, inflation target, monetary policy performance.

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Nontechnical Summary

During the last two decades, significant progress has been achieved in central bank transparency. Many central banks have adopted an inflation targeting framework, which allows the public to easily assess monetary policy performance. In this paper, we focus on this particular aspect of inflation targeting – inflation target fulfilment assessment. We argue in favour of the regular preparation and publication of such analyses of a central bank's performance.

Our survey among 19 OECD countries shows that the majority of central banks with an explicit inflation target provide the public with detailed ex post analyses of inflation target fulfilment, on either a regular or irregular basis. However, some central banks in our sample still do not even compare the inflation outcomes with the target.

We describe a possible approach to identifying the reasons underlying inflation target hits/misses based on partial simulations of a reduced-form model. We distinguish between models with endogenous and exogenous monetary policy and propose procedures for quantifying the contribution of the 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, the inflation forecasts and interest rate forecasts were biased upwards and inflation was below the target most of the time. A detailed assessment of the inflation target fulfilment reveals that a large part of the bias in the forecasts can be assigned to bias in the variables describing external developments and that some short-lived deviations of interest rates from the model recommendation can be explained by the board's risk assessment of the forecasts.

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 that explicitly announce their quantitative inflation targets, notwithstanding whether they call themselves inflation targeters or not. The existence of an explicit target allows a central bank to analyse monetary policy performance. For example, Svensson (1997a) notes that: "...a specified quantitative target ...provides an ex post measurement of monetary policy performance, namely inflation realised relative to the inflation target".

However, a fear of going too far with transparency has emerged as central banks have progressed in putting the theoretical recommendations into everyday practice. Some economists (Jensen, 2002, and Mishkin, 2004) argue that transparency has its own limits and that full transparency is less than optimal. In their opinion, recognition and public announcements of central bank mistakes might cast doubt on the 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's signals and crowd out the signals from the private sector (see Morris and 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, and Chortareas, Stasavage and Sterne, 2002).

This paper starts in section 2 with a discussion of the benefits of preparing and publishing assessments of target fulfilment. Section 3 provides the reader with a detailed overview of current practices in evaluating target fulfilment in selected "targeting" central banks. In section 4 we propose a methodological framework for decomposing the deviation of inflation from the target into underlying economic factors, based on partial simulations. Section 5 summarises the historical experience of the Czech National Bank with this particular approach to inflation target assessment. Section 6 concludes.

2. Why Produce and Disclose Assessments?

The ex post analysis of target fulfilment plays an important role in any monetary policy framework based on an explicit 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 regularly checking model accuracy and lack of bias. Second, it strengthens the knowledge among staff and board members of shock transmission in the economy as described by the modelling apparatus. Third, the publication of a sound analysis of target misses/fulfilment can enhance monetary policy transparency and credibility.

The assessment of target fulfilment disaggregates an overall forecast error into separate groups of factors (exogenous, endogenous, factors under the direct influence of monetary policy) or even into particular factors (e.g. oil prices, the output gap, interest rates). Such a detailed decomposition creates a solid basis for regular discussion of the functioning of the transmission mechanism and of potential adjustments to the modelling apparatus. The checking role of the assessment is supported by the fact that target fulfilment is usually assessed on the basis of a forecast prepared some time earlier, usually equal to the lag between a change in monetary policy

and its impact on the targeted variable. This period is commonly longer than one year, so the assessment of the forecast is performed a significant time later, which allows the observer to abstract from the currently prevailing view of the economy and to assess the forecast from a far-sighted perspective.

Since any model is only a rough (usually linear) approximation of the true behaviour of the economy[1] and since the observed data are usually random realisations of the true underlying process, the assessment always reveals some inaccuracy of the model. Due to randomness in data, it is not possible to judge model accuracy on the basis of a single assessment or a short series of assessments. Only a large number of assessments can provide some clue about model accuracy and unbiasedness. This leads to the practical problem of how long and how extensive the target-missing evidence must be before one can take a decision to adjust the modelling techniques. Even if a forecast assessment is prepared every quarter, it can take years to realise the inaccuracy or bias of the modelling apparatus. Despite the existing implementation problems it is reasonable to argue that regularity and recentness in the forecast assessment might provide a safety-fuse against divergence of the forecast from reality. As Nymoen (2005) points out, "...not doing serious empirical work on model specification and evaluation is a certain recipe for forecast failure". In this respect it can also be argued that a focus on one single forecast in the case of regular assessments allows a much deeper analysis of the forecast error than a time-to-time analysis covering a large number of forecasts.

Another benefit of the assessment is a further improvement in knowledge of the modelling apparatus and its properties and behaviour among staff and board members. The ex post view of economic developments contained in the target fulfilment analysis differs from the ex ante view contained in the actual forecast. Whereas the ex ante view gives us a coherent story of future economic developments based on pure model logic, the ex post view is usually quite far from providing a clear-cut story of past developments. Confronting the forecast with real historical data yields – on the surface – many inconsistencies and hard-to-interpret developments. For example, in spite of a more expansionary monetary policy, lower inflationary pressures might arise. Interpreting such situations is much more challenging than describing a new forecast and includes dealing with many linked relevant issues such as data revisions and forecasting technique modifications.

Last but not least, a sound analysis of target misses/fulfilment can, if published, enhance monetary policy transparency and credibility. Missing the target is usually perceived as a failure of the central bank, even though some targeters intentionally miss targets under certain circumstances[2]. If a central bank dissembles the miss, it risks being attacked by the public and undermining faith in future target fulfilment. On the contrary, if a central bank provides the public with the reasoning for the miss, it might successfully explain part or even all of the deviation from the target and preserve its credibility. Even if the whole deviation were ascribed to inappropriate monetary policy, the public announcement of such a finding accompanied by self-reflection might result in better monetary policy conduct in the future and sustained public confidence in the target.

[1] Using Clements and Hendry's (1999) classification we presume that the forecasting model coincides with the true underlying process, except for stochastic errors, but the estimate of the model parameters might be subject to structural changes in the economy.

[2] In the case of inflation targeting, such a regime is called flexible inflation targeting (see Svensson, 1997b)

There are further arguments for disclosing the analysis. Public disclosure reveals the central bank's ability for self-reflection and its willingness to learn from its past mistakes. Nobody is perfect, and that includes the central bank, so no one expects it to produce 100% successful forecasts and make the right decisions all the time. No central bank can avoid making mistakes, and these mistakes are difficult to hide from the public, since anybody can compare the economic outcome with the target. If mistakes are not discussed by the bank, they will be discussed by journalists and analysts using simple methods and usually with less precise and – for the bank – less favourable conclusions.

Also, almost every central bank is politically independent and therefore faces the dilemma of limited accountability. Some central banks address this problem by sending an open letter to the government or political representatives when a target is missed, explaining the reasons for the miss and its intended monetary policy measures.[3] But this approach has several weak points. First, the quantification of price stability, as expressed by the inflation target, is only indicative and should not be used for differentiating between right and wrong monetary policy. It is not obvious why, for example, 1% inflation lying at the lower boundary of a hypothetical target band should be considered a success while 0.9% inflation lying below the boundary should be considered a failure. In the same vein, the target might sometimes be met despite the wrong monetary policy, just because of a lucky coincidence with an external shock. Second, and more importantly, a central bank operating in a flexible targeting framework may in some situations intentionally conduct a policy of missing the target (by applying so called "escape clauses"). Then, missing the target is a sign of correct monetary policy, not the opposite. A regularly published analysis of target fulfilment avoids these shortcomings, since it is prepared regardless of the actual outcome and contains a detailed analysis of monetary policy aims and measures and their impacts. Having such thorough information available, the public has a chance of understanding the reasons behind the target hit/miss and of evaluating the role of the central bank's measures in the outcome. This can significantly increase the central bank's accountability to the public.

Finally, publishing the analysis may further enhance public knowledge of the target and the monetary policy transmission mechanism, and especially knowledge of the transmission lag between a central bank measure and its biggest impact on the economy. Hence, the educational effect of target fulfilment assessment disclosure might be similar to the educational effect of forecast disclosure.

The empirical evidence supports this line of reasoning. For example, Eijffinger and Geraats (2002) include public evaluation of target fulfilment in the operational transparency component of their transparency index[4]. A subsequent study by Demertzis and Hallett (2002) used the Eijffinger-Geraats index to estimate the impact of transparency on inflation and output variability. One of their conclusions[5] is that operational transparency, including target fulfilment assessment, significantly reduced inflation variability.

[3] This procedure is established, for example, in the Bank of England and the Central Bank of Iceland.

[4] From the sample of nine major central banks, only Sveriges Riksbank received a full score in this transparency aspect.

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

3 Survey of Current Target Fulfilment Assessment Practices

In this section we provide an overview of how selected central banks assess target hits/misses and whether central banks publicly disclose their assessments. The countries in our selection are OECD countries with an explicit target. Out of the 19 OECD members with an independent monetary policy framework[6], 17 have an explicit target and 2 (Japan and the U.S.) conduct monetary policy without any explicit target. With the exception of Danmarks Nationalbank, which has a fixed exchange rate regime against the euro, all central banks with an explicit target focus on inflation. In the rest of this section we describe the assessment of target hits/misses in the 16 countries with central banks that explicitly target inflation, namely at the Reserve Bank of Australia, the Bank of Canada, the Czech National Bank, the European Central Bank[7], the Magyar Nemzeti Bank, the Central Bank of Iceland, the Bank of Korea, the Banco de México, the Reserve Bank of New Zealand, the Norges Bank, the National Bank of Poland, the Národná Banka Slovenska, the Sveriges Riksbank, the Swiss National Bank, the Central Bank of the Republic of Turkey and the Bank of England.

First we searched the central banks' websites for publicly available documents on the issue of target fulfilment and analysed whether these documents describe, in detail, the factors underlying target (non)fulfilment and whether they explicitly contain an evaluation of the monetary policy contribution. Second, we sent a questionnaire to each central bank in the sample asking it 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 declared transparency of central banks operating inflation targeting regimes, and despite the key role of inflation target fulfilment in building a 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 inflation outcomes with their inflation target (we consider a joint 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 a 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 compare 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.

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

[7] Although the 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)]

Source: Central banks' websites, author's survey.

Note: 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 monetary 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, the Governor of the Bank is obliged to write an open letter to the Chancellor explaining why the target was missed.
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.

Table 1 shows that if a central bank decides to compare actual inflation with the target, it also provides an analysis of the factors underlying the inflation outcome. A strong tendency seems to exist among the banks to explain deviations from the target, if such a deviation is revealed. This finding is intuitive, since a detailed explanation allows the bank to sustain the credibility of the inflation target by blaming the deviation from the target fully or partially on factors that lie outside 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 we exclude the Bank of England, only six banks in our sample provide a full description of the factors behind target hits/misses, including a discussion of the monetary policy contribution. These are: the Bank of Canada, the Bank of England, the Czech National Bank, the Magyar Nemzeti Bank, the Norges Bank, the National Bank 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 the 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 the pros. It is then reasonable to conduct the assessment for internal purposes only. In that case, it is hard for outsiders to find out whether such an analysis is conducted 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 the 16 central banks responded (a response rate of 69%)[8]. 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, out of the 11 banks which sent back the questionnaire, only two claim that they do not disclose the target fulfilment analysis to the public in full. Notably, these two banks use sophisticated modelling techniques for decomposing the overall deviation from the inflation target into its separate underlying factors. These banks do not publish all the technical details of the computation or the exact results of the simulations, but do provide a verbal description of the main results, primarily for the sake of clarity.

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

Roughly half of the responding central banks employ a modelling technique in their target fulfilment assessments, while the other half rely rather on expert judgement. If a macroeconomic model is used in the assessment, in most cases it is the core model used for building the central bank forecast. The main advantages of applying the same model for both tasks are consistency of the assessment with the forecast and the possibility of using the results of the assessment immediately for improving the forecast. Indeed, all the banks which use the same modelling 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 the assessment implies that the same staff usually prepare both the target fulfilment assessment and the forecast. This is the case in the majority of the central banks in our sample, and especially in those which use sophisticated modelling techniques. Consequently, incentives to perform 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 a target miss primarily to vis major, i.e. external developments). But there are ways of reducing this problem. For example, a rewards scheme based on improvements in forecast accuracy (not on forecast accuracy itself) can be implemented.

[8] 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.

4. How to Assess Target Fulfilment

In this section we describe the target fulfilment evaluation methodology 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 and 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 makes the analysis more difficult. If monetary policy reacts to exogenous shocks, the inflation forecast stays near the inflation target in the longer term regardless of the deviations in other variables. This prohibits us from simulating the impact of a deviation in one variable 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 of 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 a deviation in a given variable on inflation is not offset by a central bank reaction. Alternatively, we can simply evaluate the impact of a deviation in a given variable on the interest rate trajectory instead of its impact on inflation. Since either approach has its shortcomings we analyse both of them in the following text, starting with a transitory switching off of the reaction function.

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

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

where π_t stands for actual inflation and π_t^{target} for the inflation target[9]. 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) can be explained either by calling escape clauses into effect or by smoothing the interest rate trajectory. Both explanations should have already been incorporated into the central bank forecast, decided *n*-time periods ago, when the central bank was influencing inflation at 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 monetary policy transmission lag. *x* denotes exogenous variables (input variables from the model perspective), *ir* interest rates and the E_{t-n} operator their expected behaviour. $\varepsilon^{escape\_clauses}$ specifies intentional missing of the target as ex ante explained by escape clauses and $\varepsilon^{smoothing}$ as intentional missing of the target as explained by interest rate smoothing. The values of $\varepsilon^{escape\_clauses}$ and $\varepsilon^{smoothing}$ are known at the time the forecast is made and equation

[9] 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 the range as the benchmark.

(2) should always hold for consistency reasons. This becomes evident when we subtract actual inflation from both sides of 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 target miss factors in more depth either jointly or separately. If we opt for a separate analysis, we can obtain the contribution of the application of the escape clause by running the simulation with the assumption that the central bank reacts to overall inflation and not to a part of it, as in the case of escape clause application. The contribution of smoothing is then easily obtained as the complement.

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

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

where $E'_{t-n}\pi_t(E_{t-n}x, E_{t-n}ir)$ stands for the inflation forecast, as if it were made at 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 regarding exogenous variables and nominal interest rates. Equation (3) then compares the target miss using the historical model specification and the target miss when the latest model specification is applied. $\varepsilon^{model\_change}$ stands for the part of the target miss explained by changes in the model specification and improvements in the understanding of the economy since the original forecast was formulated.

Again, equation (3) can be rewritten as:

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

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

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

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

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

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

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

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

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

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

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

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

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

More precisely, $\varepsilon^{model\_inaccuracy}$ is the part of the target miss unexplained by the previous simulations. This term captures 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 the historical data, as published, for example, by the statistics office, are perfect measures of reality. Second, we treat historically observed shocks as expected in the simulations. Third, we consider the latest version of the model to be the best available description of reality. We should carefully bear these assumptions in mind, especially when interpreting the last part of the target miss as defined by equation (6).

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

$$\pi_t - \pi_t^{target} = \varepsilon^{escape\_clauses} + \varepsilon^{smoothing} + \varepsilon^{model\_change} + \varepsilon^{exogenous} + \varepsilon^{monetary\_policy} + \varepsilon^{model\_inaccuracy} \quad (7)$$

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 minimise the extent of the unintentional missing of the target, i.e. the values of $\varepsilon^{model\_change}$, $\varepsilon^{exogenous}$, $\varepsilon^{monetary\_policy}$ and $\varepsilon^{model\_inaccuracy}$.

Some central banks, including the CNB, when forecasting exogenous variables mechanically draw on the consensus 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 $\varepsilon^{model\_inaccuracy}$. $\varepsilon^{model\_change}$ is the disclosed part of the model inaccuracy, while $\varepsilon^{model\_inaccuracy}$ is the undisclosed part. It is reasonable to assume that the forecasting team gradually improves its forecasting techniques, so non-zero values of $\varepsilon^{model\_change}$ consequently reduce the values of $\varepsilon^{model\_inaccuracy}$. If the forecast is based on 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 (the monetary policy committee, the bank board) to identify the risks of the forecast and to choose the $\varepsilon^{monetary\_policy}$ that offsets the inaccuracy of the forecast and minimises the overall sum of $\varepsilon^{model\_change}$, $\varepsilon^{exogenous}$, $\varepsilon^{monetary\_policy}$ and $\varepsilon^{model\_inaccuracy}$, i.e. the future unintentional deviation of inflation from the target. In the ideal case, the decision-making body should fully compensate for the forecast inaccuracy:

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

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 was completed. To differentiate between the effect of risk assessment and the effects of changes in monetary policy behaviour, one must carefully read the minutes of the decision-making body's meetings and identify the overall risk assessment.

A similar approach can 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[10]. Assuming fixed interest rates, the forecast is usually outside the inflation target at the monetary policy horizon. Writing from an ex post perspective:

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

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 on the bias in the inflation forecast caused by model inaccuracy and by the evolution of exogenous variables, but also on the bias in the forecast caused by adhering to the assumption of fixed interest rates, ε^{fixed_ir}:

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

The aforementioned target assessment procedure with a temporarily switched-off reaction function or with exogenous monetary policy is rather tricky. Besides being vulnerable to the Lucas critique[11], 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 target fulfilment is derived from a comparison of the implied interest rates.

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

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

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

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

or, if rewritten:

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

where *ir* denotes the actual development of interest rates, and $E_{t-n}ir^{inflation\_in\_target}(E_{t-n}x)$ refers to the interest rate trajectory which will keep inflation on 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:

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

or:

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

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

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

or:

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

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

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

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

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

$$ir - E_{t-n} ir^{inflation\_in\_target}(E_{t-n}x) = \eta^{escape\_clauses} + \eta^{smoothing} + \eta^{model\_change} + \eta^{exogenous} + \eta^{model\_inaccuracy} \quad (15)$$

The main shortcoming of the approach based upon a switched-on reaction function is that it is impossible to determine the extent to 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 5, we show an example of target fulfilment assessment based on the switched-on reaction function approach, as applied in the Czech National Bank.

5. Example of Target Fulfilment Assessment – The 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 the year-end and the inflation target fulfilment assessment was performed on an annual basis and published each year in the January Inflation Report. In 2002 a continuous target was introduced, and since then the inflation target assessment has been an integral part of every issue of the Inflation Report (section 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).[12] Starting from the January 2004 Inflation Report, the regular assessment stands upon simulations of a model with endogenous monetary policy.

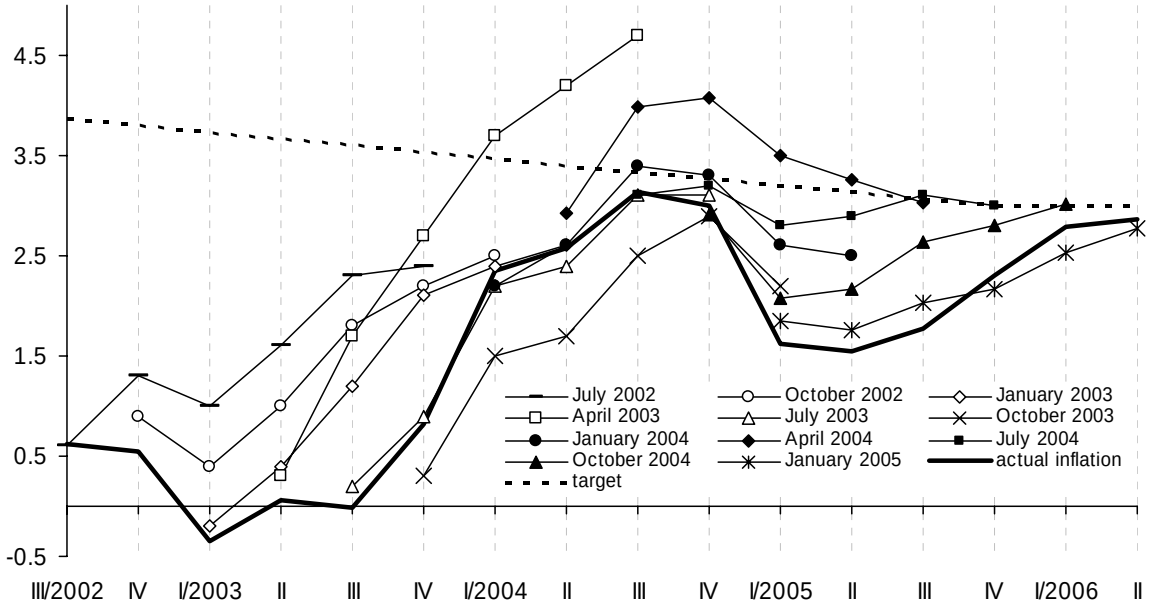
Eleven assessments were made between January 2004 and July 2006 using the approach described in section 4 with a switched-on reaction function. As previously discussed, in this approach we discuss interest rate residuals rather than inflation residuals. In all the assessments, the following effects were identified: (i) 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 ($\eta^{model\_inaccuracy}$). Starting from the first quarter of 2004, the assessment was extended to include (v) the effect of regulated prices and changes in consumption taxes (let's denote this effect by $\eta^{regulated\_prices}$), and finally, since the second quarter of 2005 the assessment has also included (vi) the effect of the deviation of the fiscal impulse from the original assumptions of the forecast (let's denote this by $\eta^{fiscal\_impulse}$).

Figures 1 and 2 show the inflation and interest rate forecasts from the CNB's model with endogenous monetary policy together with the actual outcomes. Although the forecasts are in

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

practice made for an infinite horizon, only the first six quarters – corresponding to the monetary policy horizon of the CNB – are depicted in the charts. Several observations can be made from Figure 1. First, in the majority of the forecasts actual inflation was below the forecasted values. Out of the eleven forecasts in the sample, three (July 2003, January 2004, January 2005) almost matched the ex post outcomes and one (October 2003) stood below actual inflation for much of the forecast. This finding is consistent with the series of negative exogenous shocks that occurred in the sample period (the prolonged recession in Germany, the slow pace of price deregulation, and the exceptionally good harvests in 2004 and 2005), whose disinflationary impact on inflation was only partially offset by the unexpectedly high oil prices. The second observation is that, with the sole exception of the April 2003 forecast, the inflation forecasts tend to return to the inflation target in the longer term. This reflects the nature of the forecasts with endogenous monetary policy, which over a sufficiently long time horizon pushes the inflation forecast close to the target. Only the April 2003 forecast departed significantly from this rule within the monetary policy horizon, because of the temporary effect of expected adjustments to consumption taxes, which were dealt with by applying escape clauses.

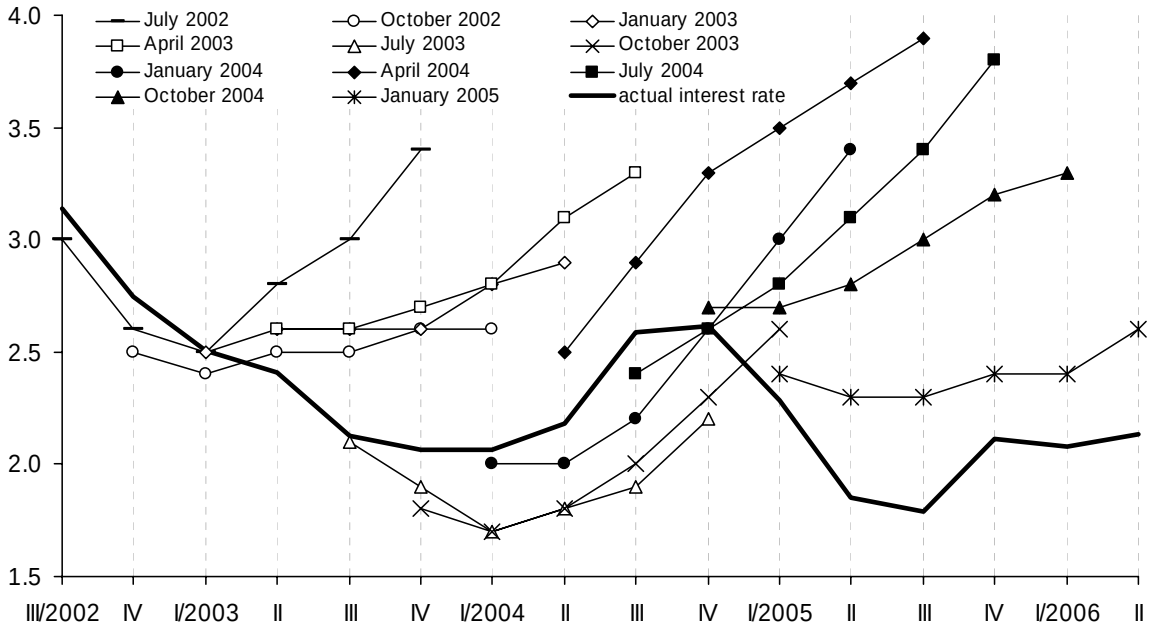
Figure 1: The CNB's Forecasts for the CPI, July 2002 – January 2005



Source: CNB Inflation Reports.

The interest rate forecasts, presented in Figure 2, provide a similar picture. The majority of the forecasts exceeded the outcome in the longer term. The 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's perspective, interest rate forecasts, as opposed to inflation forecasts, are the most important in the short term, as they have an immediate effect on decision-making. The accuracy of interest rate forecasts is significantly higher in the short term than in the longer term. This can be explained partially by interest rate smoothing and partially by self-fulfilment of the interest rate assumption. In the sample, the CNB Bank Board usually followed the forecast recommendation, the exceptions being October 2002, April 2003, October 2003 and April 2004.

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



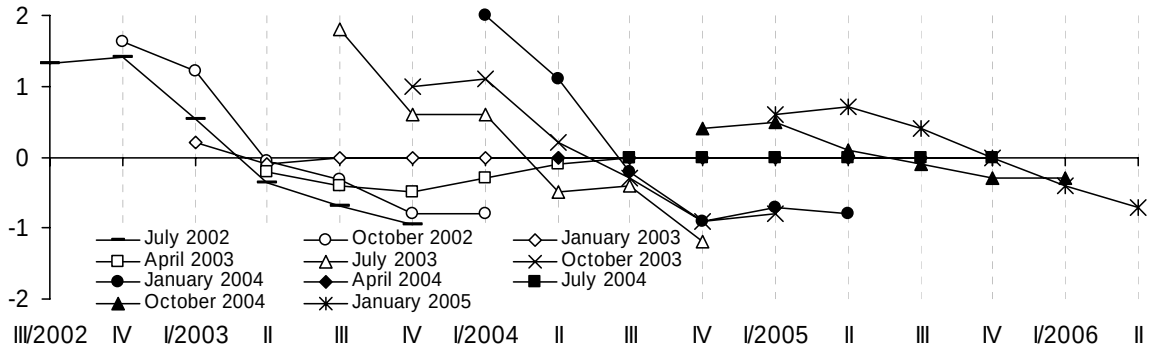
Source: CNB Inflation Reports.

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 term. This is a result of the 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 that initial interest rates lie uniformly 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 developments in the analysed period, but they cannot tell us which particular factor made the actual outcomes deviate from the forecast and whether the modelling 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, if so, in which direction. In order to obtain 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 $\eta^{model\_inaccuracy}$. As mentioned earlier, the values of $\eta^{regulated\_prices}$ are available since the 2004 Q1 assessment and the values of $\eta^{fiscal\_impulse}$ since the 2005 Q2 assessment.

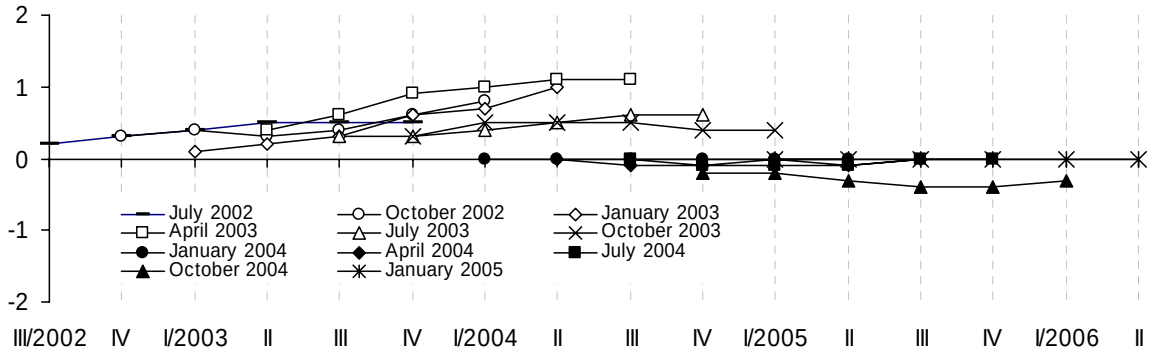
Figure 3: Values of $\eta^{escape\_clauses} + \eta^{smoothing}$



Source: CNB calculations.

Figure 3 shows that the CNB quite often does not aim exactly at the middle of the inflation target at 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[13]. In most forecasts, meeting the target would have required a lower initial interest rate than the suggested baseline scenario (the positive residuals in Figure 3). However, after just three quarters a more aggressive rule pushes interest rates above the original forecast in order to compensate for the previous easing of monetary policy. The April 2003 forecast was the only forecast to predict that inflation would be above the target at the monetary policy horizon (see Figure 1). In this case, meeting the target would have required higher interest rates for all six quarters.

Figure 4: Values of η^{model_change}

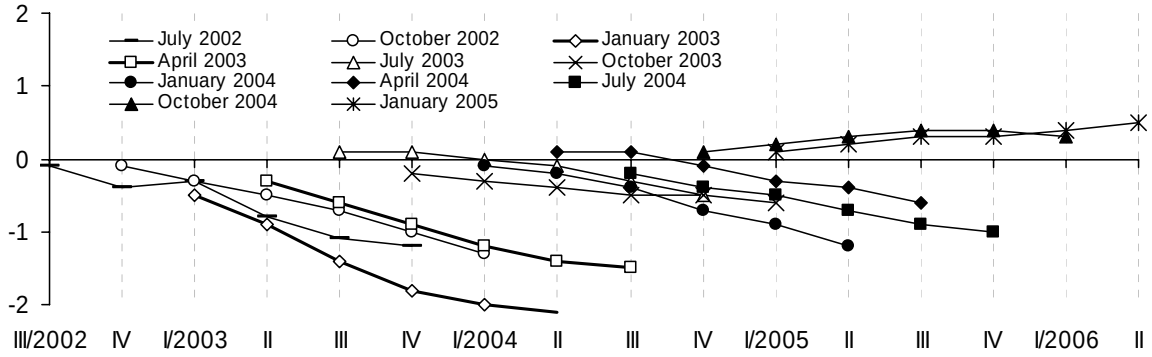


Source: CNB calculations.

[13] Theoretically, there is an infinite number of interest rate trajectories that would lead to the inflation forecast being on target. In our simulations we 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.

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 have been made to the modelling techniques.[14] These changes acted in the direction of higher inflation and interest rates, the only exception being the October 2004 forecast assessment, based on the model specification as in January 2006.

Figure 5: Values of $\eta^{exogenous}$



Source: CNB calculations.

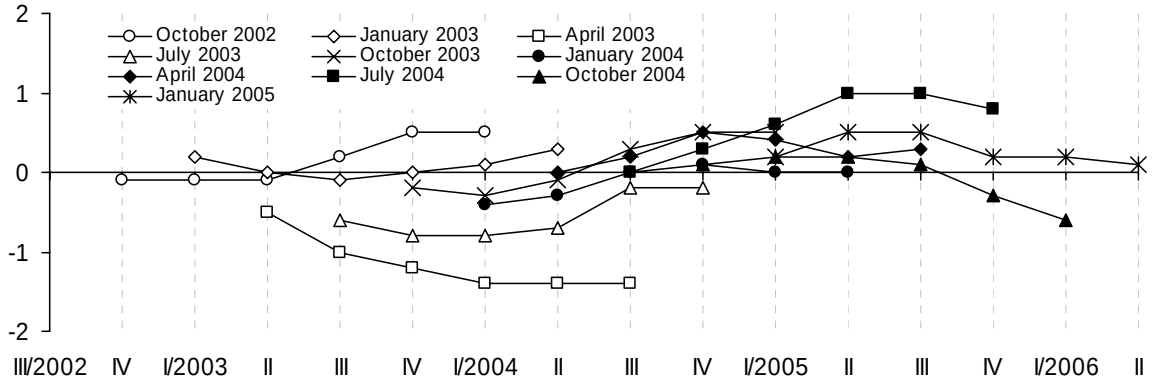
The effect of the external environment is depicted in Figure 5. The interest rate trajectory with ex post knowledge of external developments lies uniformly below the interest rate forecasts based on ex ante expectations until the July 2004 forecast. This reflects the disinflationary effect of the external 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 in oil prices in 2005 and 2006 outweighed the weak foreign demand in the October 2004 and January 2005 forecasts. Figure 5 shows the average highest absolute values from Figures 3–8, implying that external factors explain the biggest part of the deviation of inflation 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 tax adjustments from the original assumptions is presented in Figure 6. Although some of the forecasts in the sample predicted a significantly different path of administrative prices than subsequently occurred (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 price changes (if their contribution to overall inflation is "normal"[15]) and only the secondary effects of tax changes. The primary effects of tax changes and "abnormal" contributions of regulated prices to inflation are included in the simulation of escape clause effects.

[14] The most important adjustments were the abandoning of the assumption of 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 forecast and 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.

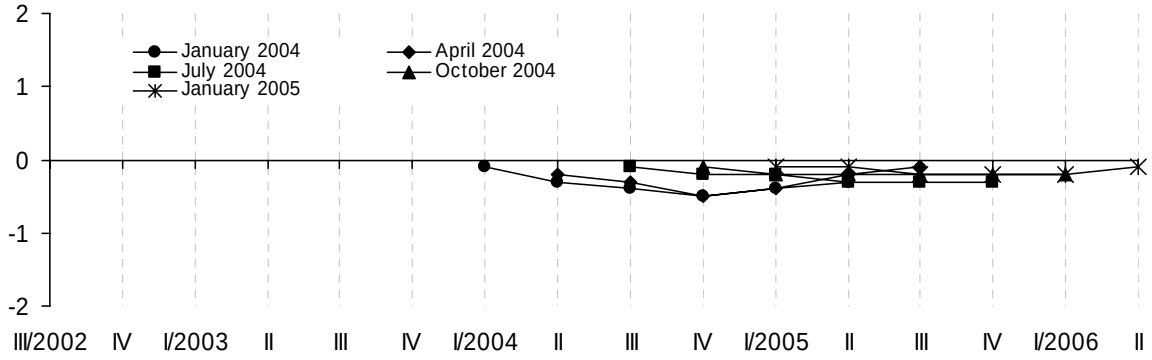
[15] The contribution of 1–1.5 percentage points to y-o-y inflation was considered to be "normal."

Figure 6: Values of $\eta^{regulated\_prices}$



Source: CNB calculations.

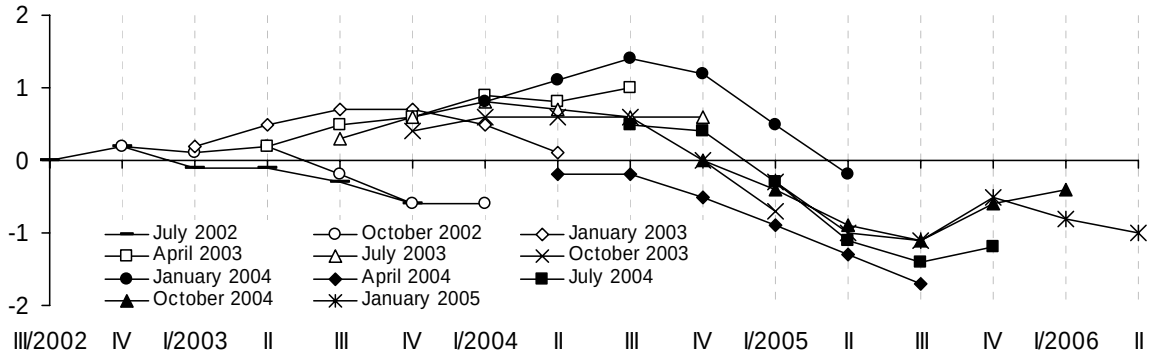
Figure 7: Values of $\eta^{fiscal\_impulse}$



Source: CNB calculations.

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). With this limited number of observations it is difficult to identify any systematic pattern. However, all the observations have so far been in the negative region, i.e. the CNB tended to overestimate the fiscal impulse in its forecasts. 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 the central bank's forecasts, despite some discounting of the official budget plans, were influenced in the direction of higher fiscal impulses.

Figure 8: Values of $\eta^{model\_inaccuracy}$



Source: CNB calculations.

Finally, Figure 8 captures the remaining residuals of the forecasts unexplained by the previous simulations. Among these, a prominent role should be assigned to the central bank reaction function residual, as discussed in section 4. The bank board might disagree with the forecast message and might assign asymmetric risks to the baseline scenario of the forecast. In the 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 inflation in line with the forecast. However, the identified risks are only rarely fully realised to the anticipated extent and it would be useful to distinguish between ex post appropriate risk identification (corresponding to the model inaccuracy) and ex post inappropriate risk identification (interest changes beyond the model inaccuracy). But as we mentioned in section 4, this is not possible using the 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 the residuals in Figure 8 are on average balanced, three specific periods can 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. actual interest rates were higher than the model would suggest based on a perfect knowledge of all the relevant information. Starting from the April 2004 forecast the sign of the residuals turns around and becomes mostly negative. The differences between the residuals in these three periods might be a result of either a shift in the risk evaluation, changes in the forecasting techniques that were not captured in the previous simulations[16], or 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 of the decision-making meeting, and by comparing this finding with the actual settings of interest rates. In the first period, the risks were either slightly disinflationary (the July 2002 forecast) or balanced (the October 2002 forecast). The 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

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

contrary, the risks in the third period were mostly biased in the disinflationary direction (the April 2004, January 2005 forecasts). 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 risk assessment of the forecasts.

To sum up, our analysis based on partial simulations shows that a large part of the target misses in the period under review stemmed from 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 actual interest rates from the recommendation of the model with full knowledge, can be assigned to the risk assessment of the board.

6. 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 understanding among central bank staff and board members of the capabilities and limitations of the forecast, and enhances monetary policy transparency and credibility. We argue in favour of publishing such analyses.

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, on either a regular or irregular basis. However, some central banks still do not even compare the inflation outcomes with the target.

Subsequently, we describe a possible approach to identifying the reasons underlying inflation target hits/misses based on partial simulations of a reduced-form model. We distinguish between models with endogenous and exogenous monetary policy and propose procedures for quantifying the contribution of the 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, the inflation forecasts and interest rate forecasts were biased upwards and inflation was below the target most of time. A detailed assessment of inflation target fulfilment reveals that a large part of the bias in the forecasts can be assigned to bias in variables describing external developments and that some short-lived deviations of interest rates from the model recommendation can be explained by the board's risk assessment of the forecasts.

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