EVALUATION OF THE FULFILMENT OF THE CNB'S INFLATION TARGETS 1998–2007

CNB CZECH NATIONAL BANK

Evaluation of the Fulfilment of the CNB's Inflation Targets 1998 – 2007

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GOVERNOR'S FOREWORD

The Czech National Bank (CNB) introduced the inflation targeting regime in 1998. This represented a major step forward both in the history of Czech monetary policy and international inflation targeting history, since the CNB commenced implementation of the strategy as the first central bank among the transition economies. Inflation targeting was in addition to that introduced after preceding exchange rate turbulence, in the period of comparatively high inflation that was recording two digit levels, and was therefore focused on decreasing inflation during its initials stages. Given the need to decrease inflation, first inflation targets of the CNB were set as downward ones.

Ten years have now passed since the initial stage. In the current stage of inflation targeting, the CNB implements standard inflation targeting with a horizontal target, in full correspondence with the strategy applied across the advanced market economies. During the ten years, the CNB joined the most transparent central banks of the world and became a renowned provider of international assistance to the central banks of the developing economies that intend to move to the inflation targeting strategy.

The ten year anniversary since introduction of inflation targeting has become an opportunity for the CNB to take a look back and evaluate its experiences and fulfilment of inflation targets. I believe it is important to emphasise that the average inflation rate was low during the assessed period 1998-2007, that the inflation expectations were successfully anchored and the CNB contributed to a stable macroeconomic environment of the Czech economy.

Since I perceive the inflation strategy as highly successful, the ten year anniversary has become an impulse to me to think about possible improvements, In view of the fact that deviations in inflation from the inflation targets were occurring during 1998-2007 – mostly in a downward direction – the CNB Bank Board invited selected experts in autumn of 2007 to give their assessment of the fulfillment of inflation targets and of the factors that were the source of inflation deviations from the targets in separate stages of inflation targeting. The factors considered by the Bank Board during its discussions included particularly exogenous shocks damping inflation, specific features of the CNB's forecasting apparatus, asymmetry of the decision making process and decreasing inflation expectations.

Based on the terms of reference defined by the Bank Board, first an internal document of the CNB was prepared, and, upon its discussion, the Bank Board subsequently decided to publish the collection of papers as the proceedings. I believe these proceedings will provide an interesting look into the CNB's "kitchen" for the professional public and will also contribute to further improved transparency of Czech monetary policy.

EDITOR'S INTRODUCTORY NOTE

This anniversary volume *Evaluation of the Fulfilment of the CNB's Inflation Targets 1998–2007* has been prepared upon request by the Bank Board of the Czech National Bank. Original versions of the included papers were written by an extensive team of authors for the meeting of the Bank Board with experts. The aim of this meeting was to assess the ten-year experience with inflation targeting and to contribute to its improvements in the forthcoming years. Following the above mentioned internal discussion, the papers were redrafted and then reviewed by three renowned experts in the Czech monetary policy. Afterwards, they were finally revised making use of the suggestions from the three selected external experts and prepared for publication in electronic format as chapters in this volume. Publication of the volume represents part of the Czech National Bank's efforts to achieve the maximum transparency of the monetary policy. Individual chapters represent views and positions of their authors, by which they have contributed to the internal discussion about inflation targeting during 1998-2007 and, as such, they do not necessarily represent official views of the Czech National Bank.

I wish to express my sincere thanks to the entire team of the authors Juraj Antal, Zuzana Antoničová, Jan Babecký, Michal Hlaváček, Tomáš Holub, Roman Horváth, Jarek Hurník, Ondra Kameník, Karel Musil, Jiří Podpiera, Luboš Růžička, Michal Skořepa and Jan Vlček for their excellent collaboration. I would also like to acknowledge the work that our three referees Aleš Bulíř, Martin Čihák and Viktor Kotlán put into the creation of this volume by reviewing repeatedly the whole collection of the papers. Further thanks go to Eva Grénarová for preparation of the publication.

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Kateřina Šmídková

CHAPTER 1

EVALUATION OF THE FULFILMENT OF THE CNB'S INFLATION TARGETS 1998–2007

KATEŘINA ŠMÍDKOVÁ

THE ORIGIN OF THIS VOLUME

The anniversary volume *Evaluation of the Fulfilment of the CNB's Inflation Targets 1998–2007* contains analyses by experts of the central bank prepared at the turn of 2007 and 2008 that provide an overview of the elapsed ten years of inflation targeting in the Czech National Bank (CNB). The analyses were primarily concerned with identifying the factors that most significantly drove inflation away from the CNB's inflation targets over the past decade. The analyses also supplied a number of additional discussion ideas, whether through international comparison of achieving inflation targets or institutional comparison of inflation forecasts.

The volume includes nine papers that analyse the central theme with the help of various methodologies. The papers cover three stages of inflation targeting. The initial stage (1998–2001) focused on disinflation. During this stage, the CNB used a purely expert-based forecasting system that relied on expert estimates and assessments supplemented with the results of partial models. This initial stage was followed by the advanced stage (2002–2004), during which the disinflation continued. The CNB implemented a new central component into its forecasting system - the new forecasting model (QPM). Finally, for the standard targeting stage (2005–2007) the CNB declared a horizontal target. In this stage, the monetary policy documents are based on a fully developed forecasting system with the extended version of the central forecasting model (QPM+).

Only some of the papers span all inflation targeting stages. Others concentrate on the later stages, as the methodologies employed by them require a wider data base unavailable for the initial stage.

This chapter has been written as a guide to this volume, with the aim of assisting the reader in developing a methodology-independent view of the factors that were diverting inflation from the CNB's inflation targets during the individual inflation targeting stages.

POTENTIAL FACTORS AFFECTING INFLATION DEVIATIONS FROM THE TARGET

Any central bank targeting inflation has to cope with deviations of inflation from the target. Over the past decade, inflation for the selected sample of central banks deviated from their targeted bands in 47% of cases[1]. The Czech experience with inflation targeting was different in the initial and advanced stages. That is why the frequency of fulfilment of the target was lower for the whole decade under review - 34% (see Table 1). What also made the Czech experience distinct from the sample was the asymmetry of deviations during the first decade of inflation targeting. While inflation for the sample of central banks was above the target in half of the cases and below it in the other half, basically only downward deviations could be observed in the Czech case. This asymmetry, accompanied by a higher frequency of deviations from the target in the initial and advanced inflation targeting stages, was a motivation for researching into the factors causing inflation to deviate from the target. Comparison of the more recent Czech experience with that of the sample of countries shows that the Czech inflation targeting matched international standards. During the standard stage of inflation targeting, inflation moved away from the target in 50% of cases. Moreover, the current inflation shows that the distribution of the inflation deviations might steadily converge into a symmetric distribution.

[1] The selected sample of countries is described in Chapter 2 of this volume. Similar conclusions have also been arrived at by other studies using different samples of countries; see Bulíř, Šmídková, Kotlán and Navrátil (2007).

Table 1: The scope of undershooting inflation targets

Inflation:	Czech Republic				Sample of countries			
	1998–2007	1998–2001	2002–2004	2005–2007	1998–2007	1998–2001	2002–2004	2005–2007
within the band	34 %	23 %	33 %	50 %	53 %	56 %	57 %	52 %
below the band	66 %	77 %	67 %	50 %	24 %	25 %	24 %	22 %
above the band	0 %	0 %	0 %	0 %	23 %	19 %	19 %	26 %

Note: A target is considered an entire band in this table. The above approach corresponds to the declared target in the first two stages of inflation targeting in the Czech Republic, while only a point target exists in the standard stage. Therefore, the declared tolerance band has been used in this table. The table employs quarterly data; the distribution would look somewhat different if monthly data were used, while several instances of an overshot Czech inflation target would also occur in that case.

From the outset of the analytical works, the CNB Bank Board asked experts to assess the impact ofpotential factors that could be behind the asymmetric deviations of inflation from the target. These were mainly the following three factors: (i) the target undershooting might be caused by a series of anti-inflationary shocks, (ii) the forecasting system might be the cause of undershooting, and (iii) the decision-making system itself might cause undershooting. Since inflation targeting has recently often been associated with "managing" inflation expectations[2], the role of expectations, too, was examined together with the above mentioned three factors[3]. It has been obvious since the beginning of the analytical works that interpretation of their results will be somewhat difficult. The point is that the factors may cause inflation deviations in concurrence and their relative importance may even be subject to change over time, but no methodology is capable of evaluating all the factors at once. The authors of the contributed papers therefore mostly concentrated on selected factors and selected inflation targeting stages - always taking the employed methodology into account. Obtaining conclusions, independent of the chosen methodology, requires a comparison of the conclusions from all papers on the roles of the analysed factors.

THE FOCUS OF CONTRIBUTED PAPERS

The first three papers, including *Basic Characteristics of Inflation Targeting in the Czech Republic* (Chapter 2), *A Simple, Model-independent Analysis of Reasons for Non-fulfillment of the Declared Inflation Target* (Chapter 3) and *Causes of Deviations of Inflation from CNB Targets – An Empirical Analysis* (Chapter 4), provide an introduction to assessing fulfilment of the CNB inflation targets during the period of 1998–2007. As they have adopted relatively simple methodologies that are less data demanding than the models applied in further papers, they are therefore able to cover the entire period under review. The conclusions of this first set of papers, given the simplicity of the chosen methodologies, are also relatively independent of model assumptions. A price paid in exchange for these two strengths of the foregoing papers (a relative model independence and the entire targeting decade coverage) is rooted in an inability to differentiate all potential factors in

[2] A credible monetary policy may use communication as a complementary tool to the policy interest rates, and to directly manage inflation expectations; see Eusepi, Stefano, and Preston (2007).

[3] These factors were classified as working hypotheses in the course of the analytical works, and some of them are actually tested in the papers. The names of the hypotheses were as follows: (i) the surprised central bank hypothesis; (ii) the hypothesis of the skewed sight; (iii) the asymmetrically considered target hypothesis; and (iv) the overly credible target hypothesis.

detail. The papers can discern between two major sets of factors only – shocks and other factors. It is apparent from the conclusions of these introductory papers that inflation targeting was successful with respect to the disinflation process and ensured a low inflation rate for the Czech economy. Several episodes of more distinct deviations in inflation from the target may be identified during the past decade, mostly related to anti-inflation shocks, both global and specific to the Czech economy. Also, periods of inflation target undershooting are identified that occurred even though no marked anti-inflation shocks were present, suggesting that there may also have been a role to play for the forecasting system or decision making process in these episodes. An international comparison indicates that the Czech experience is in no way unique and that other transition economies were also hit by significant shocks and deviated from inflation targets.

The next four papers, including *Prediction Bias and Undershooting of the Inflation Target* (Chapter 5), *Inflation Forecasts Errors in the Czech Republic: Evidence from a Panel of Institutions* (Chapter 6), *Evaluation of the Quality and Success Rate of Forecasts – A Historic Overview* (Chapter 7) and *The History of Inflation Targeting in the Czech Republic through Optic of a Dynamic General Equilibrium Model* (Chapter 8), employ more intricate methodologies that enable more detailed discussions of separate inflation deviation factors. These more structured discussions increased data demand, and limited some of the analyses only to the later stages. This also leads to a certain degree of dependence of the conclusions on the adopted model and its assumptions. Similarly to the first set of papers, this second set with a more structured view of the factors of inflation deviations also attributes a significant role to the anti-inflation shocks, irrespective of the chosen methodology. The CNB's forecasting system probably also played a certain role, in particular during the first two stages of inflation targeting. Given the similarities between the deviations recorded by the CNB's forecasting system and systems of other Czech analytical institutions, the role of shocks appears dominant. The model analyses further support this interpretation, although it is impossible to discern in certain instances whether the respective impact resulted from the forecasting system or the decision making process. A more prominent role was attributed to the forecasting system where such differentiation was possible. The reason given is that, during the advanced targeting stages in particular, decisions on the monetary policy interest rates were quite close to the suggestions of experts based on the forecasting system itself. If the decision making process contributed to the deviations, it was rather due to too small a correction of the forecasting system.

Two final papers, *Asymmetric Monetary Policy in the Czech Republic?* (Chapter 9) and *Reasons of Undershooting the Inflation Target in the Czech Republic: The Role of Inflation Expectations* (Chapter 10), are both concerned with one specific factor of inflation deviations. Both factors – the asymmetry of the decision making process and role of expectations - are actually difficult to analyse using the methodologies adopted in the previous papers. These complementary analyses indicate that the decision making process may have contributed to undershooting of inflation targets due to its asymmetry in the initial targeting stage. During this stage, CNB used two target types (short-term and medium-term)[4] and might therefore consider an inflation drop below a short-term target, in an environment of global deflation shocks, as a quicker and cost-efficient way of achieving a medium-term target (i.e., practising opportunistic disinflation). Alternatively, the CNB might have been concerned that a decrease of the policy interest rates (which would have been required to compensate for the deflation shocks) would have caused depreciation of the Czech koruna, which

[4] One-year and three-year inflation targets were declared in the initial stage of inflation targeting; see Šmídková and Hrnčíř (1998).

would have put the credibility of the new inflation targeting strategy at risk[5] at a time when the memory of exchange rate turbulences was still fresh[6]. Apparently, empirical results suggest that the Czech monetary policy anchored the inflation expectations[7], and that the inflation expectations were not a primary factor behind the inflation deviations. Anti-inflation shocks, however, were reflected with relative significance in the expectations; hence, expectations might play a certain secondary role in undershooting the target.

POTENTIAL FACTORS BEHIND THE INFLATION DEVIATIONS FROM THE TARGET

Although there are methodological differences between the contributed papers, together they provide a sound basis for compiling an overview of the most frequently identified factors behind the asymmetric deviations of inflation from the target (Table 2)[8]. Two key conclusions follow from this overview: (i) undershooting of inflation targets in 1998–2007 cannot be explained by a single factor, and (ii) individual factors possessed different degrees of importance during different stages of inflation targeting. Each stage involved a combination of factors. Anti-inflation shocks are the most frequently identified source of the deviations. The second next significant source, specifically during the initial and advanced targeting stages, was probably the forecasting system. The decision making process about the policy interest rates, on the contrary, is the least frequently identified factor. Interestingly, the role of the decision making process was the most dynamic one over time. While, in the initial stage, it is seen as a factor that might have added to undershooting of the inflation targets, the authors of the papers even dismiss it as a potential source of deviation in the later inflation targeting stages.

The most marked deviation from the target (by up to 6 percentage points at the most) over the past decade was observed in the initial stage of inflation targeting. The deviation was caused by a combination of three factors: (i) global anti-inflation shocks, (ii) the rigidity of the forecasting expert system, and (iii) opportunistic disinflation. Global shocks pushed inflation the furthest below the target and as the first in the time order. At that time, prices of oil and food decreased significantly and there was even a drop in the global industrial producer price index. This global decrease of prices previously occurred for the last time in 1986–87. In addition to the CNB, other countries within the selected sample of the inflation targeting central banks also undershoot inflation (7 out of 10 went below the target midpoint). Certain domestic shocks additionally joined the global shocks. The Czech koruna appreciated sharply and unexpectedly. Subsequently, problems of the then forecasting system were revealed, as the system responded slowly to new information or repeatedly indicated it probable that the decreasing global prices would shortly reinstate their pace from the first half of the 1990s and that pass-through of the appreciating

[5] The necessity to maintain the credibility of monetary policy was on the agenda of the Bank Board, e.g., in March 1998; see CNB (1998).

[6] At that time, the International Monetary Fund warned that a strategy based on a credibility built using own efforts (instead of being imported with the help of an exchange rate fixation) might fail under the Czech circumstances; see IMF (1998).

[7] Empirical analyses document that inflation targeting anchored expectations in the Czech economy, although inflation deviations from the target were comparatively frequent; see Holub and Hurník (2008).

[8] Table 2 presents a simple "meta-analysis" of the contributed papers. A meta-analysis is currently a popular tool wherever answers are sought to difficult questions in economics, the apparent big problem of which consists either in (i) a dependence of results on a model (model dependence), or (ii) doubts as to the correct model (model uncertainty), or even (iii) non-existence of a model capable of describing the entire problem (only partial analyses are available). Identification of factors behind the inflation deviations falls under this category.

exchange rate into inflation would be relatively weak. The opportunistic disinflation policy was practised in the anti-inflation shock environment. In addition to that, a relevant concern existed during the first year of inflation targeting that an excessively accelerated decrease of the interest rates could cause a loss of credibility in the monetary policy and return of exchange rate turbulences[9].

Table 2: Factors behind the inflation deviations in three stages of inflation targeting in the Czech Republic

	Initial stage (without QPM, disinflation)	Advanced stage (newly with QPM, disinflation)	Standard stage (QPM+, stabilisation)
	1998–2001	2002–2004	2005–2007
Anti-inflation shocks	2 4 5 8 10*	2 4 5 6 8 10*	5 6 7 8
Forecasting system	3* 8* 5	3 5 6	3 5 6 7* 8*
Decision-making process	3* 4 8* 9	8 9	8* 3 9
Inflation expectations	10*	7 8* 10*	7* 8*

Note: Each cell of the table sets out in red those chapters of the volume whose authors consider the respective factor significant for an inflation deviation from the target during the respective stage. Green, on the other hand, is used to denote those chapters that dismiss the respective factor as a source of deviation. For some of the papers, the adopted methodology prevents differentiation of two factors from each other. In that case, both factors are set out with an added asterisk. QPM is a model that has been integrated within the forecasting system since 2002. QPM+ refers to an extended version of QPM.

During the advanced inflation targeting stage, inflation took the furthest departure from the target in 2003. This episode represented the second largest deviation over the ten-year period (by 4 percentage points at the peak). An interaction of only two factors was material at this stage. Anti-inflation shocks – which involved a combination of global and specific shocks – teamed their impact with the introduction of a new forecasting system that, instead of expert analyses, relied on the model forecasts complemented with expert corrections. These corrections were based on the short-term forecasts and partial empirical analyses. The decision making process already ceased to be a source of undershooting in this targeting stage. Once again, global shocks played an important role, as the prices of oil and food dropped and industrial producer prices slowed down during the year preceding the target undershooting. And once again, other countries also undershot the inflation target (8 out of 10 countries below the midpoint). Specific shocks included the koruna strengthening in 2002–2003. The currency appreciation was a surprise to all domestic institutions at that time, and is therefore classified as a shock. Specific shocks also included a surprising (from the forecast system perspective) deceleration of the pace of price deregulations in 2002–2003. The forecasting system contributed to inflation undershooting in this stage, too. In fact, the system distinctly overestimated all inflation elements at the time of its introduction (summer 2002), partly due to the effects of expert intervention with the newly introduced model. In addition, there was still some rigidity as to revaluation of the forecast assumptions. At the same time, the decision

[9] The importance of credibility may be underestimated across the ten-year period. It is important to keep in mind that exchange rate turbulences and their consequences were still very fresh in the memory at that time; see Šmídková et al (1998).

making process put a comparatively bigger emphasis on the forecast developed by the forecasting system, since integration of the central forecasting model into the forecasting system increased the system transparency and consequently its role in the monetary policy debate. At this stage of inflation targeting, the decision making process started focusing on explicit assessment of the forecast risks. This risk assessment gradually led to more frequent correction of the monetary policy suggestions that experts put forward after producing the forecast.

During the standard targeting stage, the most marked inflation deviation from the target occurred at the turn of 2006 and 2007. However, it was the least deviation over the ten-year period (by 2 percentage points at the peak). Key for this deviation, once again, was interaction of anti-inflation shocks and the prognostic system, which was encountering problems in 2005[10]. However, the decision making process was already fully focusing on the forecast risks at this stage. As a result, the decision making process played a much more distinct corrective role in the forecasting system and was moderating undershooting rather than contributing to it. In this stage, inflation expectations probably contributed to decreasing inflation, since they could already have integrated the experience of the target undershooting from the previous two stages[11].

CONCLUDING REMARKS

The findings obtained from the contributed papers are further utilised by the CNB experts when they implement the inflation targeting strategy. Although the initial decade of inflation targeting was characterised by a comparatively atypical asymmetry in inflation deviations from the target, the CNB experts strive to generalise the obtained findings in order to utilise them in the forthcoming years of inflation targeting implementation.

Undershooting of inflation targets in 1998–2007 cannot be explained by a single factor. Anti-inflation shocks are the most frequent source of deviation of inflation from the target. The experience from the previous decade indicates that in the case of large shocks, the rigidity of the forecasting system can also play an important role in inflation deviating from the target. While external shocks cannot be prevented by any central bank, the work with the forecasting system can be changed.

From this point of view, it is important to emphasize that a strategy of more frequent changes in a forecasting system is more beneficial than the strategy of slow adaptation to new information. A less rigid forecasting system supports the decision making process better. The CNB has already begun to follow this approach – by introducing the extended QPM version in 2005, by more frequent changes to the forecast assumptions (e.g. on the pass-through from prices into inflation expectations) and by introducing a new forecasting model (G3).

The forecasting system with the central forecasting model is highly beneficial for structuring the monetary policy discussions and for setting up the core scenario of the economic development. The experience from 2002 and 2005 highlighted that the forecast is an input into monetary policy

[10] The forecasting system repetitively overestimated the increase of food prices, underestimated the exchange rate appreciation (as all domestic institutions did) and had problems with defining equilibrium trends or with describing the supply side of the economy. These problems are particularly related to the non-standard development of the Czech economy, which is still an economy in convergence. It is therefore much more difficult, compared to fully developed economies, to empirically describe the equilibrium trends and supply side of the Czech economy.

[11] Empirical estimates may identify potential differences between the official target and the target as seen by the public. The latter was presumably lower than the official one in the Czech case; see Franta, Saxa, Šmídková (2007).

discussions and that the second topic for these discussions should be the forecast risks[12]. It is important that the decision making process focus on assessing these risks and that it correct monetary policy suggestions, based on the forecast, in the case of their asymmetric distribution around the core scenario.

Inflation targeting is increasingly considered a strategy that should manage inflation expectations. In this respect, the Czech experience of inflation targeting corresponds to the international findings. Compared to the initial stages of inflation targeting, communication has gradually developed into the second tool of the monetary policy that complements monetary policy interest rates and enhances the Czech monetary policy efficiency.

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[12] There are two significant reasons for focusing on forecast risks during monetary policy meetings: (i) the Bank Board members often have a larger and more recent set of information than that available to the experts at the time of preparation of the forecast, and (ii) there is uncertainty related to the model assumptions; see Šmídková (2005).

CHAPTER 2

BASIC CHARACTERISTICS OF INFLATION TARGETING IN THE CZECH REPUBLIC

JURAJ ANTAL
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1. INTRODUCTION

This paper deals with the description of basic characteristics of inflation targeting in the Czech Republic. The first part of the paper starts by briefly indicating some general macro-economic conditions of inflation targeting in the Czech Republic, including the identification of the main shocks, which affected them. This basic description further serves (Section 3) the discussion of the extent of (non-)fulfilment of the target, based on a comparison of the actual course of inflation compared to the targets in various phases of inflation targeting in the Czech Republic in the years 1998 to 2007. The fulfilment of the target is evaluated here using several simple approaches, such as the average deviation from the target, the Root Mean Square Error (RMSE), the ratio of time with inflation under the target or the application of the t-tests of deviation of inflation from the centre of the target and the evaluation of the target fulfillment in view of the hypothetical loss function of the central bank.

The second part of the paper (Section 4) then provides a comparison of the extent of non-fulfilment of the inflation target in the Czech Republic to the experience of several foreign countries, which also apply inflation targeting. This paper does not deal with an analysis of sources of prediction errors or any formal analysis of the success-rate of inflation targeting in the individual countries, or comparisons to any countries, which do not perform inflation targeting (see e.g., Ball, Sheridan, 2003). Our goal is to provide a basic description of the course of the deviations of inflation from target in some selected countries, making use of some basic descriptive statistics and graphic illustrations. This approach may inspire a more formal analysis of shocks, which affected inflation in the individual countries. If we discover any common development of the deviations of the inflation from the target among individual countries, this may serve as a signal of the existence of a potential common source of such deviations. That may provide the information on whether the extent of the target non-fulfilment in the Czech Republic compares with the other countries, and/or it could help us identify periods of major global shocks, which affected all countries implementing inflation targeting.

The conclusion of the paper can be summarized as follows: challenges related to the fulfilment of the goals of the monetary policy concentrated within two periods of time (1998-99 and 2002-03), which were marked with episodes of exchange rate appreciations, something that the monetary policy could not (or did not want to) respond to in a sufficiently quick and resolute manner. The exchange rate appreciation episodes were very strong and their consequences were fairly persistent so the occurrence of two such episodes in less than ten years could have caused a deviation in the direction of target undershooting (at the same time, however, it is hard to explain why no target overshooting took place during the period of exchange rate depreciation and pro-inflationary shocks). Moreover, the periods characterised by the strengthening of the exchange rate were combined with some other anti-inflationary factors, some of which were of a global nature. This has been documented also by the fact that periods of target undershooting in the Czech Republic correspond to periods of low inflation in the sample of other economies targeting inflation.

A comparison of the inflation target fulfilment in various phases of inflation targeting shows a changing success rate in the fulfilment of the target in time. While deviations of inflation from the targets were very high in international comparison in the early phase of inflation targeting, the Czech National Bank has lately come closer to the characteristics of relatively more successful inflation targeters. This may result from a process of "learning", whereby the Czech National Bank has been gradually applying more advanced approaches of the execution of its monetary policy. At

the same time, this may be the outcome of a generally more stable macro-economic situation in the Czech Republic as compared with the initial years of inflation targeting. The Czech National Bank does not stand out significantly in the group of the central banks in the inflation-targeting emerging market economies as far as the frequency and extent of missing the target tolerance band is concerned. However, it has a specific (although not exceptional) position due to having undershot the target on average, with the empiric distribution of the inflation deviations from the target fairly significantly asymmetrical. Our simple analysis shows that the periods of the most extensive target undershooting in the Czech Republic in the years 1998 to 1999 and 2002 to 2003 correspond fairly well also to the periods characterised by the most frequent occurrence of negative deviations of inflation from target among the group of the monitored economies. It seems, therefore, that the Czech Republic, at least to a certain extent, suffered from global anti-inflation shocks within these periods.

2. MACRO-ECONOMIC DEVELOPMENT AND TARGET FULFILMENT OVER THE PAST 10 YEARS

Prior to the evaluation of the inflation targeting record in the Czech Republic, it is useful to briefly mention in the introduction the general economic context of inflation targeting in the Czech Republic (see Table 1). The Czech National Bank announced its first inflation target in December 1997. The beginning of inflation targeting was marked with the aftermath of the financial turbulence occurring in the Spring of 1997 and by the related challenging overall macro-economic situation (high inflation as well as inflationary expectations, despite high interest rates, a drop in the real GDP, depreciation of the exchange rate, high deficits of the trade balance).[1] A certain "backward looking nature" or "cautiousness" of the monetary policy in that period, therefore, could mean that any improvement of the situation as compared with the very turbulence (in 1998 appreciating exchange rate of the crown and improved trade balance, renewal of foreign direct investment inflows, a drop in the interest rates as well as inflation, etc.) could result in a material non-fulfilment of the target in the years 1998 and 1999.

A partial improvement of the economic growth in the years 1999 and 2000, however, was followed by its repeated slowing down, which was connected, among other things, also with an excessive appreciation of the crown at the end of 2001 and in 2002, combined with low international demand. This appreciation was caused, among other things, by a fairly strong inflow of foreign direct investment and market expectations about future major privatisations. Although the response by the Czech National Bank to the appreciation was fairly strong,[2] its scope was so large that a further significant undershooting of the target could not be prevented.

However, foreign direct investments made in the period of 2003 to 2007 assisted an acceleration of the economic growth, a drop in unemployment as well as an improved trade balance. The trade balance has recorded surpluses ever since 2005, despote the continued appreciation of the crown

[1] For a more detailed discussion of the causes and consequences of the financial turbulence, see e.g. Šmídková, et al. (1999) or Dědek (2000).

[2] The CNB two-week REPO rate dropped from 5.25%, which applied at the beginning of November 2001, down to 2% as of 1 August 2003 (that is, below the level prevailing in the eurozone). The Czech National Bank performed fairly extensive intervention in the foreign exchange market in 2002 (for a description and an analysis of the success rate of foreign exchange interventions, see e.g. Geršl and Holub (2006)), and the exchange rate appreciation was addressed also by some less standard approaches of sterilisation of the capital inflow from the privatisation of the State property (see e.g., CNB (2002)).

exchange rate. The improvement of the overall macro-economic situation over the past five years has also been to a large extent caused by the positive effects of the accession of the Czech Republic to the European Union at the beginning of 2004. An example of such positive effects is represented by improved institutional environment in the Czech Republic in connection with the accession, better access to the EU markets, and further strengthening of the inflow of the capital from the EU.

Table 1: Development of basic macro-economic variables in the Czech Republic

		1997	1998	1999	2000	2001	2002	2003	2004	2005	2005	2007
Real GDP growth rate		-0.7	-0.8	1.3	3.6	2.5	1.9	3.6	4.5	6.4	6.4	6.5
Year-on-year CPI inflation		10	6.8	2.5	4	4.1	0.6	1	2.8	2.2	1.7	5.4
Interest rates (3M PRIBOR)		17.6	9.5	5.5	5.4	4.6	2.6	2.1	2.6	2.2	2.6	4.1
Year-on-year exchange rate change CZK/USD[1)]		26.7	-13.8	20.5	5.1	-4.1	-16.9	-14.9	-12.8	9.9	-15.1	-13.4
Year-on-year exchange rate change CZK/EUR[1) 2)]		9.9	-7.6	3.4	-2.9	-8.9	-1.2	2.6	-6.0	-4.8	-5.2	-3.2
Unemployment (Labour Force Survey)		5.4	7.3	9.0	8.3	7.8	7.3	8.1	8.2	7.8	6.5	4.8
Balance of payments (in % of GDP)	Current account	-6.2	-2.0	-2.4	-4.8	-5.3	-5.5	-6.2	-5.2	-1.6	-3.1	-2.5
	of which: Trade balance	-8.6	-4.2	-3.2	-5.5	-5.0	-2.9	-2.7	-0.5	2.0	2.0	3.3
	Balance of services	3.1	3.1	2.0	2.5	2.5	0.9	0.5	0.6	1.2	1.3	1.6
	Incomes balance	-1.4	-1.8	-2.2	-2.4	-3.6	-4.7	-4.7	-5.6	-5.2	-6.2	-7.1
	Foreign Direct Investment	2.2	5.8	10.4	8.7	8.9	11.0	2.1	3.6	9.4	3.2	4.4

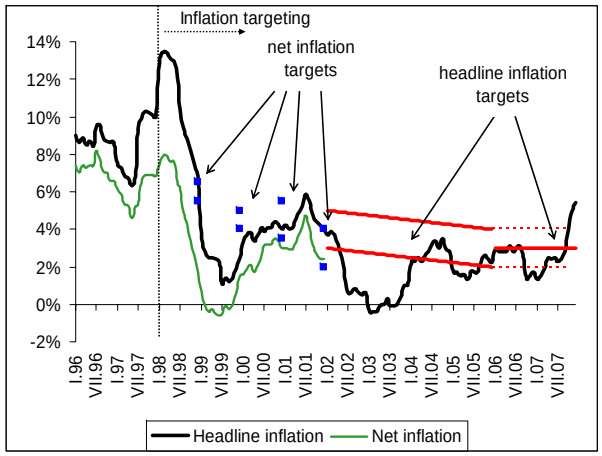
Source: Czech Statistical Office, Czech National Bank. Notes: 1) A positive value represents year-on-year depreciation, a negative value represents year-on-year appreciation; 2) The CZK/DEM exchange rate change for the years 1997 to 1999.

3. EXTENT OF TARGET NON-FULFILMENT AND ITS DEVELOPMENT IN TIME

Figure 1 shows the development of inflation as compared with the CNB targets. It shows that the Czech National Bank entered the inflation targeting regime at a time of relatively high inflation,[3] and one of the main intentions behind its introduction was to achieve disinflation and reduce inflationary expectations (see CNB, 1998). In this respect and during this period, the monetary policy of the Czech National Bank can be assessed as relatively successful since the high inflation faded quickly. Subsequently, the Czech National Bank was – for the entire inflation targeting period –mostly undershooting the target, while its overshooting occurred only in exceptional cases. Target undershooting was most pronounced at the end of the years 1998 and 1999, and in 2003. Out of the four net inflation targets, (the first) two were substantially undershot, one was moderately undershot, and one (the last one) was fulfilled. So far, the headline inflation targets have been undershot in a slightly more than one half of the cases (37 cases in 72 months), while inflation fluctuated under the middle of the target band (65 cases in 72 months) for most of the time.

[3] The year-on-year inflation in the Czech Republic in the first quarter of 1998 reached the historically highest rate since 1994 (in 1993, inflation was still higher due to the introduction of the value added tax). An increase of the year-on-year inflation in January 1998 was mainly contributed to by the administrative factors (increased VAT on energy from 5% to 22%, higher excise taxes, price deregulation), the previous increase of inflation in the second half of 1997 was related in particular to the depreciation of the exchange rate during the financial turbulence.

Figure 1: Inflation – targets vs. reality



Source: Czech Statistical Office and CNB estimates.

Table 2 shows the basic descriptive statistics of inflation target fulfilment, including their comparison for the main periods of inflation targeting. The table shows that inflation was on average roughly 1.7 percentage points below the target for the entire inflation targeting period. At the same time, the extent of undershooting was more significant in the net inflation targeting period (2.5 percentage points) than in the headline inflation targeting period (1.3 percentage points). The "Root Mean Square Error" (RMSE) statistics, which reflects the average target undershooting as well as inflation volatility around the target, reached 2.5 % for the entire period (3.3 % for the net inflation period, and 2.0 % for the headline inflation period).[4] The average deviation of inflation from the target for the entire inflation targeting period has been statistically significant at the 1 percent level. This standard test, however, is based on the assumption of independent random distribution of the individual observations, which does not hold in practice, as inflation deviations from the target have been significantly auto-correlated. Therefore, an AR(2) process[5] for the time series of deviations from the target was estimated as an alternative test, and statistical significance of the (negative) constant in the process was tested. The constant was identified as statistically significant at a 5 percent probability level. This evidence counters the hypothesis of shocks skewed in the anti-inflationary direction, although it needs to be pointed out at the same time that this is a very mechanical statistical test, which does not analyse any causal links.

Table 2 also indicates gradual improvement of the target fulfilment in various phases of inflation targeting in the Czech Republic. In the initial phase, the Czech National Bank introduced targeting of net inflation, which did not contain any impact of the changes of indirect taxes and

[4] See also Holub and Hurník (2008).

[5] The AR(1) process was not sufficient to remove auto-correlation of residuals. This is because the inflation deviation from the target, in the event of major shocks, tends to increase for some initial time before its turn and gradual disappearance. This dynamics is better described by an AR(2) process, as also confirmed by the statistical significance of the AR(2) term at the 1% significance level.

deregulations.[6] The subsequent phase may be described as a transition to headline inflation targeting motivated, among other things, by better comprehensibility of such inflation rate for the public (see CNB (2001)). In the last phase, which can be formally connected to the introduction of a more sophisticated model apparatus applied by the Czech National Bank since 2002,[7] the practice of inflation targeting in the Czech Republic came close to the "best practice" in those countries where inflation targeting has had a years-long tradition. Beside the above-mentioned introduction of a higher-quality core prognostic apparatus, this step primarily involved increased quality of supporting statistical and econometric analyses, improved communication of the Czech National Bank as well as the entire decision-making process regarding the monetary policy decision-making.

Table 2: Inflation deviation from target – basic statistics

	Period	Number of observations	Average deviation	Standard error	Root Mean Square Error	Ratio of cases in %			
						Under the middle of target[3)]	Under the band	In the band	Above the band
Inflation targeting – total[1)]	1/99-12/07	109	-1.74	1.80	2.51	90.83	59.63	37.61	2.75
Net inflation [1)]	12/98-12/01	37	-2.53	2.14	3.32	91.89	75.68	21.62	2.70
Headline inflation	1/02-12/07	72	-1.34	1.44	1.96	90.28	51.39	45.83	2.78
Prior to introduction of QPM[2)]	1/02-7/03	19	-2.71	1.36	3.04	100.00	78.95	21.05	0.00
After introduction of QPM[2)]	8/03-12/07	53	-0.84	1.10	1.39	86.79	41.51	54.72	3.77
Monetary-policy relevant inflation	1/02-12/07	72	-1.61	1.24	2.03	97.22	66.67	31.94	1.39

Notes: 1) The "December" net inflation targets had to be linearly extrapolated into the separate months, subject to equal reduction of the target in the course of each year;
2) The QPM model was introduced in April 2002; given the monetary policy delays estimated at 4-6 quarters, we deemed the "QPM period" to commence in August 2003 (that is, with a delay of 5 quarters);
3) The ratio of cases "above the middle of the target" complements the ratio of the cases under the middle of the target up to 100%.

Following a change in the targeting from net inflation to headline inflation, the average target undershooting increased (the deviation from the target grew from -2.5 % to -2.7 %) as well as, to some extent, the frequency of target undershooting (an increase from 75.7 % cases under the target band to 79 % cases). This can to a certain extent be explained by a larger number of headline inflation items outside the reach of the monetary policy as against net inflation (regulated prices, indirect taxes), which – immediately following the change to headline inflation targeting – surprised the Czech National Bank in the downward direction due to the declining global energy prices. However, the extent of target undershooting relatively significantly declined during the last, i.e. advanced phase of inflation targeting.

It is interesting – but not surprising – to note that if we apply the so-called monetary-policy relevant inflation[8] in measuring inflation deviations from the target, then the average target undershooting is higher than its evaluation with help of headline inflation (the average deviation of -1.6 % as against -1.3 % for headline inflation). This situation ensues from the fact that tax changes executed in the

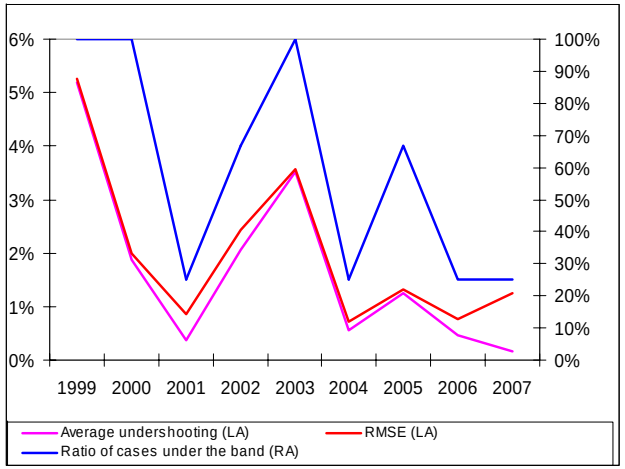
[6] For definition of the net inflation target, see CNB (1999). The recently published "Transcripts of the Bank Board Meetings" (CNB (2008)) represent a unique opportunity of how to get involved in the decision-making of the Czech National Bank regarding the setting-up of the monetary policy in that period.

[7] QPM (Quarterly Prediction Model) introduced in May 2002 represents a so-called "unconditional model" comprising also an estimate of the future development of interest rates (for description of the original model, see CNB (2003), for its partial changes, see CNB (1998-2007)). The previous models were so-called "conditional models", which presumed a constant level of interest rates.

[8] Monetary-policy relevent inflation represents inflation to which the monetary policy reacts ex ante. It is defined as headline inflation adjusted for the primary effects of changes to indirect taxes.

past resulted in the overwhelming majority of cases in increased inflation, and thus brought headline inflation closer to the target. In the following text, however, we do not mention monetary-policy relevant inflation due to two reasons. Firstly, it would disturb international comparability of the results for the Czech Republic because all international comparative studies are based on comparisons of officially targeted price indices with the declared targets, and they do not consider any potential *ex ante* escape clauses from target fulfilment. Secondly, the application of escape clauses was changing in the course of inflation targeting in the Czech Republic and it would be difficult to approach it in a consistent manner.[9]

Figure 2: Target fulfilment indicators in the individual years (average values of the indicators in the individual months of a given year)



The fact that the extent of target undershooting was changing in the course of time is obvious also from the comparison of the development of the target fulfilment indicators in the individual years (see Figure 2). This development shows a fairly significant fluctuation in the success-rate of fulfilment of inflation target. In the years 1999, 2002, and 2003, a fairly significant worsening occurred in hitting the target, while on the other hand, inflation came closer to the target in the years 2001 and 2004 to 2007.[10] Despite the rather significant volatility of the target fulfilment indicators, the figure also indicates the above-described trend of gradual improvement of target fulfilment in time.

[9] E.g., in 2002-2005, there was an option of applying an *ex ante* escape clause to the contribution of regulated prices to inflation outside the interval of 1-1.5 percentage points. If such an escape clause was taken into consideration, it would reduce the extent of target undershooting in the years 2002-2003, which is something we do not opt for in this analysis.

[10] The strong correlation between the RMSE indicator and the average target undershooting in a given year results from the fact that the Czech National Bank was overshooting its inflation target only in exceptional cases, and to a very minor extent. Moderately differing development of these indicators in 2007 results from the overshooting of inflation at the end of 2007, which reduced the average inflation undershooting but had a positive impact on the RMSE indicator.

Figure 3a: Loss function components[12]

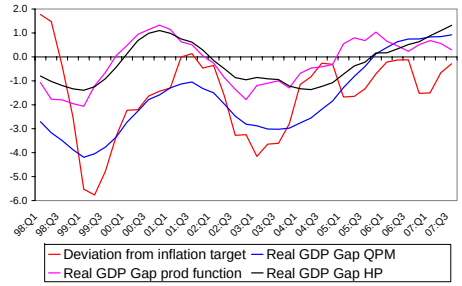
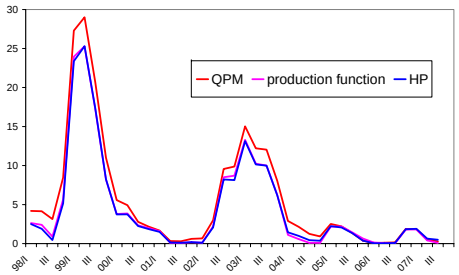


Figure 3b: Loss function values (3/4 inflation, 1/4 output gap[12])



Source: CNB, own calculation.

The time dimension of target undershooting will also come out if we interpret the periods of the largest missing of the target with help of values of a hypothetical central bank loss function (see Kotlán and Navrátil (2003)). In line with the standard assumptions contained in economic literature concerning central bank preferences under the flexible inflation targeting regime, the applied loss function weighs the square of inflation deviations from the target and the square of the output gap.[11] Components of the loss function are shown in Figure 3a, which shows a clear relationship between the extent of inflation targets undershooting and the various estimates of the output gap;[12] any significant undershooting of the target was typically linked to the widening of a negative output gap, while coming closer to the target was accompanied either by closing the negative output gap or its opening into positive values. Calculations of the values of the loss function for $\alpha = 3/4$ are shown in Figure 3b. They confirm the previous conclusion that the most serious problems regarding the fulfilment of inflation targets concentrated into the years 1998-1999 and 2002-2003. Those periods saw inflation target undershooting as well as negative output gaps at the same time, pursuant to all and any approaches we applied. On the other hand, in the years 2000-2001 and 2004-2007, inflation returned closer to the inflation targets following the previous shocks, and the economy stabilised close to its potential. The figure shows that if the output gap from the QPM model determined with help of the Kalman filter approach is applied, the value of the loss function is the highest. This

[11] The loss function was specified as follows: $L_t = \alpha . (\pi_t - \pi_t^{TAR})^2 + (1-\alpha).(y_t - y_t^*)^2$, where α depicts the weight of inflation deviations from the target, $(1-\alpha)$ the weight of the output gap, π_t^{TAR} the inflation target, π_t inflation, and $(y_t - y_t^*)$ the output gap. It is possible to see loss functions also with other variables in literature (see e.g., Kotlán and Navrátil (2003)). The simplest approach would only consider the inflation, whereby the value of the loss function corresponds to the RMSE indicator. Beside the output gap, the loss function may also incorporate exchange rate volatility, interest rate volatility, unemployment, etc. In this paper, we included only the output gap in the loss function. The applied higher weight of inflation as against the output gap reflects the logics of inflation as the main goal of monetary policy. The responsibility of monetary policy to contribute to economic stability has been stipulated in the legislation only as a secondary goal, which is supposed to be met by the Czech National Bank only subject to the fulfilment of its main goal (see section 2(1) of Act No. 6/1993, on Czech National Bank, as amended). The results, however, have been fairly robust with respect of the selection of that parameter. The loss function, moreover, could be changing in time as the composition of the Bank Board was changing.

[12] We applied three estimation methods of the output gap: the simple smoothing with help of the Hodrick- Prescott (HP) filter with the parameter λ=1600, an estimate of the output gap with help of the production function method (see CNB (2005)), and an estimate of the output gap used in the QPM core prediction model, which is executed with help of the Kalman filter method (see CNB (2003)).

results from the structure of the filter, which – beside the development of the GDP – interprets, among other things, also the development of inflation, the low value of which logically implies that the estimated output gap remained in negative values during the period of inflation targets undershooting. This estimate of the loss function applied the weight of the square of inflation deviation α at 0.75; still, calculations of the loss function for other values of the same parameter bring about similar conclusions.

4. INTERNATIONAL COMPARISONS

Our results as presented in the previous section can be compared with the conclusions of the available empirical studies analysing the success-rate of inflation targeting on a broader sample of countries. Roger and Stone (2005) discovered that those countries, which target inflation, were outside the target band (± 1 percentage point wide) for 43.5 % of time, i.e., less often than in the Czech Republic. In countries characterised by declining inflation targets, i.e. in the course of disinflation, however, the band was missed in 59.7 % of cases, i.e. about as often as in the Czech Republic. However, as against the Czech Republic, those deviations from the target were roughly balanced in both directions within the entire sample, and in countries characterised by declining targets, they deflected in the direction of its overshooting. The RMSE of deviations of inflation from the target reached the value of 2.2 % for all countries, and the value of 2.7 % for those countries in the process of disinflation, so that the Czech Republic, for its inflation targeting period as a whole, falls approximately in the middle between those two values.

Bulíř et al (2007) analysed a sample of countries made up of Chile, the Czech Republic, Hungary, Poland, Thailand, and Sweden. They discovered that those countries were outside the band in 57 % of cases on average, i.e., roughly as often as the Czech Republic. In some countries, target overshooting prevailed (e.g., in Hungary), while some other countries rather experienced its undershooting (the Czech Republic, Poland, Sweden).

The results of the Czech National Bank are therefore roughly comparable to the results reached by those countries, which applied the inflation targeting regime in order to achieve disinflation, namely from the point of view of the frequency of missing the target tolerance band as well as the statistics of the RMSE deviation of inflation from the target. As against this group of the countries, however, the average inflation deviation from the target in the Czech Republic moves in an opposite direction, i.e., in the direction of undershooting, although even such countries can be found.

The success-rate of inflation targeting on a panel of the OECD countries was analysed also, for example, in Johnson (2002), Ball, Sheridan (2003), or in Lin, Ye (2007). Those studies typically compare the development of inflation prior to and after the introduction of inflation targeting against the development of inflation in those countries where inflation targeting was not introduced. While Johnson (2002) finds evidence for arguments that inflation targeting reduced inflation expectations, Ball and Sheridan (2003) show that a higher drop in inflation in those countries, which introduced inflation targeting, was mainly due to their higher initial inflation (the issue of "mean-reversion"). Lin and Ye (2007) confirm this hypothesis; moreover, they complement the model with endogenous selection of the monetary policy regime when inflation targeting is opted for by those countries, which have been facing higher inflation. Applicability of the above-described approaches to the situation in the Czech Republic, and/or in any other countries, which applied inflation targeting in order to achieve disinflation, however, is contentious. All of the above-described studies, in fact, exclude from their analyses those countries where the targets

decreased in the course of time. High initial inflation occurring in various transforming economies may result from a number of factors of administrative nature deserving exemption, such as – for example – deregulation or changes in the indirect taxes so the "mean-reversion" analyses may bring about different outcomes.

It is not intended that this study should evaluate whether inflation targeting represents a suitable instrument in the execution of disinflation, or that inflation targeting was more successful in the Czech Republic than in other countries. Since the Czech Republic represents a small open economy, its development of inflation to a significant extent results from the course of the global economy. In the following text, therefore, we compare the the fulfilment of the target in the Czech Republic and in some selected economies applying inflation targeting (that is, in such economies, which are characterised by similar transmission mechanisms of their monetary policies). If we discovered any common or similar development of inflation deviations from the target in those countries, such finding would support the hypothesis that inflation targets undershooting occurred with the contribution of global shocks and trends, which appeared also in other economies besides the Czech Republic.

This analysis focuses on ten economies, in particular: the Czech Republic, Hungary and Poland representing Central Europe,[13] the eurozone,[14] Sweden and the United Kingdom, which represent the advanced European countries, and Canada and Chile representing America. This set of the countries is then complemented by New Zealand and Israel. Our selection gave preference to small open economies over the large ones (such as – for example – Brazil), and also to those economies that maintained business relations with the Czech Republic; beside "traditional" inflation targeters, we strove to cover especially those countries, which applied inflation targeting for the purposes of achieving disinflation.

Figure 4 shows deviations of quarterly inflation from the middle of the target for the individual economies in the period commencing at the beginning of 1998. At the same time, it depicts the inflation target band in the relevant period. Most economies targeted inflation within the band of ±1 percentage point around the inflation targets; the Czech Republic started with a narrower band of ± 0.5 percentage point, New Zealand, on the contrary, started with a wider band (± 1.5 percentage points) and Israel adjusted its band width twice (once, it narrowed its band from ± 1.5 percentage points down to ± 0.5 percentage point, then it widened it up to ± 1 percentage point). The eurozone reports an asymmetric band, by reporting only its ceiling for the definition of the price stability (up to 2 %).[15] The inflation target increased within the relevant period only in New Zealand where the inflation band was adjusted from 0-3 percentage points to 1-3 percentage points. The Czech Republic, Poland, Hungary, and Israel decreased their targets.

[13] Unfortunately, we could not include in our analysis the geographically and historically proximate Slovakia, which had not been explicitly targeting inflation until 2004, when its first target for the end of 2005 was published. Moreover, Slovakia has experienced over time a shift from a symmetric target to an asymmetric, ECB-style target, which – moreover – dropped from up to 2.5% at the end of 2006 to up to 2% at the end of 2007 and in 2008. Therefore, the number of comparable observations is very low.

[14] The ECB is typically not considered as a central bank targeting inflation because it combines an asymmetric target for inflation with a target for the money supply growth. Still, we decided to include eurozone in this analysis because it acts as the most important business partner of the Czech Republic and – moreover – it reflects the monetary policy relevant for the Czech Republic following its future adoption of the euro.

[15] In 2004, the ECB clarified its definition of price stability in that sense that inflation should fluctuate under two percent but close to such level. In this text, for the sake of simplicity, we considered the value of 2% to represent also the middle value of the band for the eurozone.

The targets currently stand either at the level of 2 percentage points (Sweden, United Kingdom, Canada, New Zealand, Israel, and the eurozone), or 3 percentage points (Czech Republic, Hungary, Poland and Chile). All economies currently explicitly or implicitly (United Kingdom, Czech Republic) tolerate the band of ± 1 percentage point around the target. Although this band has currently been equally wide for all monitored economies, Figure 4 shows that, in the less advanced economies (Czech Republic, Hungary, Poland, Chile, and Israel), inflation volatility has been significantly higher, which makes target fulfilment more difficult in the longer-run. The first glance at the figure shows that quarterly inflation in the Czech economy never exceed the target band, while inflation appeared more often above the target than under the target in the eurozone. Hungary reported inflation target overshooting, as against Poland, which – together with the Czech Republic – ranks among the most important inflation target undershooters. Inflation in the United Kingdom, as well as in Canada and New Zealand, diverted from the band only in exceptional cases. On the contrary, inflation in Israel and in Chile, due to its high volatility – was moving away from the target band relatively often. Among the advanced economies with lower inflation volatility, Sweden reported certain asymmetry of deviations of inflation from the target.

A simple t-test of symmetry of deviations of inflation from the target[16] shows that the Czech Republic, together with Poland, Sweden, and Israel, was undershooting inflation targets in a statistically significant manner; target overshooting occurred in Hungary and New Zealand (see Table 3). As far as the ECB, Canada, the United Kingdom, and Chile are concerned, it is not possible to reject the hypothesis about symmetric deviations of inflation from the target.

Table 3: Tests of symmetric deviations of inflation from the target

	CZ	ECB	POL	HUN	SWE	UK	CAN	Chile	NZ	Israel
t-statistics	-6.27	-0.78	-4.78	1.96	-5.39	-1.15	1.25	0.85	2.51	-2.33
p-value	0.00	0.44	0.00	0.06	0.00	0.25	0.40	0.22	0.02	0.03

Table 4: Target fulfilment in the individual countries

	Countries with declining target				Countries with constant target						Total	Declining target	Const. target
	CZ	POL	HUN	Israel	Chile	SWE	UK	CAN	ECB	NZ			
No. of observations	36	27	23	39	39	39	38	38	39	37	355	124	231
Average	-1.94	-1.44	0.92	-0.91	0.26	-0.86	-0.08	0.11	-0.06	0.44	-0.36	-0.98	-0.04
Median	-1.50	-1.60	0.17	-1.39	0.40	-1.00	-0.11	0.19	0.04	0.54	-0.22	-1.30	0.02
Standard deviation	1.83	1.57	2.26	2.43	1.31	1.00	0.42	0,83	0.50	1.06	1.62	2.27	0.99
Skewness	-0.98	0.51	0.73	0.57	-0.52	0.03	0.32	0.55	-0.84	-0.59	-0.20	0.50	-0.20
Minimum	-6.29	-4.20	-2.43	-4.88	-3.70	-3.10	-0.75	-1.23	-1.18	-2.01	-6.29	-6.29	-3.70
Maximum	0.54	1.50	5.58	4.21	2.85	1.00	0.84	2.48	0.90	2.48	5.58	5.58	2.85
RMSE	2.50	2.11	2.39	2.57	1.32	1.34	0.42	0.83	0.49	1.12	1.66	2.47	0.99
Relative frequency (in %)													
under target middle	91.4	82.0	30.4	71.8	46.2	82.1	55.3	39.5	41.0	29.7	57.1	71.8	49.1
within band	34.0	15.0	48.0	28.0	67.0	54.0	100.0	78.0	41.0	62.0	54.2	30.6	67.0
outside band	66.0	85.0	52.0	72.0	33.0	46.0	0.0	22.0	59.0	38.0	45.8	69.4	33.0
under band	66.0	70.0	17.0	51.0	10.0	46.0	0.0	11.0	0.0	8.0	26.8	53.2	12.6

[16] The test based on t-statistics and the presumption of an independent normal distribution (therefore, it does not consider any auto-correlation of the inflation deviations from the target – discussion relating to the Czech Republic is in Section 2 – or potential violation of normality of their distribution – see below in this part of the text). The higher the absolute value of the t- statistics (and/or, the lower the p-value), the higher the probability of the rejection of the hypothesis about symmetric deviations of inflation from the target.

Table 4 provides some basic statistics on inflation deviations from the targets for the individual economies. Six economies experienced a negative average deviation, among them the Czech Republic with the highest absolute value (-1.9 percentage points). The standard deviation – compared to the Czech Republic – is higher only in the cases of Israel and Hungary. The RMSE indicator applicable to the Czech Republic is comparable to the same indicator for the other economies, which applied declining targets within the relevant period; however, in comparison to the economies with constant or growing targets, the indicators were worse in general.

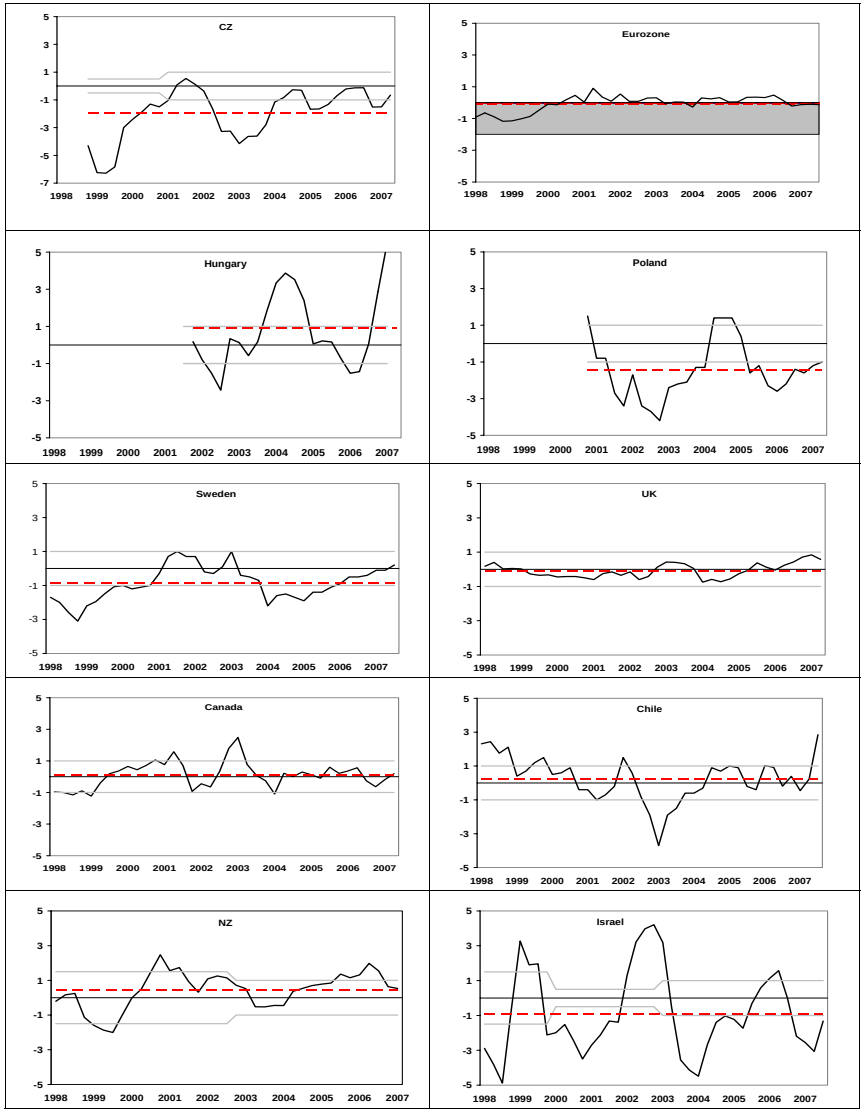
Beside the assessment of the basic descriptive statistics of target fulfilment, it is fairly important to monitor also the empirical statistical distributions of the deviations of inflation from the target, particularly for those countries, which apply declining targets. This is shown in Figure 5, which presents histograms of inflation deviations from the middle of the target. The histograms for the Czech Republic, Poland, Hungary, Chile, and Israel show that those countries report significant frequencies also in the more distant intervals of the deviation from the target. It is possible to identify a certain multi-peak distribution characteristic for them, which indicates that those countries obviously suffered from a number of major shocks over time. Thus, the interpretation of what a symmetric monetary policy means is fairly complicated for the transition economies, due to the importance of such shocks.

The histograms and also the skewness statistics[17] in Table 4 also show that the presumption of symmetric distribution of deviations of inflation from the target has been violated in some of the countries. This fact may affect the results of the standard t-tests regarding the symmetry of deviations from the targets (violation of the presumption of normal distribution).

If the empiric distribution function skews to the right (i.e. if it has a negative skewness value), it can be relatively easily explained in the case of central banks with asymmetrically defined targets, such as – for example – the ECB, for which an overshooting of the target is less "pleasant" from the communication point of view than an identical undershooting. This situation may give rise to certain asymmetry in responses of the monetary policy and the monitored asymmetric distribution of the deviations of inflation from the target. It is fairly interesting that the Czech Republic reports a similarly "inclined" distribution function as the ECB. A negative skewness value may be given here by implicit asymmetric monetary policy (that is, the central bank assesses target undershooting as less costly that its overshooting, even if its target has been defined as symmetric), which can also be identified, for example, in New Zealand and partially also in Chile. It is also interesting that all of the other countries, which were identified by the t-test as significantly undershooting the inflation target, either reported relatively symmetric distributions of the deviations of inflation from the target (Sweden) or they have this distribution inclined to the other side (Poland and Israel). Asymmetric distribution of the deviations of inflation from the target may be explained in these countries, for example, by the hypothesis of their worries concerning cutting the interest rates below their level in the reference country. An alternative hypothesis may be based on certain worries of very low inflation and its negative impact on the economic growth. A fairly high asymmetry in the distribution of the deviations of inflation from the target (positive skewness) in Hungary may be explained by a not entirely clean regime of inflation targeting in that country (Hungary, beside inflation, also targeted the exchange rate in the past, and it preferred in several cases the maintenance of the exchange rate within the fluctuation band to the fulfilment of the inflation targets).

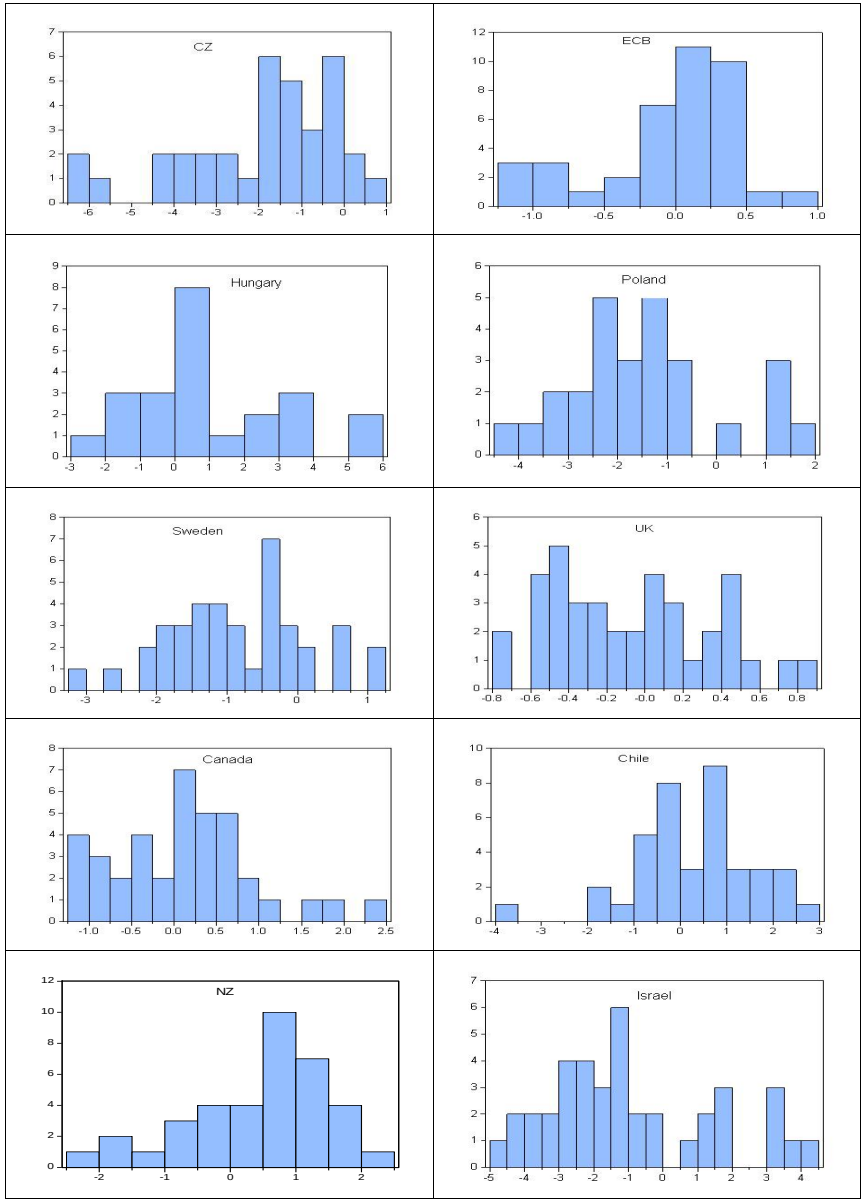
[17] Positive skewness means that the distribution function is inclined to the left, while negative skewness means that the distribution function is inclined to the right. With symmetric distribution, such as normal distribution, the skewness equals to zero.

Figure 4: Inflation deviations from the middle of the target



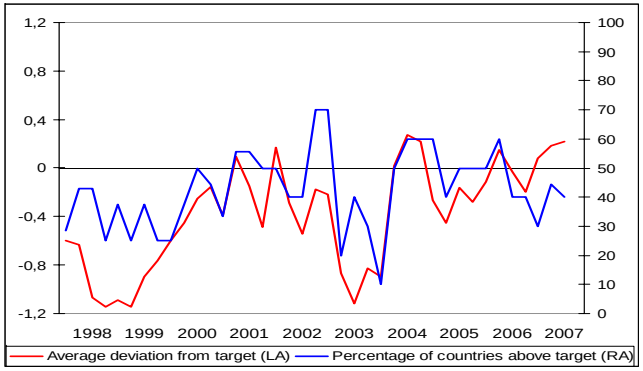
Note: The solid black line marks the deviation of inflation from the target, the grey line marks the tolerance band around the middle of the target, and the dashed red line marks the average deviation for the entire period. The "shading" of the band for the Eurozone reflects the asymmetric nature of its target (inflation under 2%). For the purposes of this analysis, the ECB target is presumed at 0-2%.

Figure 5: Histograms of deviations of inflation from the middle of the target



Although undershooting of the inflation targets in the Czech Republic is to a certain extent specific as regards its distribution function, the development of the indicators of the target undershooting for the entire group of the ten monitored economies (see Figure 6) shows that the development in the Czech Republic fits fairly well in the international context. The group of the monitored countries was on average undershooting inflation targets in the years 1998-2007, which is in line with the generally accepted opinion that the period of the past ten years represented a major weakening of the global inflationary pressure. The periods of the most extensive target undershooting in the Czech Republic (the years 1998 to 1999 and 2002 to 2003) also correspond fairly well with the periods characterised by the most negative deviations of inflation from the targets in the group of the monitored economies, as well as with the increased ratio of the countries whose inflation appeared under the target in those periods. It seems, therefore, that the Czech Republic, at least to a certain extent, suffered from some global anti-inflation shocks at those times, which were multiplied by the specific transformation nature of the Czech economy and the development of the exchange rate.

Figure 6: Target fulfilment across the countries (evolution in time)



5. CONCLUSION

The challenges related to the fulfilment of the monetary policy goals concentrated into two periods (1998-99 and 2002-03) in the Czech Republic, which were characterised by exchange rate appreciations that the monetary policy could not (or did not intend to) respond to sufficiently quickly and resolutely. A comparison of the characteristics of inflation targets fulfilment for various phases of inflation targeting shows that the success rate of the target fulfilment changed in time. While the inflation deviations from the target were very high in the initial phase of the inflation targeting in international comparisons, lately, the Czech National Bank was nearing the characteristics of relatively more successful inflation targeters. The Czech National Bank does not stand out significantly from among the group of the central banks belonging to the inflation-targeting emerging market economies from the point of view of the frequency and extent of missing the target tolerance band.

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CHAPTER 3

A SIMPLE, MODEL-INDEPENDENT ANALYSIS OF REASONS FOR NON-FULFILLMENT OF THE DECLARED INFLATION TARGET

MICHAL SKOŘEPA

1. INTRODUCTION

Success of a central bank managing its monetary policy under an inflation targeting regime may be measured in many ways. In addition to the indicators such as inflation stability, its trend toward the values targeted over a long period, or inflation expectations hovering close to inflation targets, unquestionably the degree of alignment between actual inflation and inflation targets is a natural yardstick of success for an inflation targeting central bank. A comparison of inflation targets of the Czech National Bank (CNB) and actual evolution of inflation as from 1998, the year when the CNB began to manage its monetary policy under an inflation targeting regime, until the end of 2007, shows that the inflation target midpoints were distinctly more frequently undershooted than overshooted.

Using purely statistical tools, this paper will examine options for explaining the above asymmetries in non-fulfillment of inflation targets. An advantage of this approach is the simplicity and maximum possible elimination of arbitrary expert interventions in the form of calibrated coefficients or in the form of a model corresponding to a single one out of the multiple and competing macroeconomic schools of thought. A price to pay for such elimination of additional information sources utilisable for estimation is the fact that the results are indicative only.

The causes of observed undershooting of inflation targets could be either outside the CNB, i.e. undershooting was due to a prevailingly anti-inflationary character of external shocks, or inside the CNB, i.e. undershooting was due to the CNB's monetary policy being conducive to lower than officially targeted values (whether or not such biased targeting was deliberate). And this CNB-made undershooting might have been already included in the documents available to the CNB Bank Board for their decision making, or it might have been developing in the Bank Board members' minds during their decision making only.

Our computations suggest that an explanation through a bias of the CNB's monetary policy seems statistically more credible. A closer look at the period since 2002 then leads to a conclusion that the bias of the CNB's monetary policy over that period came into existence not in the course of decision making by the Bank Board but already during the preparation of forecasts, on which the Bank Board based its decisions.

The rest of this paper is structured as follows: Section 2 provides a description of the inflation gap during the period under review, while Section 3 articulates three core hypotheses addressed by the paper. Section 4 brings details on the procedure used to identify which of the hypotheses is better in describing the time series of the inflation gap values. Section 5 presents the results of computations and Section 6 contains a summary of the key ideas of the paper.

2. PERIOD UNDER REVIEW

Monetary policy of the CNB followed the inflation targeting logic commencing as of the turn of 1997 and 1998. If we assume, for the sake of simplicity (throughout this paper), an approximately one year lag between a monetary-policy decision and its impact on inflation, then it makes sense to examine the reasons of unmet targets starting with the turn of 1998 and 1999. On the overall, we will therefore analyse (non-)fulfillment of targets for the period 12/1998–12/2007. In the period 12/1998–12/2001, targets were set only for December of each year and, for that period, we design implicit inflation targets for the other months of each year by linear interpolation of actual targets. We obtain 109 months in total, in each of which we can compare the target to actual inflation (Figure 1) and to obtain the inflation gap value defined as a difference between actual inflation and inflation target (Figure 2).

Figure 1: Evolution of the (implicit) inflation target and the respective inflation indicator

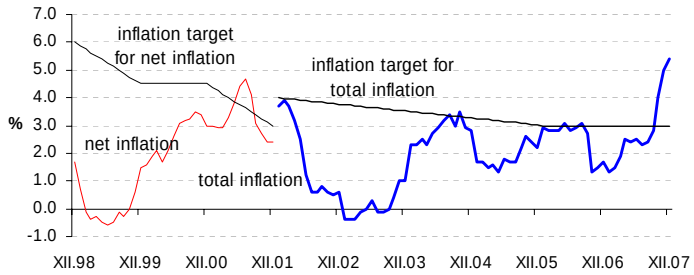
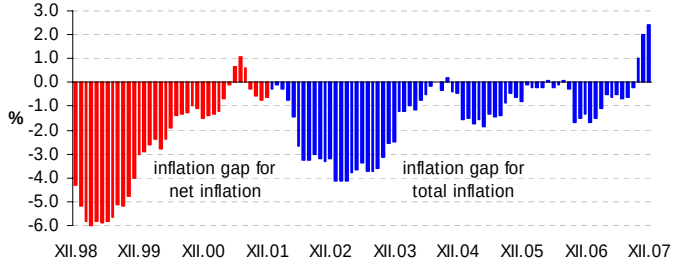


Figure 2: Evolution of the inflation gap



This period may be examined either in total as a single stage or broken down into multiple stages. The more refined analysis (more stages) we choose, the more detailed information on evolution of target non-fulfillment factors over time is gained but at the same time the less quality such information has in statistical terms because by using a larger number of stages we reduce the number of observations (and, consequently, the number of degrees of freedom) in each of them.

Several breaks may be found across the entire period of 1998–2007 that may be used as a basis for defining specific stages. From the perspective of the inflation targeting implementation technique at the CNB, e.g. the year 2002 is significant when the CNB forecasting team migrated from predominantly expert-based preparation of forecasts to forecasting that integrated both the expert and model approaches (CNB, 2002, Coats, Laxton & Rose, 2003). From the viewpoint of the basic inflation targeting philosophy in the Czech Republic and also the experience of the CNB Bank Board with the regime and evolution of domestic inflation, specifically the year 2003 was highly important. In that year, two strong (and interrelated) reasons existed for a shift in the CNB Bank Board's preferences towards more relaxed monetary policy: A period of intensive deliberate disinflation came to an end and the Czech economy even experienced several months of deflation. Furthermore, there were gradual personnel changes within the CNB Bank Board during 1998–2007, which were probably causing changes in the Board's overall preferences as well.

Therefore, reasons exist to believe that certain structural breaks occurred during the period under review. In the interest of maintaining a sufficient number of degrees of freedom, however, we will present results only for the period 12/1998–12/2007 as a whole in our paper.[1]

3. HYPOTHESES

There are two core potential causes of asymmetries in deviations of inflation from the inflation target: a bias in the shocks hitting the Czech economy (i.e. such shocks have a nonzero value on average) and a bias of the CNB. Within the CNB's bias, a bias of the forecasting apparatus might be identified (i.e., its outputs help to achieve an inflation target that differs from the declared one), as well as a bias in the preferences of the Bank Board (i.e., its decisions help to achieve an inflation target that differs from the declared one). The bias of the Bank Board's preferences may take the form of either a biased minimum of a symmetrical loss function of the Bank Board (see e.g. Svensson, 1996) or an asymmetry of the loss function of the Bank Board (see e.g. Cukierman & Muscatelli, 2007).

The majority of other potential sources of non-fulfillment of the inflation target may be viewed as included under one of the above-mentioned core spheres. A biased picture of the economy, for example, that may be contained in the statistical data available at the time of monetary policy decision making (i.e. the problem of working with the data in real time), may be categorised under the biased forecasting apparatus sphere (even though the factor is in fact outside the CNB's control).

The above potential reasons may be briefly summarised into three hypotheses:

Hypothesis A (derived from the word "apparatus"): The CNB's forecasting apparatus was biased.
Hypothesis B (derived from the phrase "Bank Board"): Preferences of the CNB Bank Board were biased.
Hypothesis S (derived from the word "shocks"): Shocks were biased.

4. THE METHOD

In fact each, even a seemingly absolutely non-model, purely statistical procedure has to be based on some, though rudimentary model of reality. In our case, we will start from a simple model, under which monetary policy always takes such steps as to keep inflation in proximity of the inflation target, i.e. to maintain an inflation gap close to zero; in case such inflation gap, due to a shock, is nonzero at a given point in time, monetary policy will take steps to drive the gap back to zero step by step. The speed of return of the inflation gap to zero is subject to persistence of inflation that may be modelled as an autoregressive process. [2]

An actual inflation gap may more or less differ from such a modelled trajectory in certain months, i.e. we are able to measure the error of our statistical model. If such an error occurs, the model will fully adapt to it in the very next month, while it will also begin to "dissolve" the error immediately through the autoregressive process. The dissolution process may be joined by another, new error of

[1] Computations made for shorter stages, in a manner explicitly revealing potential influence of the above structural breaks, led to non-intuitive results, in particular for the stages covering several recent years - probably due to an insufficient number of degrees of freedom.
[2] A method of the inflation gap analysis based, in contrast, on a detailed model of economy functioning is described e.g. by Filáček (2007).

the inflation gap model at any time later on. If the new error points further away from zero (i.e. in the same direction as the preceding error), the decay of the total error will of course take longer; conversely, if the new error points towards zero, the decay of the total error will be faster.

The larger the error that occurs during the inflation gap evolution as opposed to the model trajectory, the stronger is the suspicion that it is a shock - a manifestation of an unusual event that is "exogenous", i.e. it is not a part of the entire process: monetary policy has not expected the event and its impact on the inflation evolution and could not therefore make any pre-emptive steps that would prevent such an impact on inflation. The below-described statistical procedure implicitly offers one possible definition of the limit beyond which we will treat an error as "exogenous", i.e. as a shock.

We will study how well various combinations of intensity of impact of the two basic reasons of the non-fulfillment of the inflation target (CNB's bias vs. shocks) provide an explanation of empirical data on the inflation gap evolution. The impact of the CNB's bias, i.e. the bias of its forecasting apparatus and bias of the Bank Board's preferences, may be modelled as the difference a between an inflation target that is *manifested* (towards which monetary policy truly drives inflation), symbolically $\pi_t^T + a$, and an inflation target that is *declared*, symbolically π_t^T. We will generally suppose that, during the whole period under review, monetary policy was behaving as if striving for the inflation gap of size a. The case of the CNB's bias towards undershooting can be expressed as $a < 0$. Hence if the computation gives $a < 0$, that will support hypotheses A and B.

We will model the second basic possible cause of undershooting, i.e. shocks, with the help of dummy variables within an autoregression process, i.e. as abrupt shifts of the inflation gap to another level, at which it will restore its gradual convergence to a.

Of course, we need to define a meaningful method of identification of concrete periods in which a shock is most likely to have occured, i.e. periods in which we will assign the value of 1 to a dummy variable (while the dummy value will be 0 in all other periods). We will suppose now that the suspicion of a shock occurrence – and therefore use of value 1 for its corresponding dummy variable – is substantiated particularly in the month in which we identify a major error of the autoregression model alone, i.e. without any dummy variables. A shock that will manifest itself by changes in the inflation gap (and therefore by errors within the autoregression model) in two or more months in a row will be recorded as a series of two or more of one-month shocks, i.e. in the form of two or more dummies, each of which attains value 1 in just one month.

If we use dummy variables for one or multiple months selected according to the described method (each dummy variable for one month) and if the computation leads to the conclusion that such enrichment of the autoregression model with one or more dummy variables statistically helps to explain the observed evolution of the inflation gap, it will become a support for hypothesis S.

It should be pointed out that a lesser difference exists between the "shocks" and the "CNB's bias" than it may appear: both cases basically represent a set of shocks. The difference between the two categories is in what types of shocks (in terms of their duration) they include. The "CNB's bias" is a set of long term (or repetitively acting) shocks, such as a discrepancy between the manifested inflation target and the declared target; the set may however include also e.g. a recurring, unexpectedly strong appreciation of the nominal exchange rate, or an unexpectedly long-term and fierce fight of chain-stores over their shares of the Czech market through suppressing planned increases in retail prices. The "shocks", on the other hand, represent a set of one-off shocks, whether that means a leap in the regulated prices, a change in the VAT rates, a short-term and

abrupt appreciation of the exchange rate, or e.g. an isolated considerable mistake of the CNB apparatus in preparing a forecast or of the Bank Board in setting the levels for the monetary policy rates.[3]

Consequently, if the CNB was *repetitively* surprised by e.g. a stronger than forecasted appreciation of the nominal exchange rate, the method adopted in this paper will classify such a factor under the "CNB's bias" category instead of the "shocks" category. This approach appears not to be in any gross conflict with the intuitive meanings of the words "shock" and "CNB's bias": we might talk about a "shock" to refer to the central bank's surprise, which surfaces at times only and is therefore uncommon, while if the central bank is surprised from a certain direction either repetitively or throughout a long period of time, we should view it as a consequence of the fact that the bank misunderstands the fundamental rules of functioning of the domestic economy and the environment in which the economy works.[4]

We will estimate the statistical significance of separate types of bias using the method of minimisation of the Akaike Information Criterion over three arguments:[5]

- degree of autoregression of the inflation gap (p),
- number of shocks (n) ordered in the descending order from the largest one,
- extent of the CNB's bias (a).

In the first step, we will run an OLS regression in which we will use the process AR(p) to model the time series of the values of the inflation gap $\pi_t - \pi_t^T$ for a given p and a given a. We will consider any errors (residuals) of the model to be indications of the key shocks to inflation during the period under review. The larger the error, the more probable it is that there is a shock (in the above meaning) hidden behind the error. We therefore order the AR(p) process errors by their size, from the largest to the smallest; in the below estimations, we will pay particular attention to the largest errors as they are the most probable reflections of shocks.

In the second step, we will perform an OLS regression in which the simple AR(p) process will be enriched with the dummy variable D_1, which corresponds to the *largest* shock. That way, we will develop a model which consciously supposes that the inflation gap evolution over the period under review may be explained by the CNB's bias and this *single* shock. The dummy variable will have the value of 1 in the month in which the *largest* error of the AR(p) process was measured, and, value 0 in the other months. This of course does not mean that our expectation is that the respective shock manifested itself in inflation as a shift by that particular 1 percentage point: the estimated scope of manifestation of the given shock in inflation will be identified by the coefficient (coefficient β_{21} in the below equation) that will be assigned by the estimation procedure to this dummy.

[3] Apart from short-term shocks ("the shocks") and long-term shocks ("the CNB's bias"), also medium-term shocks may of course occur that were neither manifested by a leap within the inflation gap month to month, nor recurring for most of the period under review. Using the econometric method selected in this paper, these latter shocks are classified under one or the other extreme category (the CNB's bias vs. shocks), according to their specific duration. This simplified perception of the inflation evolution as short- and long-term shocks is a price we pay for the model-independence, simplicity and transparency of the entire method.

[4] The conclusion made by J. Filáček (2007) that the inflation gap evolution in the Czech Republic in 2000–2006 is to quite a degree explained by *repetitively* erroneous assumptions of foreign evolution, may be therefore also interpreted, using the language of our paper, as a consequence of the CNB's bias.

[5] The computations were carried out using a suite of applications developed in the EViews 6 environment.

In the next step, we will then perform another regression where the simple AR(p) process will be enriched with the dummy variable D_1 and, in addition, the dummy variable D_2, which corresponds to the *second largest* shock. The dummy variable D_2 will have the value of 1 in the month in which the *second largest* error of the AR(p) process was measured, and value 0 in the other months. By enriching the AR(p) process with the variables D_1 and D_2, we will develop a model which consciously supposes that the inflation gap evolution may be explained by the CNB's bias and by *two* shocks. After that, we will keep enriching the simple AR(p) process with D_1, D_2 and additional dummy variables, corresponding to even smaller shocks.

We obtain a set of regressions for given p and a; the regressions differ in the value of n, i.e. in the number of explicitly modelled potential shocks. In the same way, we will obtain sets of regressions with various values of n also for other realistic values of p and a. Within the whole array of regressions thus obtained, we will then look for the regression that records the lowest value of the corrected Akaike Information Criterion (AIC) (i.e. a standard AIC with the second-order correction for small samples).[6]

We will select values of a at degrees of 0.25 pp and, for the sake of maintaining the largest possible number of the degrees of freedom, we will assume a constant a throughout the entire period under review. Therefore, we will estimate relationships in the form

$$\pi_t - (\pi^T_t + a) = \sum_1^p \beta_{1i} * [\pi_{t-i} - (\pi^T_{t-i} + a)] + \sum_1^n \beta_{2i} * D_i + v_t,$$

where v_t is a random element, and we will use the grid search method to find that particular triple (p; a; n)* for which the value of $AIC_c(p; a; n)$ is minimised.[7]

If we find out that e.g. (p; a; n)* = (1; -0.5 pp; 2), it will mean that the inflation evolution over the entire period under review was defined by two shocks and also by the CNB's bias, i.e. the bias of the forecasting apparatus or of the Bank Board preferences, in the form of the manifested target positioned approximately half of the percentage point below the officially declared target, while the inflation gap persistence corresponded to the AR(1) model.

An advantage of this method of analysis consists in its simplicity, understandability and transparency provided by its exclusively empirical, statistical nature: except for the core assumption of the persistent return of inflation to the (manifested) inflation target, there are neither any theoretical assumptions present in the background of the computations as to the structure or functioning of an economy, nor any quantitative, calibration-type assumptions as to the values of parameters, nor any other expert interventions. A disadvantage consists in the fact that the method may miss the shocks that did not last very long and did not occur recurrently (and therefore are not reflected in the CNB's bias), while they were manifested not through any abrupt and extensive shift in the inflation gap values but through a "creeping" increase of these values over several months (and therefore are not reflected within the shocks).

[6] If, after another explanatory variable (another shock in our case) is entered in to the estimation, the improvement in the quality of the estimates is big enough to compensate for the loss of one degree of freedom as a result of the use of the added variable, then the AIC value decreases; and it increases in the opposite case. Therefore, when deciding whether to enter another explanatory variable into our statistical model we should minimize the AIC values, see e.g. Burnham & Anderson (2004).

[7] It may be expected intuitively that if all shocks were anti-inflationary, then for the given p, an increase in n (an increase in the number of shocks) will result in an increase in a (the estimated degree of anti-inflationary CNB's bias toward zero will move from negative values closer to zero). However, we will see later that the reviewed set of observations contains what seem to be shocks towards higher inflation, too.

The described method per se will demonstrate a combined statistical force of hypotheses 1 and 2 (as compared to the force of hypothesis 3), i.e. the statistical significance of the combined impact of the bias in the forecasting apparatus and the bias in the preferences of the Bank Board. A separated impact of the two factors then may be estimated by adding information on the deviations in the Bank Board decisions from the decisions consistent with the outputs of the forecasting apparatus: for example, if the actual monetary policy decisions were not systematically deviating from the forecasting apparatus outputs, the identified combined force of hypotheses and 2 may be fully attributed to hypothesis 1 (the forecasting apparatus' bias).

Such separation of the impact of the bias in the forecasting apparatus from the bias in the preferences of the Bank Board is, of course, possible only for the periods in which the forecasting apparatus outputs contained recommendations in terms of concrete monetary policy decisions. In the CNB case, this condition is met from the point of migration to the "unconditional" integrated forecast in 2002.

In order to obtain the difference between forecasted and actual setting of the interest rates for each month in the context of quarterly forecasts (which has been the case of the CNB), the setting of interest rates that would be hypothetically forecasted one and two months, respectively, after the actual preparation of the last forecast will be approximated here as a weighted average of the forecast for the complete quarter and of the actual setting in a given month (because such actual setting includes information on implications of the data published after the forecast completion). To derive the hypothetical forecast for the first month after the preparation of the last actual quarterly forecast, we will use the weights 2:1 in favour of the last forecast, while for the second months, the weights will be 1:2 in favour of the actual setting.

5. RESULTS

For the period of 12/1998–12/2007, we have 109 monthly values of the inflation gap.

Minimisation of the *standard* AIC suggests AR(2) as the best suitable model of the inflation gap evolution and identifies a few shocks as statistically significant. Nevertheless, since the AIC_c is more suitable for small samples, while converging to the standard AIC for large samples, it is better to follow the AIC_c values.

Minimisation of the AIC_c leads also to the conclusion that the inflation gap evolution over the period under review may be best explained as a result of the AR(2) process. With AR(2) process, there are 107 observations available. The deviations of the actually observed values of the inflation gap from the model values identify potential shocks. These deviations, in the order of their occurrence over time, are displayed (together with the inflation gap evolution) in Figure 3 and, in the order of their size, in Figure 4.

Figure 3: Inflation gap and residuals of its AR(2) model

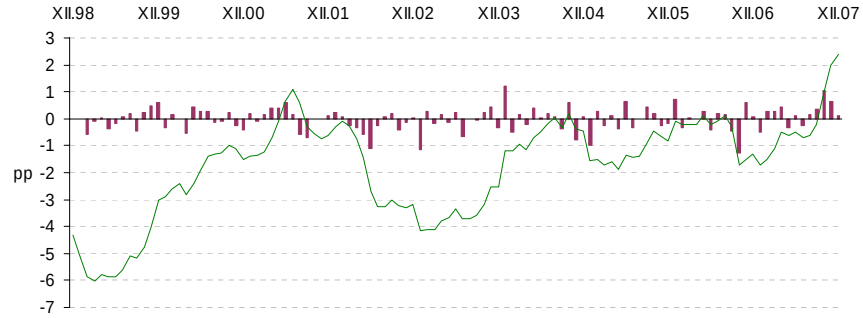
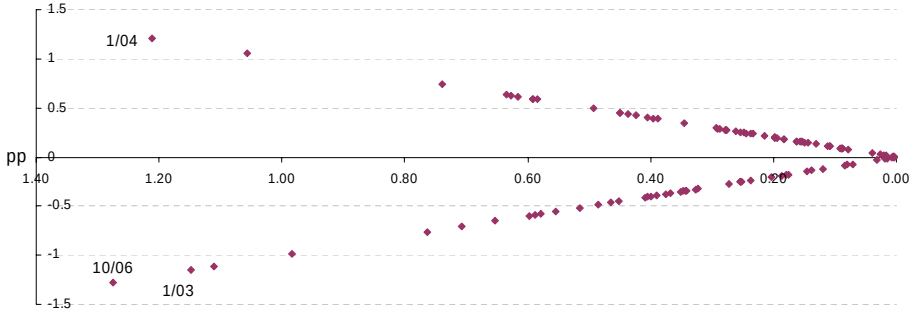


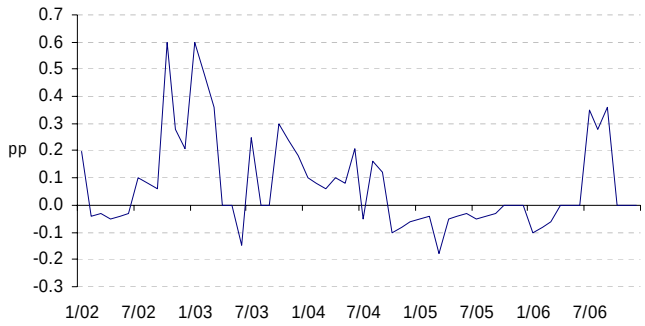
Figure 4: Residuals of the AR(2) model of the inflation gap, ordered by their size



Numerous sizeable differences between the actual inflation gap and the AR(2) model value occurred in the course of the period under review. In spite of this, minimisation of the AICc leads to the conclusion that the AR(2) process without a single distinct shock provides the best description of the reality, in the context of a clear (-0.5 pp) constant bias of the CNB in favour of a lower than officially targeted inflation level.

Thanks to the CNB's migration to "unconditional" integrated forecasting in 2002, we are able to distinguish, within the impact of the CNB's bias, the impact of the forecasting apparatus' bias and the impact of the Bank Board's preferences. A simple computation shows (see Figure 5) that the Bank Board deviated, in its decisions at the corresponding points of time (1/2002–12/2006), by approx. 0.08 pp on average from the decision consistent with the forecasting apparatus output. Taking into account the sensitivity to the interest rates that inflation exhibits within the apparatus, the above deviation corresponds to the average impact on inflation of approximately 0.03 pp. It may be then claimed that the identified bias of the CNB over the period of 1/2003–12/2007 is largely attributable to the biased forecasting apparatus.

Figure 5: Estimated deviations of actual setting of 3M PRIBOR from setting consistent with the forecasting apparatus outputs



It is apparent from Figures 3 and 4 that several unexpected shifts occurred in the inflation gap evolution, raising suspicion that they were manifestations of actual shocks: this involves e.g. periods in mid-2002, in the autumn of 2006 or at the end of 2007. However, as is implied by the results of AICc minimisation, even the largest of the shifts (observed in October 2006) is not dramatic enough to make its explicit classification as shock in a regression worth the loss of one degree of freedom in terms of AICc. As a result, out of the three hypotheses on the causes of undershooting, hypotheses A and B are likely to gain more support at the expense of hypothesis S, i.e. undershooting was due to a bias of the CNB rather than to biased shocks.

As noted above, a disadvantage of the shock identification approach adopted in this paper is that is records as "shocks" only those shocks that manifested themselves through an abrupt change in inflation on a month-to-month basis, rather than through changes in inflation that would take place over the long term or recurrently. Many shocks, however, might manifest themselves in inflation as distributed over time, i.e. rather as a series of inflation shifts in one direction, while none of the individual shifts within such a series need in fact be dramatic in itself. Such potential shocks might be identified in the inflation evolution not as deviations of the respective autoregressive process from reality within a single month, but as a series of deviations over several months.

If we wished to identify shocks into inflation in this more structured form, we would have to define a priori what the shock profile over time should precisely look like: how many months in a row the respective dummy variable would need to have a nonzero value and if it were to have an identical value in all such months or if its values were to decrease from an initial maximum, or if they were to initially increase toward such maximum for a month or two, etc.

By transiting to any such "expert" model of the shock into inflation, we would however depart from the core idea of this paper, which consisted in an effort to gain understanding of the key determinants of undershooting inflation targets over the period under review, with the help of maximally model-independent, purely statistical tools. Therefore, if any shocks occurred that were manifested over multiple months in a row, either their manifestations in each of the month were so mild that they escaped the methodology applied in this paper or (if they were acting over the long term or recurrently) they became part of the estimated CNB's bias.

6. SUMMARY

A purely statistical procedure was used for a simple, model-independent analysis of the reasons of non-fulfillment of inflation targets by the Czech National Bank in 12/1998–12/2007, based on an assumption that the suspicion of a shock occurrence is highest in the periods of the largest deviations of the actual inflation gap from its autoregression model. An advantage of the procedure, as opposed to the currently much more popular model approaches, dwells in its simplicity, transparency and no "contamination" by theoretical or expert assumptions of relationships in the economy and by calibration of values of parameters that are difficult to estimate.

There is of course a price to pay in an empirical paper for abstaining from the use of additional sources of information. The price is our ability to discern only two general types of shocks. First, they are the shocks that were manifested in the long term or recurrently; we understand these shocks as a manifestation of a permanent bias of the central bank, whether or not deliberate, and whether or not such bias was given by an asymmetry of the Bank Board's preferences or asymmetry of the forecasting apparatus (e.g. by constantly underestimating the forecasted appreciation of the nominal exchange rate). Second, they were the shocks that manifested themselves through a one-off, abrupt change of inflation from month to month – only these shocks are considered actual shocks under the procedure adopted in this paper.

The adopted statistical procedure leads to the conclusion that the CNB's bias over the examined period of 12/1998–12/2007 was rather towards lower than officially targeted inflation. The extent of this bias in the anti-inflationary direction was approximately 0.5 percentage points. The best statistical fit among autoregression models of inflation deviations from the target was provided by the AR(2) process around a manifested target, deviating by the above 0.5 pp from the official target in the direction of lower inflation, while this evolution was not affected by any statistically significant one-off shock to inflation.

Furthermore, a comparison of the interest rate forecasts produced by the forecasting apparatus and of actual monetary policy decisions of the CNB Bank Board since 2002 showed that the Bank Board sticked in its decisions rather firmly to the forecasts. Thus, at least over the years 2003–2007, the CNB's bias was due primarily to the forecasting apparatus bias rather than the bias in the preferences of the Bank Board.

This paper, based on the simple, model-independent procedures, certainly brings no detailed and exhaustive analysis of the given issue; instead, it provides just a sketchy and indicative idea of the relative weights of core potential causes of the non-fulfillment of the inflation target in the Czech Republic during the period under review.

We may view the contribution made by this paper on a more general level, specifically in drawing attention to a seemingly marginal fact, no longer perceived by many researchers and policy analysts in the current era of very complex and highly structured models: The price to pay for being free of theoretical, expert, calibration and similar assumptions is the low information content of results; conversely, we pay for rich results by carrying the burden of all the theoretical and empirical assumptions made explicitly or implicitly.

In addition, this paper points indirectly to the following terminological and perhaps somewhat provocative question: for how long or how often must the central bank be surprised from a certain direction (let us say from the direction of the nominal exchange rate appreciation) to make us assess such surprises ex post not as "shocks" but as "the bias of the forecasting apparatus of the central bank"?

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CHAPTER 4

CAUSES OF DEVIATIONS OF INFLATION FROM CNB TARGETS – AN EMPIRICAL ANALYSIS

TOMÁŠ HOLUB

1. INTRODUCTION

This paper offers an empirical analysis of the causes of deviations of inflation from the CNB targets during the first ten years of inflation targeting. Section 2 presents a review of such causes as contained in the existing literature dealing with inflation targeting in the Czech Republic, and it applies a simple cross-correlation analysis and Granger causality tests to identify which explanatory variables – and with what time lag – seem to have a statistically significant relationship to such deviations of inflation from the target. Section 3 then offers estimates of two VAR models examining impulse responses of the deviations of inflation from the target to the individual shocks, and a variance decomposition of these deviations.

Based on those analyses, it can be concluded that the most important short-term factor of deviations of inflation from the target are the shocks relating to prices of agricultural producers. In the medium-term horizon, however, the development of the real exchange rate gap unequivocally takes over as the most important factor. The main common macro-economic feature of the two periods of the most significant undershooting of inflation targets indeed was a noticeable and unexpected strengthening of the exchange rate of the Czech crown. Difficulties caused by the exchange rate were further accentuated by the coincidence with other factors, although these were less significant and – as such – they would have probably only resulted in a less distinct and merely short-term undershooting of inflation targets. The analysis, however, does not provide an answer to the question of why the target fulfilment was asymmetrically skewed in the undershooting direction and why the periods characterised by depreciation corrections of the exchange rate did not see any overshooting of the CNB targets.

2. LITERATURE REVIEW AND BASIC STATISTICAL TESTS

Fulfilment of the CNB targets in the course of the first decade of inflation targeting was affected to a significant extent by two episodes characterised by noticeable undershooting of the targets, namely in the years 1998–99 and 2002–03. The existing literature has consented on a list of the relevant causes of such distinct target undershooting (see e.g., Kotlán and Navrátil, 2003; Geršl and Holub, 2006). They involved declining food prices (in both periods), low oil prices (in both periods), a pause in deregulations (in 2002–03), fiscal and monetary restrictions (in 1998–99), a growth slow-down in the EU (in 2002–03), and strengthening of the exchange rate of the Czech crown (in both periods). To compare, the CNB assigned in its Inflation Reports the 1998–99 target undershooting in the first place to the food prices, and then to the weak local demand, strong exchange rate, and low oil prices in 1998. In the years 2002–03, the CNB pointed out particularly to the disinflationary effects of regulated prices, food prices, appreciation of the exchange rate, and the international developments.

A disadvantage regarding the above-described papers lies – with the exception of the CNB Inflation Reports – in that they would not quantify the relative importance of the individual factors. At the same time, they do not take into consideration any endogenous links of those factors, such as, e.g., the effect of the exchange rate, the monetary and fiscal policy or international developments on the local food prices and on regulated prices, as well as the feedback effects of the price developments on the monetary policy decisions. Without considering such links, any quantification would be difficult, something which throws a shade of doubt also on the analysis of both of the two periods as presented in the Inflation Reports. The CNB forecasts were compiled for both of those periods

using short-term forecasting methods, and they were also assessed with these tools afterwards concerning their fulfilment. Those methods were not particularly suitable for capturing any medium-term endogenous relations in the economy (see Coats, et al., 2003). The existing QPM model was not used until mid-2002, i.e. until the second exchange rate appreciation episode was already peaking. Therefore, it was possible to use it in the analysis of the causes of deviations of inflation from the target (see Filáček, 2007; Antoničová, et al., 2008) only starting at the beginning of 2004 when inflation already commenced to return to the target.

Holub and Hurník (2008) express the opinion that the exchange rate development was the common key feature of both of the two target undershooting episodes. For the sake of brevity, however, no sufficiently detailed evidence for such claims has been presented, and/or, such evidence is only mentioned in a footnote. The present paper removes the above-described shortcomings and brings about a detailed empirical analysis of the causes of the deviations of inflation from the target.

The cited papers – despite their shortcomings – may help us compile a list of variables to be further examined as regards their statistical and economic significance in the explanation of deviations of inflation from the target. More specifically, this paper focuses on the following variables: the real exchange rate, agricultural producer prices, crude oil prices in USD, foreign and domestic economic activity, and domestic real interest rates.

All variables have been used on a quarterly basis in the form of their deviations from estimated equilibrium levels, because the variable in focus – i.e., deviations of inflation from the target[1] – may also be considered as deviations from the equilibrium. As far as prices of crude oil and agricultural producer prices are concerned, they always represent deviations from the trend as estimated with help of the Hodrick-Prescott (HP) filter.[2] In the event of the real exchange rate gap, real interest rates gap, and domestic and foreign output gaps, we work with two alternative estimates. The first one is based the structural Kalman Filter, which has been applied by the CNB in its analyses and forecasts (see Beneš and N'Diaye, 2003); the other one is based on the HP Filter. The advantage in using the Kalman Filter is in that the estimated "gap" values correspond to the view of the central bank concerning the development of the Czech economy. On the other hand, however, its application may cause certain distortions in the analyses in the form of an implicit "a priory" presumption about the course of monetary transmission as captured by the QPM model applied by the CNB. The application of an alternative estimate with help of the HP Filter, which represents a non-parametric filter, therefore, may be understood as robustness check of the results.[3]

All the applied data and estimates correspond to the CNB forecast as published in its Inflation Report I/2008, and cover the first ten years of inflation targeting, i.e., the period of time from the first quarter of 1998 until the fourth quarter of 2007.

[1] In the period 1998–2001, this is a deviation of net inflation from the middle of the target, which had been extrapolated in a linear manner into the individual quarters from the year-end values. As far as the later period is concerned, talk goes here of deviations of the headline inflation from the middle of the target range, or the CNB point target.

[2] We also tried to use year-on-year changes instead of deviations from the H-P trends because unexpected changes of those prices may cause a deviation of inflation from the target irrespective of whether they concern shifts in the long-term equilibrium or temporary fluctuation. However, the results were similar in quality, so we do not present them in the subsequent text.

[3] As concerns the real interest rates gap, there also exists a difference in that – as regards the Kalman filter – nominal rates have been deflated by partly forward-looking expectations, while inflation expectations in the event of the HP filter have been deemed as purely backward-looking.

Testing of statistical significance of the above-described variables was first made with help of a simple cross-correlation analysis and Granger causality pair-wise tests. One of the variables was always represented by deviations of inflation from the target, while the other side was always occupied by one of the above-described explanatory variables. The results are reported in Table 1. The results of both tests are always shown for the time lag which would maximise the value of the correlation coefficient, or the probability level of the Granger causality test.

All of the above-described explanatory variables have a statistically significant and in the majority of cases economically intuitive correlation with the deviations of inflation from the target with a time lag ranging from "zero" (for agricultural producer prices) up to 10 quarters (for foreign output gap). In the event of real exchange rate, the time lag amounts to three quarters; in the event of real interest rate gap it reaches 0-2 quarters (depending on the method of calculation). The only surprising outcome is the long lag and the sign attached to the foreign output gap, which runs counter to the economic intuition, indicating that the correlation may be spurious rather than reflecting a true causal relationship.

All of the explanatory variables, with the exception of agricultural producer prices[4] and the real interest rate gap estimated with help of the HP Filter, at the same time, Granger-cause the deviations of inflation from the target at least at the 10-percent significance level, usually with a time lag of 1-2 quarters (only with the foreign output gap the time lag would extend to 10 quarters, in line with the correlation analysis, making this relationship hard to interpret). These results, therefore, justify further research of relationships between those variables and the deviations of inflation from the target.

Table 1: Factors of inflation deviations from target – cross-correlation analysis and Granger causality tests

Explanatory variables	Correlation coefficient [1, 2)]	Granger causality test – probability[2)]
Foreign output gap – KF	-0.40* (10)	4.0 % (10)
Foreign output gap –HP	-0.44* (10)	5.1% (10)
Oil prices	0.51* (3)	0.8% (1)
Real exchange rate gap - KF	-0.59* (3)	0.0% (1)
Real exchange rate gap - HP	-0.52* (3)	0.0% (1)
Agricultural producer prices	0.58* (0)	14.1% (1)
Output gap – KF	0.55* (0)	0.5% (2)
Output gap – HP	0.47* (1)	5.4% (1)
Real interest rate gap – KF	-0.51* (2)	0.0% (0)
Real interest rate gap – HP	-0.75* (0)	14.1% (4)

Source: Own calculations.

*Notes: HP denotes estimates produced with help of the HP Filter, KF denotes estimates produced with help of the Kalman Filter; 1) * denotes statistically significant results at the 5% probability level. 2) The numbers in brackets show the time lag between explanatory variables and the deviations of inflation from the target maximising the statistical significance of the identified relationship.*

[4] The statistical insignificance of agricultural producer prices has probably resulted from the fact that the relationship – according to the performed correlation analyses (and in line with empirical experience) – was contemporaneous, which cannot be captured by definition by the Granger causality test.

Also examined was the reverse correlation and causality directed from inflation deviations from the target to the analysed variables, which – however – is not presented in Table 1 for the sake of brevity. The reverse causality was statistically significant at least at the 10% probability level with almost all variables, with the exception of the foreign output gap estimated with help of the Kalman Filter. In the case of oil prices, which can be deemed as a purely exogenous factor, this conclusion is not very intuitive. It can be presumed – in view of the small time lag – that it rather represents a co-incidence of both variables than any causal relationship. In the case of domestic variables, however, the option of a reverse causality is not surprising and it only confirms opinions expressed in the introduction to this Section, namely that a number of factors used in the literature so far to explain deviations of inflation from the target is in reality of an endogenous nature, which needs to be considered in the analysis.

3. ESTIMATES OF VAR MODELS

Consideration of the endogenous links among the individual variables can be performed by way of estimates of the VAR models, which are presented in the present Section. Those VAR models at the same time allow for the identification of not only the statistical significance of the individual factors with help of examining impulse responses to shocks, but also for an analysis of the economic significance via a variance decomposition of the deviations of inflation from the target. More specifically, two models have been estimated, which can be expressed in general as follows:

$$Y_t = aLY_t + v_t \qquad (1)$$

$$Y_t = [ea\_gap_t, poil\_gap_t, er\_gap_t, czv\_gap_t, gdp\_gap_t, pi\_gap_t, ir\_gap_t] \qquad (2),$$

where *ea_gap* denotes the foreign output gap (approximated by the effective eurozone, i.e., with the individual countries weighed according to their shares in the Czech foreign trade), *poil_gap* denotes the deviation of the USD crude oil price from the equilibrium, *er_gap* denotes deviation of the real exchange rate from the equilibrium, *czv_gap* denotes deviation of agricultural producer prices from the equilibrium, *gdp_gap* denotes the domestic output gap, *pi_gap* denotes deviation of inflation from the target, *ir_gap* denotes the real three-month interest rate gap, while v_t means the vector of residuals and L stands for the lag operator. Both of the models differed only in one sense: whether they included the gaps of foreign and domestic demand, the real exchange rate, and real interest rate estimated with help of the Kalman Filter or the HP Filter.

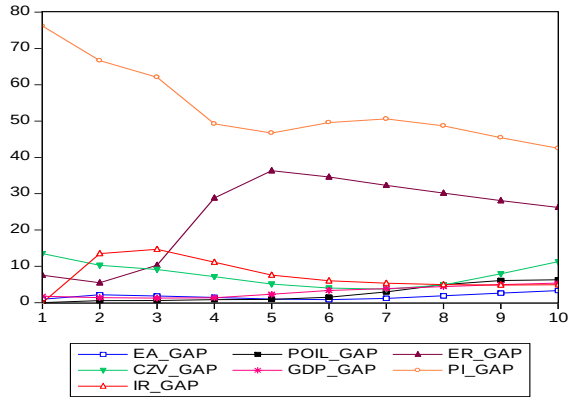
Shocks to the individual variables were identified in a standard manner on the basis of the Cholesky decomposition, with the variables ordered according to Equation (2). This is a fairly standard ordering, which corresponds to the view of the transmission of shocks in a small open economy applying inflation targeting. The ordering means an implicit presumption that shocks to exogenous variables (*ea_gap* and *poil_gap*) may have an immediate impact on the exchange rate of the Czech crown, rather than the other way round. The exchange rate, together with the agricultural producer prices and the domestic output gap may then directly affect inflation deviations from the target which, however, does not influence immediately the said variables. The monetary policy then responds, under the inflation targeting regime and via the set-up of the interest rates, to the

development of all available information. The lag length in the model was determined at 2 quarters, in view of the relatively short time series and making use of the standard tests.[5]

A variance decomposition of the deviations of inflation from the target is presented in Figure 1 for the VAR model making use of estimates made with help of the Kalman Filter, and in Figure 2 for the model with the input variables estimated with help of the HP Filter.

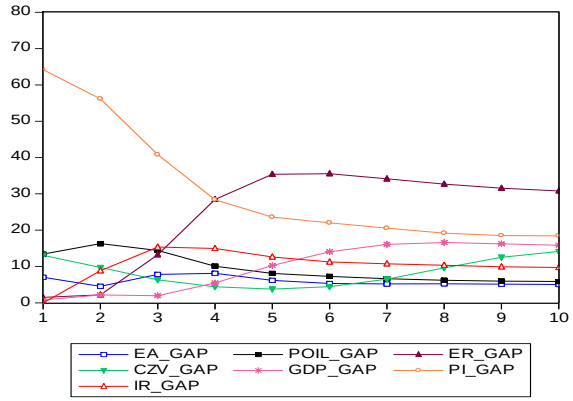
It has turned out that in the short term the most important factors of the deviations of inflation from the target (apart from the shocks to inflation itself) are represented by the agricultural producer prices and – in the case of the model making use of estimates based on the HP Filter – also the crude oil prices. Their influence, however, would get weaker in the longer run. Shocks to the real interest rates, i.e. monetary policy shocks, hold roughly a 15-percent share in both models on the variance of the deviations of inflation from the target on the horizon of approx. 2-4 quarters, and that share is at the edge of statistical significance. However, on the horizon of one year and longer, the outspokenly most distinct factor is represented by the real exchange rate gap, which explains a substantially larger portion of the variance of the deviations of inflation from the target (over 35 %) than the other macro-economic variables, and its influence is statistically significant. As far as the model making use of the HP Filter is concerned, the shocks to the domestic output gap are also at the edge of statistical significance on the horizon exceeding 6 quarters; the model based on the time series derived from the Kalman Filter, however, would not support this conclusion.

Figure 1: Variance decomposition of the deviations of inflation from the target (Kalman Filter)



[5] The application of the Schwarz criterion would result in preference of only one quarter; using the Akaike information criterion would require the application of time lags in excess of two quarters, which would be facing limitations in the form of short time series. Under this situation, a lag of two quarters was selected as a compromise solution. We also examined the robustness of our results with respect to the selection of a shorter time lag, which appeared to be satisfactory.

Figure 2: Variance decomposition of the deviations of inflation from the target (HP Filter)



The impulse responses of the deviations of inflation from the target to shocks affecting the individual variables are shown in Figure 3 for the model using variables derived from the Kalman Filter and in Figure 4 for the model using variables derived from the HP Filter. Some conclusions would be qualitatively identical for both models. Shocks hitting the agricultural producer prices are statistically significant for short time lags; however, their impact would gradually decline and would quickly become statistically insignificant. The real exchange rate shocks are most effective with a lag of 4-5 quarters, and an overvaluation (undervaluation) of the real exchange rate results in a statistically significant decline (increase) of inflation below (above) the target. The maximum real exchange rate pass-through into inflation equals roughly 28–38%, which approximately matches the conclusions from the previous studies applicable to the Czech Republic (see Babestkaia, 2007).[6] Both of the models also consent that international demand shocks would not have any statistically significant impact on the deviations of inflation from the target. The said conclusions, therefore, may be considered as reasonably robust.

[6] Usually, the pass-through of nominal exchange rate shocks to inflation would be analysed, with results slightly lower than the figures quoted here. However, under the presumption that a portion of the exchange rate shock would be reflected in inflation with a delay shorter than one quarter, it is required to have more than a proportionate shock to the nominal exchange rate to change the real exchange rate.

Figure 3: Impulse responses of deviations of inflation from the target to shocks (Kalman Filter)

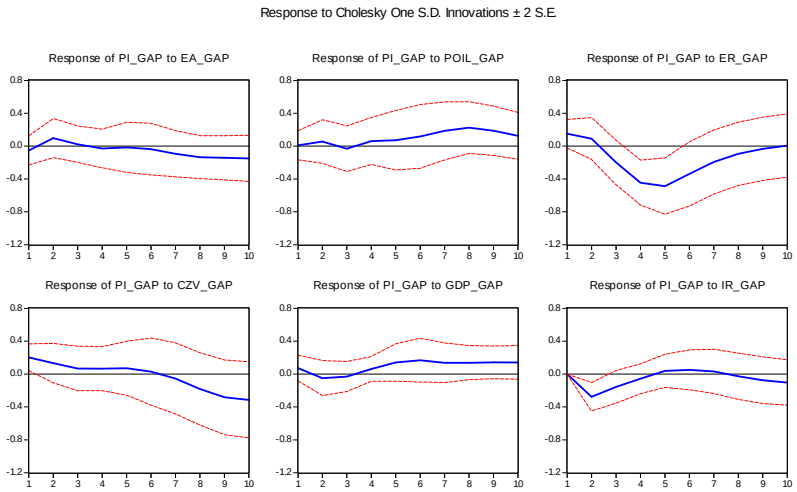
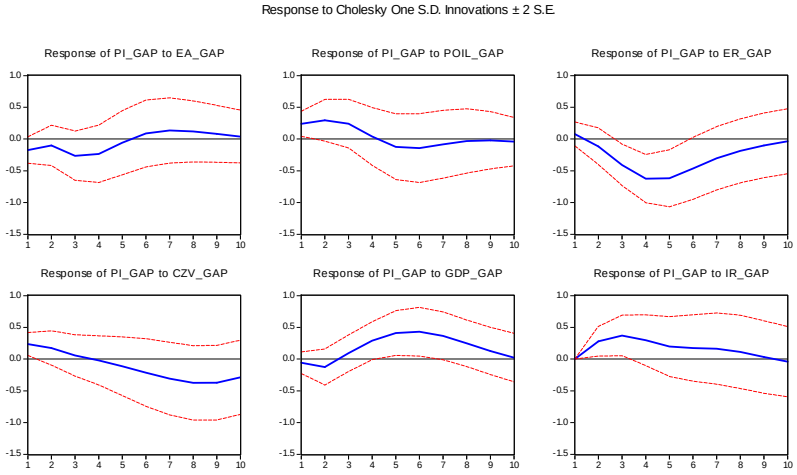


Figure 4: Impulse responses of deviations of inflation from the target to shocks (HP Filter)



However, some partial differences exist between the two estimates, which urge for cautiousness in the interpretation of their results. The model applying inputs from the HP Filter identified shocks hitting the global crude oil prices as statistically significant for short-time lags, while the model with the Kalman Filter did not. The same applies in the medium-term horizon also for the impact of domestic output gap shocks, which is surprising – among other things – also in view of the fact that the output gap estimated with help of the Kalman Filter, contrary to the HP Filter, explicitly considers the relationship between this unobservable variable and inflation. The last noteworthy difference relates to the influence of real interest rates, which are statistically significant in both cases but – contrary to expectations – only in the short horizons of 2-3 quarters and, moreover, in both of the models with the opposite sign (an intuitive one in the model with inputs from the Kalman Filter, and an counter-intuitive one in the model with inputs from the HP Filter). Such results can most probably be assigned to the existence of certain general difficulties concerning the identification of the monetary transmission with help of the VAR models (see for example, the discussion in Arnoštová and Hurník (2005) and the references contained in this paper), and to uncertainties in the measuring of real interest rates (forward-looking vs. backward looking inflation expectations).

4. CONCLUSION

The results presented here thus show on the whole that the most important role in relation to the deviations of inflation from the target was probably played by the exchange rate. This reflects the fact that the main common feature of the two most important periods of undershooting of the inflation targets in the years 1998–99 and 2002–03 was represented by a significant and unexpected strengthening of the exchange rate of the Czech crown (roughly by 8 % towards DEM, and by 15 % towards euro, respectively). The difficulties caused by the exchange rate were further accentuated by certain concurrence with other short-term factors, including in particular the development of agricultural producer prices and probably also the development of the crude oil prices. Those factors, though, were of lesser significance and they would probably in themselves have resulted only in less distinct and shorter episodes of inflation targets undershooting.[7]

Based on the econometric methods applied, it is not possible to prove or exclude that the monetary policy in itself would create any significant shocks contributing to the non-fulfilment of inflation targets. In any case, it seem obvious at least that the monetary policy did not respond to exchange rate developments sufficiently quickly and strongly to prevent distinct episodes of non-fulfilment of inflation targets. In the first place, it attempted to restrain the scope of appreciation by foreign exchange interventions, the effect of which – however – proved to be fairly small and could not prevent the occurrence of relatively long periods of the exchange rate overvaluation (see Geršl and Holub, 2006). At the same time, the CNB – like a number of other analysts – may have underestimated the strength of the exchange rate pass-through into inflation.[8] It is also possible to express intuitively the hypothesis that in particular in the first of the above-described "troubled"

[7] It remains an open question whether the given concurrence was only a coincidence or whether it was caused by some hidden causal factors. For example, the development of the global economy could have affected the prices of crude oil, the global prices of food as well as the development on the foreign exchange markets.

[8] In the first of the said periods, the short-term forecasting methods were applied, which – however – could hardly have a sufficient guidance in the data from the period of fixed exchange rate; in the other case, the exchange rate pass-through into inflation in the newly introduced QPM model was expertly restrained due to a lack of confidence in sufficient downward flexibility of prices.

periods, monetary policy in itself could contribute to the appreciation of the foreign exchange rate, when it was keeping the nominal interest rates high and the real interest rates in a restrictive position, even though the currency crisis was already fading out. It cannot be excluded that such policy may have been based also on certain asymmetry of the preferences of the CNB concerning the announced inflation targets, i.e., higher concerns regarding their overshooting than their undershooting as a result of the understanding of inflation targeting as a means for achieving disinflation and obtaining credibility, or any other monetary policy goals (e.g., efforts for the overall stabilisation of the situation after the preceding currency crisis).

Similarly, it is not possible to find out with help of the selected approach why the non-fulfilment of the target was on average significantly skewed towards its undershooting and, for example, no overshooting of the targets occurred during the periods of exchange rate depreciation.

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CHAPTER 5

PREDICTION BIAS AND UNDERSHOOTING OF THE INFLATION TARGET

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1. INTRODUCTION

Forecasting tools represent a highly important element of the inflation targeting regime. Given the forward-looking nature of monetary policy, its decision making is to quite a degree based on predictions of the evolution of inflation and other macroeconomic variables. Good predictions may contribute to implementation of monetary policy objectives. The quality of predictions and prediction tools may be assessed using various methods. The focus may, for example, cover general methodology aspects, verification of prediction model calibration, optimal combination of predictions drawn from various models or statistical evaluation of prediction performance of the models (Pagan, 2003).

This paper is primarily concerned with assessing the bias of the CNB's predictions in relation to undershooting of the inflation target. The paper concentrates on the period from 1998 to 2007, without providing particular analytical details of the inflation increase above the target at the beginning of 2008.[1] Our analysis approaches the CNB's model tool set as a "black box", i.e., deals primarily with the resultant numerical predictions for selected macroeconomic variables and with their linkages[2], and does not attempt a more detailed review of the method according to which the predictions were developed (for the prediction development description, see Coats et al, 2003, for the forecasting quality and success rate through the CNB's prediction model optics, see Antoničová et al, 2008). An advantage of this simple approach may consist in the fact that the public interprets the CNB's forecasts in a similar way. An obvious disadvantage of the approach is that our statistical analysis provides no basis for identifying reasons of prediction errors (such as whether the case is an inaccurate calibration within the model or failure to include relevant variables into the model).

The key conclusions of the paper are as follows: The inflation prediction error has decreased over time. While the (absolute) error of the one year ahead prediction recorded 1.2 pp for the entire period 1998–2007, it dropped slightly to 1 pp following introduction of QPM[3] in 2002. The trend is even more obvious in the prediction for the next quarter (0.4 pp in 1998–2007 and 0.2 pp following introduction of QPM).[4] The one quarter ahead predictions from QPM are unbiased for all variables under our review, except for oil. For a one year horizon, we find out that predictions of inflation, the GDP growth, 3M PRIBOR and oil are systematically biased (while predictions for the other variables are unbiased).

The GDP growth was above the forecast and the interest rates were below the forecast most of the time, even in the situation of systematic undershooting of the target. Undershooting then cannot be

[1] An assessment of the CNB's predictions may be found also in Babecký and Podpiera (2008), and also Kotlán and Navrátil (2003). The focus of the above studies is however different from our paper. Babecký and Podpiera (2008) compare the accuracy of the CNB's inflation predictions to other financial institutions, while limiting themselves to success of inflation predictions, or, their explanation based on the exchange rate prediction errors. Kotlán and Navrátil (2003) analyse the CNB's prediction through optics of a loss function.

[2] We observe the prediction bias for the variables that may be deemed significant for the Czech economy development: inflation (and its certain elements); GDP growth; CZK/EUR exchange rate; 3M PRIBOR; foreign inflation and GDP growth; 1Y EURIBOR; and, oil prices. Predictions for some of the variables are however unavailable for the initial phase of the period under our review.

[3] QPM – Quarterly Projection Model – the core forecasting model of the CNB, used since 2002Q2.
A detailed description of the model may be found in Coats et al. (2003). For more details of the inflation targeting regime in the Czech Republic, see Fisher (1999), Coats (2000), Kotlán and Navrátil (2003), as well as various strategic documents on the CNB's monetary policy, such as Long-term monetary strategy (1999).

[4] Predictions encompassing 1998-2007 are available only for inflation, while 2002-2007 predictions exist for the rest of the variables.

explained with the help of standard demand mechanisms. Positive supply impulses were admittedly underestimated in the past. The model tools as a rule assessed the surprisingly high GDP growth as a negative output gap closing, while closing was in fact postponed due to enduring low inflation. Repetitions of the phenomenon could lead to target undershooting.

As follows from the distribution of inflation prediction errors across separate price segments, overpredictions of inflation during a prevailing part of the period under review were to be attributed to mistakes in prediction of food prices and core CPI ex food, while prediction errors in energy prices mostly rather helped to approach the target. Prediction errors in regulated prices were acting in both directions. Over the period from 2002 until 2003 (and also from 1999 until 2007), a lower than expected growth in regulated prices contributed to undershooting of overall inflation, i.e. also to undershooting of the inflation target. At the end of 1998, in 2001 and in 2006, on the other hand, an unexpectedly high growth of regulated prices helped to move closer to predicted headline CPI inflation.

According to our findings, about half of the apparent amount of target undershooting in 2003 was to be attributed to errors in exogenous factor (foreign interest rates, GDP and inflation) predictions, which corresponds to the conclusions arrived to by Antal, Hlaváček and Holub (2008). In other years, errors in exogenous variable predictions add more or less insignificantly to target undershooting (up to approx. 10% out of total undershooting). Errors in 1Y EURIBOR predictions indicate, when compared to errors in the exchange rate predictions, that the assumption of uncovered interest rate parity used in QPM is unlikely to be much realistic. For larger part of the period, monetary policy tended to respond to anti-inflationary shocks (e.g. particularly to exchange rate shocks since 2004) that were out of its reach. From 2002 to 2004, the exchange rate depreciated more than expected by the forecast and, since 2004, it has been surprising due to higher than expected appreciation.

Our above conclusions are however comparatively significantly affected by a low number of observations. This fact, inter alia, made impossible any full-fledged, econometric analysis based assessment of the impact that errors in endogenous variable predictions had on inflation undershooting, while the analysis results need to be taken with caution even for exogenous variables.

The structure of the paper is as follows: Section 2 compares analyses of prediction tools of other central banks to our analysis. Section 3 examines the size and bias of inflation prediction errors in 1998–2007. Section 4 addresses the inflation error distribution across separate price segments. Section 5 follows with an assessment of the amount and bias of prediction errors for selected macroeconomic variables taken from QPM. Section 6 considers the extent to which the exogenous variable prediction errors contributed to undershooting of the inflation target. A conclusion follows afterwards.

2. OVERVIEW OF ANALYSES OF THE PREDICTION TOOLS OF FOREIGN CENTRAL BANKS

Certain foreign central banks published quality assessments of their forecasting tools.[5] On one side, such assessments include more general, methodological approaches, e.g. evaluation of calibration benefits compared to estimation of parameters; pros and cons of statistical and structural models; and, optimal combinations and aggregations of different prediction models. On the other hand,

[5] These assessments were carried out internally in some of the banks, as well as by outsourced experts in other cases.

central banks paid attention to evaluating the statistical performance of forecasts, carried out mainly through measurements of forecast accuracy with the help of the extent of the average error or by testing if the predictions give a systematic bias. Most of the central banks examine inflation and GDP growth forecasting errors, while less attention is devoted to other variables (in the studies available to us), compared to our study.

The Bank of England (Pagan, 2003) is a typical representative of more general methodological approaches. A trade-off is referred to between the structural DSGE models that are built from microeconomic foundations and bring an economic story, and statistical vector autoregressive models that often posses a potential for more accurate and less biased forecasts, especially over short time span. The above study also promotes an approach adopting a suitable combination of parameter calibration and estimation, and describes key factors of such optimum combination. The study recommends that results of a larger number of prediction models be used in order to have available diversification of methodological approaches and forecasts.

Sveriges Riksbank has produced a comparatively extensive document (Giavazzi and Mishkin, 2006) to assess success of forecasting, with a central focus on statistical assessment of the forecasting success rate. The study analyses also individual aspects of inflation targeting, such as transparency and communication, an optimal inflation target or the role of asset prices in inflation targeting. The study comes with a conclusion that the success rate of monetary policy in Sweden increased markedly following introduction of inflation targeting. It states that the inflation target kept on being undershooted which was accompanied by a loss in the form of a lower GDP and higher unemployment rate. The evolution however cannot be attributed to the errors in monetary policy. The set of forecasting tools was assessed as a reliable one and, according to the authors, errors in inflation forecasts could have been hardly prevented. However, the study also notes that Riksbank could have concentrated better on real economy developments in its analyses, particularly in analysing increases in productivity and in labour market analysing.

The Reserve Bank of New Zealand was initially predominantly concerned with the accuracy of short-term forecasts, while later it focused also on the bias of medium-term forecasts (McCaw a Ranchhod, 2004). The study establishes that inflation predictions have been downward biased since 1994 (i.e. actual inflation was higher than forecasted). The evolution was contributed to by underestimation of aggregate demand and overestimation of the economy's potential. An unexpected behaviour of the nominal exchange rate (stronger than forecast) was identified as the main source of inflation predictions bias. According to the study, improved predictions of the equilibrium real exchange rate, pass-through of the nominal exchange rate into CPI and potential (non-inflationary) product are key to improved inflation forecasting.

Fed, in its study (Gavin and Mandal, 2002), examines the forecasting performance of GDP and inflation since 1979, with particular focus on the accuracy of forecasts of the Federal Open Market Committee (FOMC) as compared to the accuracy of other three forecasts: those by financial analysts; so-called 'naive forecasts' (the future inflation trend assumed to be identical with the last observed one); and, predictions by the Fed experts. The study points out the fact that the level and variance of inflation have been decreasing dramatically since 1979, which has contributed to improved accuracy of the forecasts. It however continues by pointing out that all approaches showed prediction failures with regard to turning points of trend changes. The average forecast error for the GDP growth is near zero for all reviewed forecasting horizons, while the study evaluates these forecasts as non-biased. The FOMC forecasts frequently recorded the lowest error and are assessed as having at least equal quality as the financial analyst and Fed expert forecasts

and as exceeding the naive forecasts. On the other hand, the FOMC forecasts as well as all the other ones were prone to systematically overpredicting inflation forecasts. The forecast errors were, as expected, larger over a longer horizon, yet they were statistically significant also even for a one year horizon. The study further points out that the FOMC was unable to make use of the dynamic correlation between the GDP growth and inflation for obtaining an improved inflation forecast. In spite of that, the FOMC forecasts were more accurate than those by the analysts. On the other hand, they were less accurate than inflation forecasting by the Fed specialists.

3. DISTRIBUTION OF PREDICTION ERRORS OF HEADLINE INFLATION, NET INFLATION AND CORE CPI EX FOOD INFLATION, 1998–2007

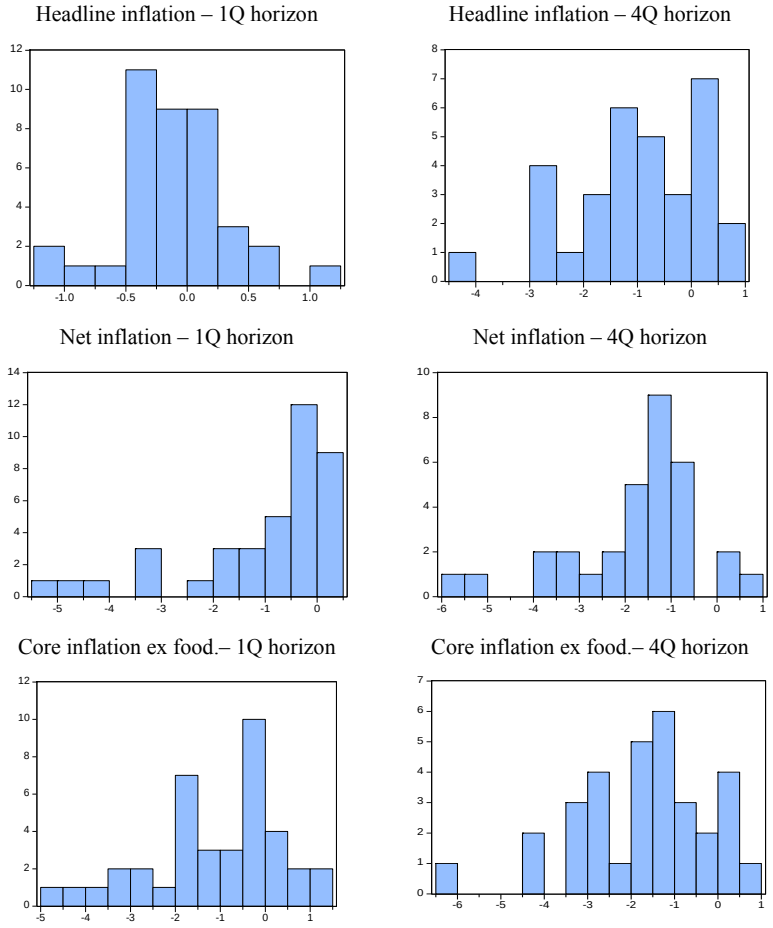
This section of our paper discusses an assessment of predictions of headline, net and core CPI ex food inflation in 1998–2007. For the 1998–2002 period, predictions for these variables are drawn from the Situation reports that are available from the following web-link: http://www.cnb.cz/cs/menova_politika/br_zapisy_z_jednani. For the period 2002Q2–2007Q3, the data have been drawn from the baseline scenarios of the CNB's core prediction model (the Quarterly Prediction Model, QPM, an internal database). Predictions of inflation and its elements somewhat differ for each of the above two periods included into the review. In 1998–2002, a conditional forecast was used that expected constant interest rates at the interest rate level at the time of the prediction preparation. In 2002Q2–2007Q3, the prediction was prepared as an unconditional forecast, under which prediction includes also modelling of the monetary policy response, i.e. including estimation of the future evolution of interest rates. Comparability of inflation prediction errors for the both periods is therefore questionable to a degree. In addition, the CNB's prediction for the period from 1998 until 2002 covered a limited set of variables, often (particularly during the initial years after inflation targeting introduction) with shorter prediction horizons. At the same time, predictions under the QPM core prediction model include a wide range of variables, as reflected by a wider scope of our analysis discussed in Section 5.

We compute prediction errors as a point forecast deviation from the observation. The CNB used to publish also interval forecasts of inflation in the form of symmetrical fan charts that to an extent reflect different degrees of prediction uncertainty along its increasing horizon. Inflation predictions using the fan charts nevertheless continued to be prepared until 2002. Even for the most of the following period, they were still prepared based on an expert judgement, while their width for separate prediction horizons remained mostly constant. The data therefore do not allow for a simple way of obtaining both information on variability of the prediction errors and information on other properties of statistical distribution of the errors for various horizons.

In Figure 1, we present the histograms of prediction errors computed as a difference of the variable's actual value and its prediction for the 1Q and 4Q horizons respectively. An analysis of a prediction at the 1Q horizon may be of interest for two reasons. First, a new forecast always overwrites the old one because of the quarterly periodicity of macroeconomic forecasting, hence an error in a 1Q prediction reflects new information to a degree, or, the amount of "surprise" for monetary policy decision making (if the 1Q prediction error were zero, the new prediction would be presumably similar to the old prediction even for a longer horizon). Second, inflation forecasts might have been especially uncertain particularly at the outset of inflation targeting during the Czech economy's transition, while monetary policy decision making might have been taking also short-term predictions into account (see Horváth, 2008), with the more or less identical fit of both the backward and forward-looking monetary policy rule. We therefore considered legitimate to

include both 4Q and 1Q horizonts. The 4Q horizon reflects the lower part of the monetary policy horizon, within which changes in monetary policy setting should get already revealed.

Figure 1: Histograms of prediction errors (actual – prediction), 1Q and 4Q horizons, 1998–2007



The horizon reflects the monetary policy lag and is assumed as 4Q or 6Q for the Czech Republic.[6] The lower part of the monetary policy horizon was chosen because of a larger number of observations (19 as opposed to 17 for QPM, 14 as opposed to 11 for 1998–2002). Table 1

[6] The monetary policy horizon is estimated for as long as 8Qs in certain economies. However, since the Czech economy represents a small open economy, it may be expected to manage somewhat accelerated transmission through the exchange rate changes.

nevertheless shows that the correlation between the prediction errors at the 4Q and 6Q horizons is comparatively high for majority of such considered variables, meaning the results of our analysis would be unlikely to change dramatically, were the 6Q horizon considered.

Table 1: Correlations of prediction errors - 4Q vs. 6Q, 2002–2007

Time series of prediction errors	Correlation coefficient	Time series of prediction errors	Correlation coefficient
Inflation	0.64***	Foreign GDP growth	0.76***
GDP growth	0.27	Foreign inflation	0.52**
Exchange rate (CZK/EUR)	0.94***	1Y EURIBOR	0.96***
3M PRIBOR	0.75***	Oil	0.69***

*Note: *, **, *** denotes the significance at the 10, 5 and 1 per cent level.*

A comparison of the results for the inflation prediction errors in Table 2 reveals that the (absolute) error of the one year ahead prediction recorded 1.17 pp for the entire period 1998–2007, while it fell slightly to 1.03 pp in 2002, following introduction of QPM (for the results after QPM introduction, see the next section). The trend becomes even more apparent of the prediction for the following quarter (0.36 pp in 1998–2007 and 0.24 pp after QPM introduction). A similar view may be formed also based on Figures 2–4 that show the development of prediction errors for headline, net and core inflation ex food over time. Clearly, absolute errors of predictions were diminishing over time but it should be noted on the other hand that a higher rate of inflation might be more volatile (Friedman, 1977), thus resulting in a potentially larger prediction error.

Table 2: Test of prediction bias, complete period 1998–2007

Time series	Avrg. 1Q error	Avrg. abs. 1Q error	Avrg. 4Q error	Avrg. abs. 4Q error	1Q bias (t-stat)	4Q bias (t-stat)
Inflation	-0.14	0.36	-1.02	1.17	1.94	**4.76**
Net inflation	-1.04	1.11	-1.75	1.83	**4.66**	**7.20**
Core inflation ex food	-1.10	1.39	-1.71	1.82	**4.55**	**6.21**

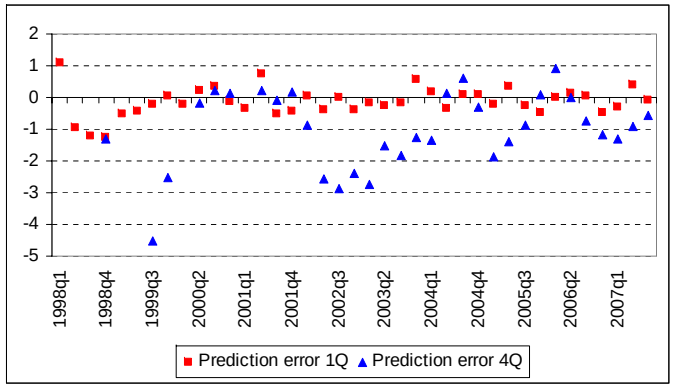
Note: The average error is set out in pp and computed as arithmetic average of prediction errors within the respective time series. The average absolute error is set out in pp (the absolute error for each quarter is computed first and then averaged). ***Bold*** *is used to denote absolute values of t-statistics for which the null hypothesis that the predictions are unbiased could be rejected at the 5% significance level.*

We follow by testing the bias of the predictions, i.e. whether or not the prediction error is nonzero on average. The null hypothesis therefore states that the average of error in predictions is $\mu=0$. The alternative hypothesis is $\mu\neq 0$. The resulting t-statistics are computed as follows:

$$t = \frac{\bar{\mu}}{s/\sqrt{N}}$$

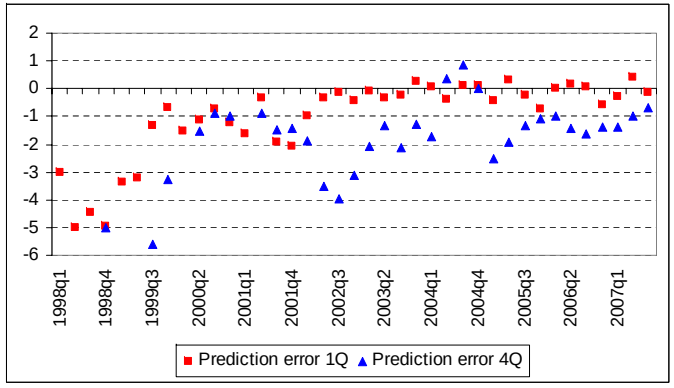
wherein $\bar{\mu}$ is the average error of predictions within the respective data sample, s is a unbiased estimate of the standard deviation for the respective prediction errors, and, N is the number of observations. The t-statistics are arranged using t-distribution with N-1degrees of freedom. As far as the bias test results in Table 2 are concerned, while 1Q prediction of headline inflation narrowly "passed" the unbiased test (t-statistics 1.94), all other predictions are statistically significantly biased.

Figure 2: Prediction errors of headline inflation (actual – prediction), 1Q and 4Q horizons, complete period 1998–2007



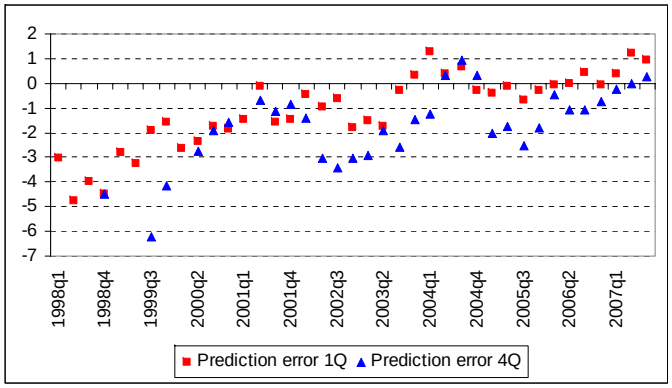
Note: 4Q prediction errors were not available for 1998Q1, 1998Q2, 1998Q3, 1999Q1, 1999Q2, 2000Q1 and 2001Q1.

Figure 3: Prediction errors of net inflation (actual – prediction), 1Q and 4Q horizons, complete period 1998–2007



Note: 4Q prediction errors were not available for 1998Q1, 1998Q2, 1998Q3, 1999Q1, 1999Q2, 2000Q1 and 2001Q1.

Figure 4: Prediction errors of core inflation ex food (actual – prediction), 1Q and 4Q horizons, complete period 1998–2007



Note: 4Q prediction errors were not available for 1998Q1, 1998Q2, 1998Q3, 1999Q1, 1999Q2, 2000Q1 and 2001Q1.

4. DISTRIBUTION OF INFLATION PREDICTION DEVIATIONS ACROSS SEPARATE PRICE SEGMENTS

This section of the paper presents an analysis aimed at identifying the inflation elements that were behind the difference of actual and predicted inflation according to the CNB's official prediction at the prediction horizon of 4 quarters. Comparison of the deviation in the predicted price increase and actual values for separate price segments enables to identify which part of the price index contributed most to the headline inflation prediction error and subsequently to missed inflation target in separate periods.

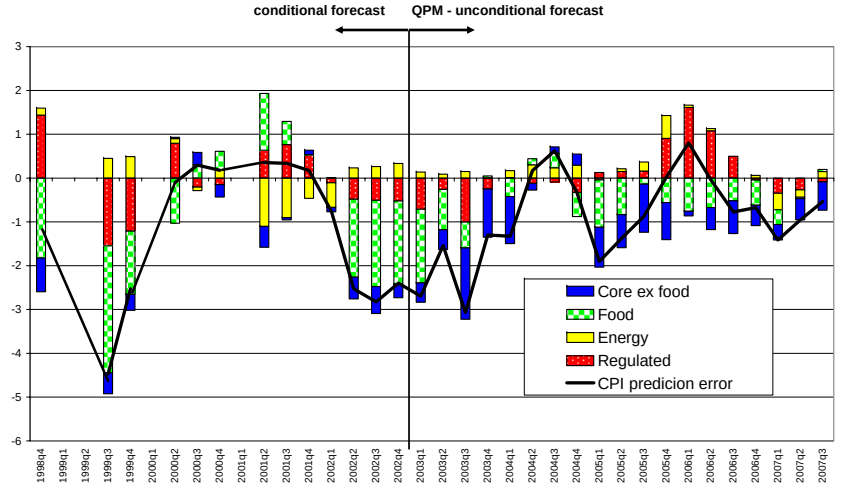
Given the above mentioned shift from the conditional to the unconditional forecast it is nevertheless somewhat difficult to interpret evolution of the total error over time, or, it is practically impossible to compare errors in predictions between the two periods. During the initial stages of inflation targeting, inflation forecasting was conditional in the sense that it assumed a constant future level of interest rates. Part of the inflation prediction error with respect to these predictions therefore corresponds to the response by monetary policy.[7] As however already noted, the QPM core prediction model in use since 2002 is unconditional (in terms of the interest rate evolution). The reaction function of the central bank in the model at the same time ensures that predicted inflation is located close to the inflation target midpoint at the monetary policy horizon.[8] The relationship between the inflation prediction error and target undershooting is therefore much more direct in this case.

[7] If, for example, an inflation prediction were markedly above the target, monetary policy would presumably respond by an increase of the interest rates, which in turn would lead to decreased inflation, below the previous prediction level. Errors in predictions may be consequently interpreted herein only respecting the ex-post assessment of the target fulfilment (see Antal, Hlaváček and Holub, 2008).

[8] This, indeed, does not apply unexceptionally. Given the fact that the monetary policy provides no ex-ante responses to immediate impacts of changes in indirect taxes, total predicted inflation may be above the target in reality. Monetary policy, in addition, may fail to give sufficiently strong responses to distinct shocks to be able to eliminate them entirely at the monetary policy horizon.

The observed elements of inflation include core inflation ex food, food price inflation, energy price inflation and regulated price inflation. We obtain contributions by separate inflation elements to the total error in inflation prediction by computing the actual and forecasted value difference for separate inflation elements and then multiply the differences by their weights in the consumption basket. The results are presented in Figure 5.[9] As may be seen from the Figure, headline inflation was overpredicted mainly due to the errors in the forecast of core inflation ex food (especially beyond 2003) and in the food price inflation forecast (practically throughout the period 1998–2003). The year 2004 represented an exception as all inflation elements were relatively close to the forecast. Prediction errors in regulated prices were acting in both directions. Over the period from 2002 until 2003 (and also in 1999 and in 2007), a lower than expected growth in regulated prices contributed to undershooting of headline inflation, i.e. also to undershooting of the inflation target. In 2006, on the other hand, actual core inflation ex food and food price inflation was once again significantly overpredicted, however the error was "compensated" by an unexpectedly steep growth of regulated prices. Had it not been for these higher than expected regulated prices in 2006, core inflation and the foodprices would have pushed headline inflation below the forecast in that period, too. Similarly, the unexpectedly sharp increase of regulated prices helped to come closer to the prediction of headline inflation forecast at the end of 1998 and in 2001. The energy price impact on the headline inflation prediction error was minor most of the time (thanks to the weight (approx. 3–4%) of the energy prices within the consumption basket) and acted typically in the direction of higher than expected inflation.

Figure 5: Forecast deviations at 4Q horizon: Contributions by separate inflation elements



Note: The Figure presents contributions by separate inflation elements to the deviation of actual inflation from the forecast. Contributions of separate inflation elements in pp are rendered in colours in the Figure. Had the prediction fully matched the reality, the total of separate contributions above and under the axis would have been zero. Missing prediction errors for 1stQ and 2ndQ 1999, 1stQ 2000 and 1stQ 2001 are due to the fact that, during the periods, inflation forecasting and its elements were prepared for a shorter than a 4 quarter horizon.

[9] For the period 1998-2003, complete time series of separate element forecasts are unavailable.

It is interesting in 2007 that, in two out of three quarters, the prediction error was moving in the same direction (the prediction being higher than the reality) for all inflation elements, although separate errors were more or less lower in absolute terms.

5. DISTRIBUTION OF PREDICTION ERRORS FROM QPM, 2002Q2–2007Q3

This section presents an analysis of errors in predictions for selected macroeconomic variables taken from QPM. A prediction error for the respective variable is computed as a difference of the variable's actual value and its prediction for a 1Q and 4Q horizons respectively. Figure 6 contains histograms of prediction errors from QPM for 4 quarters ahead, while Figure 8 (in the Appendix) provides a histogram of prediction errors from QPM for 1 quarter ahead.

Figure 6 shows histograms of prediction errors at the 4 quarter horizon. It is obvious in inflation and domestic interest rates that they were overpredicted compared to the observations. The exchange rate appreciated more strongly than the model prediction forecasted. It is clear from the histogram of the oil prediction errors that the actual oil prices were often located higher than predicted. Foreign interest rates were on average somewhat overpredicted, compared to the reality. Estimates of the GDP domestic and foreign growth[10] appear visually unbiased. A moderate underprediction tendency prevails in foreign inflation, compared to reality.

Table 3 presents the results of the prediction bias test, i.e. whether or not the prediction and reality difference was systematically different from zero.[11] While certain predictions may seem visually (see Figures 6 and 8) biased, we identify a statistical bias only in a few cases (which is certainly connected with the low number of observations, due to which a reliable rejection of the null hypothesis of an unbiased prediction is not simple to make). The results however indicate an increasing bias concurrently to the increasing horizon of prediction. While, at the 1 quarter ahead prediction, we find out that only the oil price prediction is biased, in case of the 4 quarter ahead prediction, this already includes inflation, the GDP growth, 3M PRIBOR and oil.

[10] In case of domestic and German GDP, these are so-called real time data, i.e. available at the forecast preparation (i.e. not the revised data). The real time data are compared with the prediction. In case of foreign inflation and GDP growth, the time series consists of the German data until mid-2006 and then of effective "European" inflation and the GDP growth. From the monetary policy perspective, the output gap is more meaningful as an economic activity indicator than the GDP growth, specifically over periods of extensive changes on the supply side of the Czech economy that resulted in an increased growth of the potential product. The output gap is nevertheless an unobserved variable and cannot be assessed for the bias of its predictions. The reason why we review GDP instead of the output gap is, inter alia, that the indicator is better known and understandable to the public and therefore more visible.

[11] The applied prediction bias test works well only for the stationary time series. The time series we have used reflect the difference between the predicted and actual values and should be therefore stationary, while the prediction would have had to worsen or improve distinctly had that been otherwise. We also took stationarity testing using the KPSS test (this test is more suitable for short time series as compared to ADF or PP), where we did not reject the null hypothesis of stationarity for each of the used time series at the 5% significance level

Figure 6: Histograms of prediction errors (actual – prediction), 4Q horizon, 2002–2007

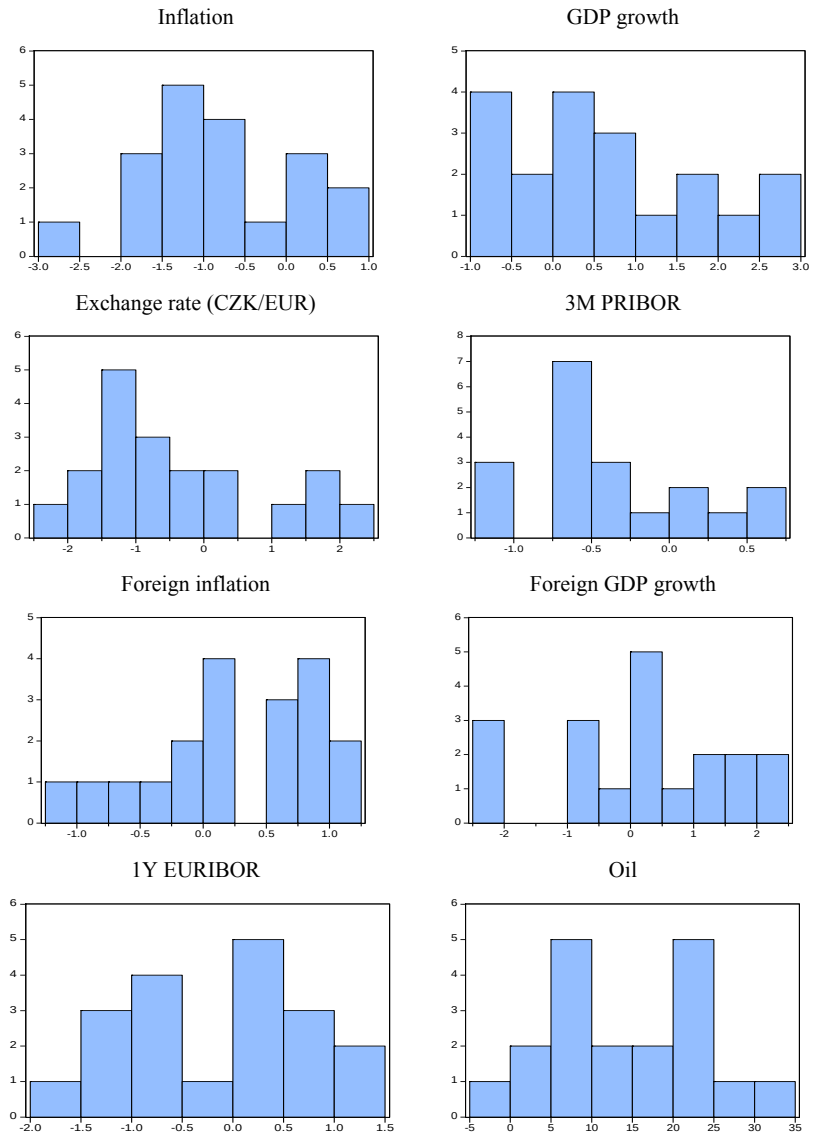


Table 3: Test of prediction bias, 2002–2007

Time series	Avrg. 1Q error	Avrg. abs. 1Q error	Avrg. 4Q error	Avrg. abs. 4Q error	1Q bias (t-statistics)	4Q bias. (t-statistics)
Inflation	-0.08	0.24	-0.85	1.03	1.34	**3.99**
GDP growth	0.09	0.55	0.65	0.98	0.48	**2.40**
Exchange rate (CZK/EUR)	-0.02	0.42	-0.37	1.23	0.17	1.20
3M PRIBOR	-0.02	0.11	-0.39	0.57	0.68	**3.12**
Foreign GDP growth	0.05	0.46	0.25	1.14	0.35	0.41
Foreign inflation	0.11	0.29	0.14	0.60	1.42	1.63
1Y EURIBOR	0.03	0.23	-0.14	0.79	0.40	0.65
Oil	5.17	5.86	14.13	14.56	**5.06**	**6.32**

Note: The average error is set out in pp and computed as arithmetic average of prediction errors within the respective time series. The average absolute error is set out in pp (the absolute error for each quarter is computed first and then averaged). ***Bold*** *is used to denote absolute values of t-statistics for which the null hypothesis that the predictions are unbiased could be rejected at the 5% significance level.*

Table 3 also presents average absolute errors at the prediction horizons of 1 and 4 quarters. We can see from the Table that e.g. the average absolute error of the exchange rate prediction for 1 and 4 quarters was CZK 0.4 and CZK 1.2 respectively. The absolute prediction error for oil was USD 5.8 for the next quarter, while a next year ahead prediction recorded the average error of USD 14.6.

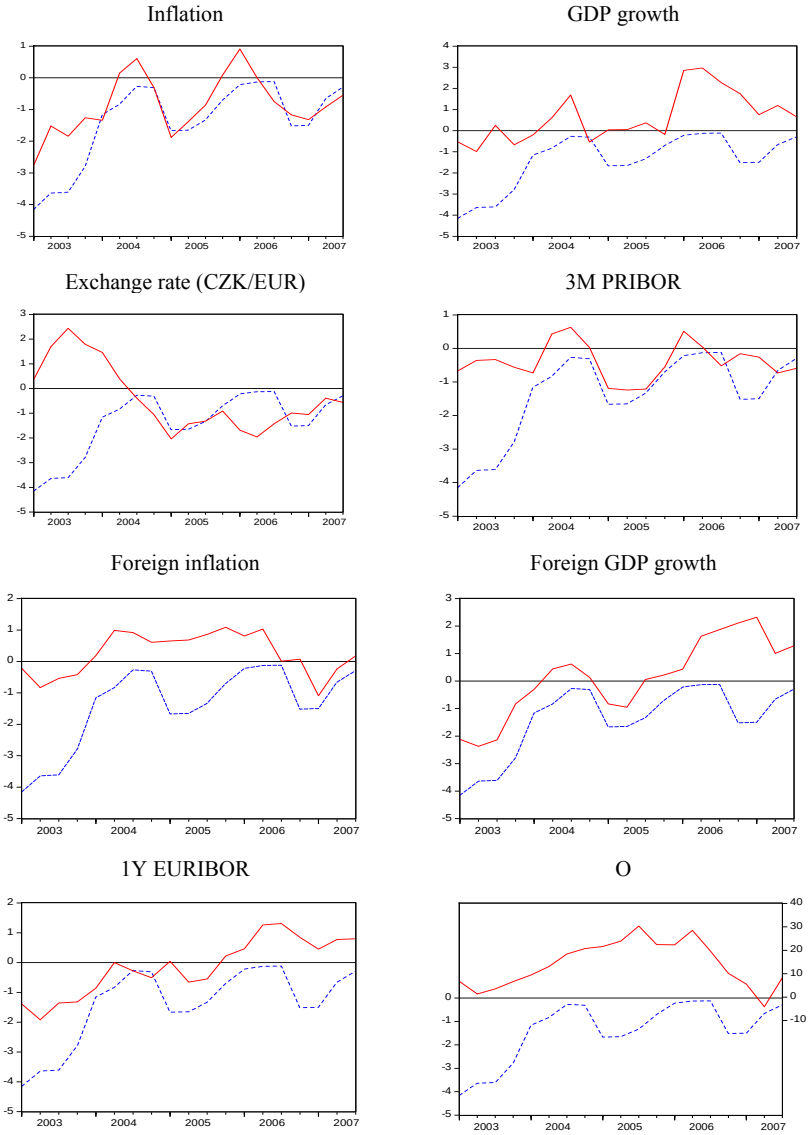
In the next step, we present figures that depict the evolution of prediction errors (at a 4Q horizon) and undershooting of the target over time (see Figure 7). The selected horizon of four quarters reflects the monetary transmission horizon. Another analytical approach would be to compute correlation coefficients between prediction errors and undershooting. However, as several of the below presented figures will show, the relationship between the prediction errors and undershooting kept on changing over time (for example, the strong exchange rate appreciation in 2002 and its subsequent correction in the next year considerably affect the resultant correlation coefficients). The blue dashed line in the prediction error figures serves to indicate the rate of undershooting of the target,[12] while the solid line indicates the forecasting error for the respective variable. Undershooting of the target is positively correlated to the error in inflation prediction.[13]

The fact that the GDP growth was above the CNB's forecast for most of the time, and even in the situation of systematic undershooting of the target, indicates that undershooting cannot be explained through standard demand mechanisms in this case. It seems that positive supply impulses towards the potential product were probably underestimated in the past, and the model tools as a rule assessed the surprisingly high GDP growth as the negative output gap closing, while closing was in fact kept postponed due to enduring low inflation. Repetitions of the phenomenon could lead to target undershooting.

[12] This series is identical for all figures.

[13] Since the monetary policy rule pushes inflation close to the target midpoint at the monetary policy horizon in the unconditional forecast, the target undershooting, from the ex post perspective, is necessarily driven by the inflation prediction error from the period(s) prior to the monetary policy horizon. A deviation may occur only if an ex ante exception is applied at the prediction preparation time The link between undershooting and the inflation prediction error is not entirely perfect either, as the figure considers prediction errors at a one year horizon, while the monetary policy horizon considered by QPM is longer (4 to 6 quarters).

Figure 7: Prediction errors (actual – prediction) at the 4Q horizon and target undershooting



Note: The blue dashed line in the figures serves to indicate undershooting of the target (this series is identical for all figures). Values of the oil price prediction errors are set out on the right axis.

The relationship of an exchange rate prediction error and target undershooting more or less matches the assumption about a positive correlation of these deviations (a more appreciated exchange rate will mean lower imported inflation and therefore undershooting of the target). An exception is represented by the start of the period under review, approximately at the beginning of 2004, when the exchange rate vis-à-vis the forecast experienced a higher depreciation (by CZK 1–2 per euro), while inflation evolved relatively considerably below the target. In this case, an explanation may consist in an unexpectedly lower foreign growth and delayed effects of the appreciation bubble of 2002 (the latter is not visible in the figure as the figure begins with 1Q2003), adjusting of which led to an overprediction of the exchange rate, due to the relatively strong backward-looking nature of the exchange rate prediction in that period. As a result, delayed effects of the overestimated 2002 exchange rate were pushing the inflation rate down. Another period, during which deviations of the exchange rate and inflation from the predictions were moving in opposite directions, was the year 2006 when the target undershooting rate was temporarily decreasing. As may be however seen from the distribution of inflation errors across separate inflation elements (see the discussion at Figure 5), moving closer to the target at that time was considerably supported by an unexpected increase of regulated prices that is unrelated to the exchange rate.

For larger part of the period under review, the amount of the interest rate error was on average lower than undershooting of the target (see Figure 7).[14] This suggests that real interest rates from the ex post perspective were somewhat higher compared to expectations. The foregoing could to an extent confirm the hypothesis of anchored inflation expectations at a level below the target midpoint target (and therefore also higher real interest rates ex ante). Furthermore, there is interesting mutual causality of the interest rate prediction errors and target undershooting in the sense of an answer to the question whether undershooting of the target was caused by more aggressive than forecasted monetary policy, or if, on the contrary, monetary policy responded with some delay to target undershooting, or, to lower inflation rate, doing so by lower than predicted rates. A simple look at the Figure indicates that, for most of the period, monetary policy was rather dominated by anti-inflationary shocks outside its reach and was not their likely source.

The link between foreign inflation predictions and target undershooting appears relatively moderate at first glance. For most of the period, foreign inflation was higher than predicted by the forecast and could therefore hardly be any source of systematic undershooting of the inflation target. An exception could be represented by the year 2003, when lower inflation pressures arising from foreign inflation matched conveniently already mentioned delayed impacts of the 2002 excessive appreciation. Recently, too, the relationship of foreign and international inflation appears "standard". Similarly to the foreign inflation deviation, oil prices do not offer much help in explaining undershooting of the inflation target, i.e. the same as the fuel prices that were distinctly higher than expected over the complete period .[15]

Relating to a somewhat weaker link between foreign inflation and undershooting of the target, an interesting comparatively strong relationship exists of the foreign growth prediction error and target undershooting, in particular until 2006.[16] A weaker foreign growth could lead to a slowdown of

[14] It may be further seen from the Figure that while the interest rate prediction errors at the 1 year horizon in Table 2 are identified, identically to the inflation prediction errors, as statistically significantly downward biased, the volatility of their error is lower as opposed to target undershooting or inflation.

[15] In other words: had the oil price and fuel price evolution matched the expectations, undershooting of the inflation target would have been even more pronounced.

[16] Certain weakening of the link may relate to the switch to the effective GDP growth indicator in the euro area, replacing the German GDP growth, in mid-2006.

foreign inflation and lower imported inflation. It would also mean weaker demand for the Czech exports and also lower inflationary pressures. It is however impossible to find the both links completely reflected in the figures "GDP growth" and "Foreign inflation" (see above). The errors in 1Y EURIBOR predictions indicate, when compared to errors in the exchange rate predictions, that the assumption of the uncovered interest rate parity used in prediction is unlikely to be much realistic (since 2004 approximately, the foreign interest rates have been underpredicted and, on the contrary, domestic interest rates were overpredicted, while the exchange rate was more appreciated as opposed to the uncovered interest rate parity logic).

6. HAVE ERRORS IN PREDICTIONS OF EXOGENOUS VARIABLES CONTRIBUTED TO UNDERSHOOTING OF THE TARGET?

A relationship was suggested in the previous section between undershooting of the inflation target and prediction errors for separate variables from the QPM model. Comparing target undershooting and prediction errors for separate variables "one by one" may however encounter a few problems. It may happen, for example, that, with respect to certain periods, prediction errors for two or multiple relevant variables may have a reverse impact on inflation and that the errors will compensate each other as a result (it used to happen quite often in the past that the effects of the unexpectedly high oil prices were damped by unexpected appreciation of the exchange rate). Errors in predictions for separate variables may be mutually related, or, may combine their effects on inflation. We have therefore decided to model the link between the amounts of prediction errors for separate macroeconomic variables (the prediction is from a 4 quarter past period, because of transmission lags) and undershooting of the inflation target, using the following regression:

$$\left(\pi_t - \pi_t^*\right) = \alpha_0 + \alpha_1\left(x_{t,1} - E_{t-4}\left(x_{t,1}\right)\right) + \ldots + \alpha_k\left(x_{t,k} - E_{t-4}\left(x_{t,k}\right)\right) + \varepsilon_t$$

wherein $\left(\pi_t - \pi_t^*\right)$ is the difference between inflation and the inflation target in time t, thus showing the rate of inflation target undershooting (for the behaviour of the target undershooting rate, see also Figure 4 in Antal, Hlaváček and Holub, 2008); $x_{t,i}$ is the value of the *i*-th macroeconomic variable at time *t*, *i*=1,…,k. $E_{t-4}\left(x_{t,k}\right)$ is the prediction of the respective variable at time t-4 (i.e. a 4Q prediction horizon).

Given the limitations due to the small number of observations, the above link was estimated using a simple least squares method. As for explanatory variables only those were included that are considered exogenous from the QPM model perspective, i.e. the variables predictions of which is mostly assumed from external sources by the CNB prediction system (Consensus Forecast forecasts were used for majority of the considered variables).[17] We do not examine the role of endogenous factors, such as the food prices or domestic GDP growth, as it is econometrically unviable to successfully apply short time series to differentiate an impact of endogenous variables on undershooting from an impact of undershooting on the endogenous variables (so-called endogeneity of explanatory variables). Consequently, if we included the endogenous variables into this regression type we would be quite likely estimating equations calibrated directly within the model

[17] The only exception was made with the exchange rate, the expected impact of which on imported inflation is significant. From the QPM perspective, this is a "semi-exogenous" variable, when the future exchange rate evolution is modelled using more or less only the uncovered interest rate parity.

(e.g. the Phillips curve). The issue is irrelevant for exogenous variables as domestic undershooting of the target may be hardly expected to affect the evolution of the foreign variables used. Dropping endogenous variables from the regression of course does not mean that we do not attempt estimating the reasons of undershooting to their full extent, but instead, that we only attempt to find an answer to the question to what extent such undershooting was driven by external shocks. Even despite such narrowed perspective, our results should be taken as illustrative only. A limitation in this case consists in the already mentioned small number of observations, as well as the fact that separate explanatory variables impact inflation through various channels and with lags of differing lengths etc.[18]

Table 4: Undershooting of the inflation target and errors in predictions of exogenous factors, 2002–2007

	(1)	(2)	(3)	(4)	(5)
Constant	-1.81***	-1.71***	-1.39***	-1.73***	-1.56***
	[0.29]	[0.11]	[0.23]	[0.31]	[0.37]
Oil	0.04**		-0.01		-0.01
	[0.01]		[0.01]		[0.03]
EURIBOR	0.94***		0.89***		0.14
	[0.20]		[0.15]		[0.41]
Foreign inflation		0.93***	0.84***	0.69*	1.05***
		[0.09]	[0.23]	[0.39]	[0.25]
Foreign GDP growth		0.62***			0.56**
		[0.20]			[0.24]
Exchange rate				-0.43**	0.03
				[0.18]	[0.18]
Number of observations	19	19	19	19	19
Adj. R^2	0.67	0.81	0.72	0.47	0.78

*Note: Standard deviations robust against autocorrelation and heteroskedasticity are set out in the parentheses below the estimated parameter. *, **, *** denotes the significance at the 10, 5 and 1 per cent level.*

The results are presented in Table 4. Given relatively high correlation of errors in separate predictions, several alternative specifications of the model are made in columns (1)–(4) where the highest correlated variables are eliminated. Nonsignificance of certain explanatory variables in column (5) that includes all considered variables is probably affected by a low number of degrees of freedom and by multicolinearity.

The estimated constant with a statistically significant coefficient around -1.5% indicates that a large portion of target undershooting cannot be explained by exogenous factors. The regression analysis results imply that the higher than expected oil price lead to lower undershooting, according to the results in column (1), even though the relationship is unlikely to be robust because the oil prediction errors in the specifications in columns (3) and (4) have no statistically significant impact on

[18] Another limitation imposed on this analysis is certainly an assumption that the CNB Bank Board never departs from the forecast, as well as leaving out from consideration ex-ante exceptions from the inflation target fulfilment.

undershooting of the target. Given the fact that both the oil prices and inflation and the foreign GDP growth were more frequently underpredicted compared to the reality, the two factors on average made no contributions to undershooting of the target during the period under review. In case of EURIBOR, on the other hand, a negative error (overpredicted actual values) was typical and EURIBOR overshooting could thus contribute to undershooting of the inflation target. If we were to quantify the effect based on the estimated coefficients in columns (1) and (3) we would arrive to a result that errors in EURIBOR predictions contributed to undershooting of the target within the extent slightly above 0.1 pp.[19] Since the target was on average undershooted by approx. 1.4 pp during the period of 2003–2007, it is apparent that the exogenous factors explain 10% out of the total undershooting amount at the maximum. If the estimated coefficient in column (5) were used, the respective effect of the prediction error would be marginal for explanation of undershooting of the target. The negative coefficient of the exchange rate in column (4) is statistically significant, however with an opposite sign, contrary to expectations. This is due to the already mentioned impact of the 2002 appreciation bubble on subsequent inflation, which resulted in weaker than expected exchange rate in 2003 that was accompanied by a low rate of inflation. In equation (5), the exchange rate (once again due to multicolinearity) appears statistically insignificant.

It is of interest to look at considerable inflation target undershooting in 2003. It is apparent from Figure 7 that EURIBOR, foreign inflation and the GDP growth were lower than expected (e.g. EURIBOR was in fact lower by 2 pp compared to expectations). That should create a pressure on the exchange rate appreciation (lower foreign interest rates), hence it can be stated, to a certain degree, that there were the exogenous factors behind the undershooted target. If we were to quantify the "net" effect of the prediction errors in case of the above exogenous variables (leaving aside their second round effects on the other variables), we would get a contribution of approx. 1.75 pp[20], i.e. to approx. half of the total rate of undershooting the target in 2003. However, as noted above, given the small number of observations there is unquestionably substantial uncertainty as to the amount of such estimated effects.

7. CONCLUSION

This paper is primarily concerned with analysing the bias of the CNB's predictions in relation to undershooting of the inflation target. The key conclusions of the paper are as follows: The inflation prediction error decreases over time. Positive supply shocks were admittedly underestimated in the past. The model tool set tended to assess the surprisingly high GDP growth as a negative output gap closing, while closing was in fact kept postponed due to enduring low inflation. According to our findings, about half of the apparent amount of target undershooting in 2003 was to be attributed to errors in exogenous factor (foreign interest rates, GDP and inflation) predictions. In other years, errors in exogenous variable predictions did not contribute significantly to target undershooting. Given the short times series, these conclusions however should be considered more or less illustrative, while numerous uncertainties are related to the performed analysis (such as various transmission channels of prediction errors for separate variables into inflation, and differing lengths of the lags of the impact).

[19] A simple average error in EURIBOR predictions is 0.14 pp-times estimated coefficient of approx. 0.9, giving the value above 0.1 pp.

[20] The average 2003 error is -1.5 pp for EURIBOR is, -1.9 pp for foreign GDP, and -0.5 pp for foreign inflation. When we multiply these values using respective coefficients in column (4), we obtain their contribution to a decrease of inflation rated approx. 1.75 pp.

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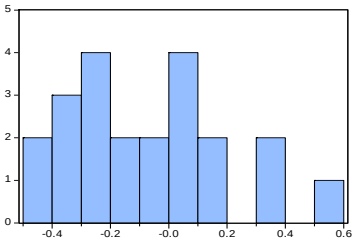
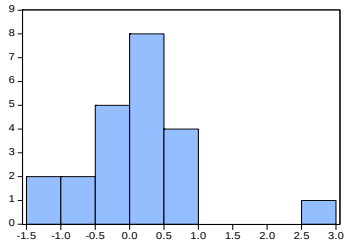
APPENDIX:

Figure 8: Histograms of prediction errors (actual – prediction), 1Q horizon, 2002–2007

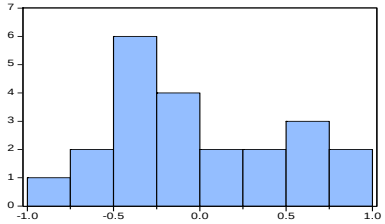
Inflation



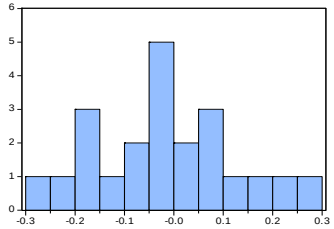
GDPgrowth



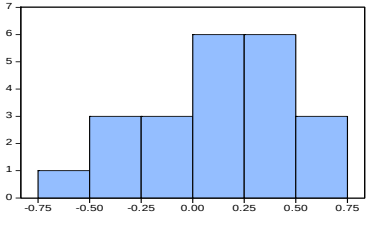
Exchange rate (CZK/ER)



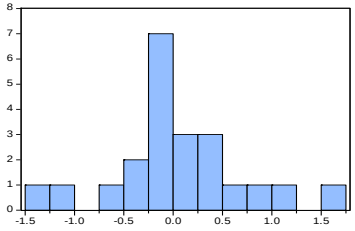
3M PRIBOR



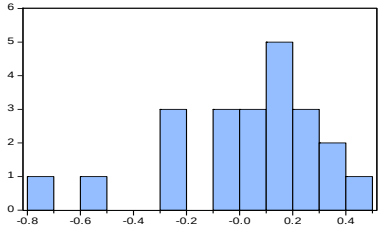
Foreign inflation



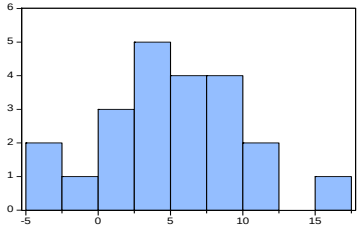
Foreign GDP growth



1Y EURIBOR



Oil



CHAPTER 6

INFLATION FORECASTS ERRORS IN THE CZECH REPUBLIC: EVIDENCE FROM A PANEL OF INSTITUTIONS

JAN BABECKÝ
JIŘÍ PODPIERA

1. INTRODUCTION

How is the CNB accurate in inflation forecasting? Why are there forecast errors, and are they systematic? Could, for example, forecast errors be at least partially explained by exchange rate shocks? Do professional forecasters learn from their past forecast errors? This analysis offers the first and to our knowledge unique feedback on forecast error decomposition and the accuracy of the past inflation forecasts produced by the Czech National Bank (CNB) in comparison with a number of alternative forecasting institutions in the Czech Republic, which report in the framework of the Macroeconomic Colloquia[1].

The assessment of inflation forecasts has traditionally been in the centre of attention of central banks (see, for example, McNees, 1992; Croushore, 1998; Canova, 2002; Espasa *et al*., 2002; McCaw and Ranchhod, 2002). It also represents the subject of a broader academic and policy debate (Granger, 1996; Diebold and Mariano, 2002; Valev and Carlson, 2003; Keereman, 1999). While the literature generally gives a detailed analysis of the macro- and micro-economic factors, which can affect the quality of inflation forecasts, there are very few studies that systematically analyse the forecast error decomposition.

Reliable central bank inflation forecasts are essential for the implementation and communication of monetary policy, serving as an anchor for future inflation expectations (Bernanke and Woodford, 1997). Inflation forecasts are also produced by a number of national and international institutions. Therefore, a comparison of professional forecasters is a compelling way of how to assess the central bank forecast performance since forecasting institutions face similar uncertainties country-wise.

The evidence for the particular approach of comparing a central bank against other professional forecasters is rather limited. For example, the analysis by Gavin and Mandal (2003) suggests that during the late 1990s the Federal Reserve's staff inflation forecasts outperformed those produced by the private sector. Giavazzi and Mishkin (2006) point out that errors in inflation forecasts by the Swedish central bank during 1997–2005 did not significantly differ from the forecast errors of other institutions. Another angle is to look at forecasting methods, types of forecasts (e.g. conditional versus unconditional), frequency of updates and institutional and other aspects. Berger *et al*. (2006) argue that geographical and country-specific factors could contribute to systematic errors in the European Central Bank's forecasts. The importance of these factors as applied to inflation forecasts remains so far unexplored.

Quality of forecasts is an important criterion for judging a forecaster's credibility, but it is not the only one. Another central criterion is how influential the central bank's forecasts are. In his recent original study, Fujiwara (2005) shows that the Bank of Japan's economic forecasts considerably affect the forecasts made by other institutions, while the reverse direction of causality is insignificant. This finding has important implications for the issue of monetary policy effectiveness and the leading role of the central bank[2].

Our analysis is based on comparisons of errors in inflation forecasts performed by institutions, which systematically forecasted inflation in the Czech Republic during 2002–2007. They are in total 16 institutions, including the Czech National Bank.

[1] Biannual framework of collecting macroeconomic forecasts from institutions residing in the Czech Republic and forecasting the Czech economy, administrated by the Ministry of Finance of the Czech Republic.
[2] We leave the assessment of how influential the CNB macroeconomic forecasts are for future research.

We examine how successful the CNB is compared to other institutions in terms of unbiasedness of forecasts and forecast standard errors. First, we estimate fixed effects in a panel of institutions; this method roughly corresponds to the simple averaging of both relative and absolute forecast errors. Second, we estimate another fixed effects specification, conditional on exchange rate forecast errors (as the main variable influencing inflation forecasts) and on past inflation forecast errors up to the fourth lag (equivalently two years given the bi-annual data).

A particular value added of our an analysis is – if the hypothesis of long series of asymmetric shocks is valid – that such shocks should be common to all institutions, and therefore the relative success of forecasts, i.e. forecast unbiasendess, should be conditional on such socks (e.g. errors in exchange rate forecasts).

Our results indicate that simple averages of forecast errors are statistically biased and have statistically significant standard errors for all institutions. However, controlling for the exchange rate forecast errors (which turn out to be significant determinant of common shocks – that is supporting the hypothesis of a long series of asymmetric exchange rate shocks) and considering learning from the past inflation forecast errors, we find that the majority of institutions (13 out of 16) are characterised by unbiased inflation forecasts. In other words, should such institutions be able to correctly foresee the CZK exchange rate, their inflation forecasts would not be biased. Moreover, the dispersion of inflation forecasts across institutions decreases significantly following the subtraction of exchange rate forecasts errors from inflation forecast errors.

The example of the CNB, which records a marginally significant (at the 10% significance level) systematic error in inflation forecasts even upon controlling for the exchange rate forecasts (the CNB forecasts higher than in reality inflation), would confirm (although only to a marginal extent) the hypothesis of the skewed sight. However, this result does not necessarily indicate a bias in the CNB prognostic apparatus. Indeed, the result may be due to an existence of other variables such as food and energy prices which the CNB forecasted with a higher error compared to other institutions.

The rest of the paper is organised as follows: Section 2 describes methodology of the analysis of inflation forecast errors, while section 3 brings the estimation results. Section 4 provides some concluding remarks.

2. METHODOLOGY

Our analysis is structured into two steps. In the first step, we perform a simple evaluation of inflation forecast errors by the individual institutions in terms of the average relative forecast error (Average Relative Forecast Error, ARFE) and the average absolute forecast error (Average Absolute Forecast Error, AAFE). While the ARFE indicates the direction of the forecast bias (over- or under-prediction), the AAFE shows the average deviation of the forecast from the outturn.

In the second step, we attempt to identify factors, which cause forecast errors. One of the most appealing hypotheses for an existence of a systematic error in inflation forecasts is the market's limited ability to predict exchange rate developments. That is, the hypothesis that – due to a limited forecasters' ability to predict the exchange rate – a systematic error occurs in inflation forecasts. Therefore, we evaluate the conditional (on exchange rate forecast error and on past inflation errors) average relative inflation forecast error (CARFE) and the conditional average absolute forecast error (CAAFE).

2.1 Model

In order to account for cross-correlations in the forecasts of various institutions (forecasts produced by institutions are not strictly mutually independent), we suggest applying the following fixed effects model specification:

$$\begin{aligned} RFE_{i,t} &= c_i + \varepsilon_{i,t} \\ AFE_{i,t} &= d_i + \omega_{i,t} \end{aligned}, \qquad (1)$$

where $RFE_{i,t}$ and $AFE_{i,t}$ are, respectively, the relative and the absolute forecast errors of institution i at time t *(one year and two year ahead forecasts)*[3], further c_i and d_i denote the fixed effects that represent the *ARFE* and *AAFE*, correspondingly. Equation (1) represents the first step of the analysis, where *RFE* and *AFE* are regressed on forecasting institution's specific constant. In the second step, the following explanatory variables are added: the forecaster's specific exchange rate forecast error, past inflation forecast errors, and the dummy variable equal to one for the second sample period 2004–2007, zero otherwise, which leads to the following specification:

$$\begin{aligned} RFE_{i,t} &= e_i + \beta RFE\_ER_{i,t} + \sum_{k=1}^{4} \delta_k RFE_{i,t-k} + d_{04\_07} + \xi_{i,t} \\ AFE_i &= f_i + \gamma AFE\_ER_{i,t} + \sum_{k=1}^{4} \theta_k AFE_{i,t-k} + d_{04\_07} + \nu_{i,t} \end{aligned}, \qquad (2)$$

where $RFE\_ER_{i,t}$ and $AFE\_ER_{i,t}$ represent, respectively, the relative and the absolute forecast error of the exchange rate forecast of institution i at time t. Coefficients β and γ stand for the forecaster institution's common elasticity of inflation forecast errors with respect to the exchange rate forecast error. These parameters speak for the consistency of the forecasting tools on average across forecasters and for the magnitude of the effect of exchange rate forecast errors on inflation forecast errors.

Next, parameters δ and θ represent the past dependence of current forecast error on its own past values; the lag length k is set to 4 periods, which corresponds to a two-year delay until forecasters can realise in full and learn from their errors. Then, d_{04_07} is the time dummy equal to one for 2004–2007, capturing the systematic difference between the two defined forecasting periods (see below).

Finally, the parameters e_i and f_i in (2) represent the *CARFE* and *CAAFE*, respectively. By the letters $\varepsilon_{i,t}$, $\omega_{i,t}$, $\xi_{i,t}$, *and* $\upsilon_{i,t}$ we denote the forecast disturbances, with zero mean and constant variance.

2.2 Data

The experience of the Czech National Bank with inflation targeting policy dates between 1998 and 2007. The sample can be, however, divided into three distinct sub-periods. The first period 1998–2002 can be characterised as the introductory period with simple forecasting framework and

[3] The analysis combines forecasts produced at a given year for the current and next years. Since information on forecasts is collected twice a year, forecasts produced in the second part of the year actually do not represent forecasts for one full year in ahead; they are rather forecasts covering the current year (half-year ahead forecasts) and forecasts for one and a half years ahead. The average forecasting horizon is thus closer to the period of one year, rather than to the period of two years in advance – which corresponds to the horizon of the CNB's monetary policy.

conditional inflation forecasts (i.e. forecasted inflation is conditional on the path of the interest rate). The second period, 2002–2004, was a phase of an upgrade of forecasting methods – introduction of the quarterly prediction model, QPM, in 2002 – using which the staff produced unconditional inflation forecasts. And finally, the last period 2004–2007 is a routine period in which the extensive experience with this framework was collected, albeit minor changes in the model were implemented (the inclusion of the labour market block or a switch to the Euro Area Czech effective indicators away from the German ones, but the reaction function calibration, for instance, remained unchanged throughout the entire period since early 2003).

In our analysis we focus on the period of a standard forecasting framework 2002–2007 at the Czech National Bank and collect unconditional forecasts produced by all institutions continuously reporting to the Macroeconomic Colloquia over 2002–2007 twice a year[4]. A nice feature of the Macroeconomic Colloquia is that institutions are asked to report their forecasts on the same day, which minimises potential causality effects between forecasters. Data thus comprises 24 observations per institution (inflation and exchange rate forecasts for current and following year). For comparison, a similar study for the Bank of England uses 32 observations; see Bank of England Inflation Report (2003).

3. RESULTS

Table 1 shows the results for equation (1). In particular, it appears that all 16 reporting institutions produce upward-biased forecasts during 2002–2007; in other words, forecasted inflation is significantly higher than actual inflation (by 0.675 pp. for the Colloquia average). While the CNB and the Ministry of Finance (MoF CR) belong to the top-three most accurate forecasters in terms of the ARFE (left column), average deviation of forecasted inflation from the outturn becomes quite substantial in case of the CNB (right column). Notice that this ranking is rather indicative. In statistical terms, the difference between the best and the worst forecaster is not statistically significant. Also, one can see (as expected) that fixed effects alone do not satisfactory explain the forecast errors – the regression's R^2 are close to zero.

Table 2 presents the results for conditional forecast errors. The exchange rate (or more precisely, difference between forecasted and actual CZK/EUR nominal exchange rate changes) and lagged inflation forecast errors turn out to be significant determinants of contemporaneous inflation forecast errors, yielding R^2 of 0.46 for the relative and 0.61 for the absolute conditional forecast errors. Negative and significant coefficient on the exchange rate means that forecasters did not expect the CZK/EUR appreciation. Conditional on the exchange rate and the lagged inflation forecast errors, there is practically no bias in inflation forecasts except three institutions, the CNB being on the margin of significance. From the view point of the conditional absolute forecast errors, the conditional average absolute inflation forecast errors become insignificant for the majority of institutions, with the CNB being marginally significant.

[4] Changes in the money market 3M Pribor yield curve between the forecasts reflect revisions of such forecasts and monetary policy reaction. Podpiera (2008) shows that the 3M Pribor market-implied rates in the horizon of one year in fact coincide with the trajectory of the CNB-model interest rates. Therefore, we assume that the expected development of the CNB and market interest rates does not give rise to inconsistencies in inflation forecasts.

Table 1: Average forecast errors – relative (left) and absolute (right) – Eq. (1) estimated over 2002–2007

	Dependent variable: *RFE*				Dependent variable: *AFE*		
	Method: Pooled Least Squares				Method: Pooled Least Squares		
	Observations: 18				Observations: 18		
	Institutions: 16				Institutions: 16		
	Total observations: 262				Total observations: 262		
	Variable	Coef.	Std. Error		Variable	Coef.	Std. Error
1	ABN-AMRO	0.450*	(0.260)	1	**MoF CR**	0.653***	(0.251)
2	**MoF CR**	0.573**	(0.268)	2	Živnobanka	0.682***	(0.243)
3	**CNB**	0.614**	(0.245)	3	Volksbank CZ	0.691***	(0.235)
4	Živnobanka	0.626**	(0.260)	4	**Colloquia_average**	0.723***	(0.229)
5	Volksbank CZ	0.632**	(0.252)	5	Patria-Finance	0.736***	(0.229)
6	Komerční banka	0.644**	(0.260)	6	ČSOB	0.739***	(0.229)
7	Patria-Finance	0.647***	(0.245)	7	HVB	0.750***	(0.229)
8	**Colloquia_average**	0.675***	(0.245)	8	Česká spořitelna	0.756***	(0.229)
9	Česká spořitelna	0.694***	(0.245)	9	WOOD	0.767***	(0.229)
10	ČSOB	0.712***	(0.245)	10	Komerční banka	0.781***	(0.243)
11	HVB	0.717***	(0.245)	11	**CNB**	0.797***	(0.229)
12	WOOD	0.767***	(0.245)	12	ABN-AMRO	0.813***	(0.243)
13	Liberální institut	0.783***	(0.245)	13	Liberální institut	0.839***	(0.229)
14	Citibank	0.843***	(0.278)	14	Citibank	0.900***	(0.259)
15	Newton	0.875***	(0.278)	15	Newton	1.018***	(0.259)
16	Raiffeisen	0.975***	(0.329)	16	Raiffeisen	1.045***	(0.307)
	R^2		0.012		R^2		0.010
	Adjusted R^2		-0.048		Adjusted R^2		-0.050
	F-statistic		0.205		F-statistic		0.174
	Prob(F-statistic)		0.999		Prob(F-statistic)		1.000
	Durbin-Watson stat		1.818		Durbin-Watson stat		1.953

*Notes: ***, ** and * denote the statistically significant parameters at the 1%, 5% and 10% levels.*

Estimated variables – the relative inflation forecast error (RFE) and the absolute inflation forecast error (AFE) –are regressed on institution-specific constant terms.

Learning-by-doing: both relative and absolute forecast errors exhibit similar time dependence: forecast errors tend to be persistent at the horizon of up to one year (one and two lags correspondingly), due to the fact that forecasters can not realise and learn from their past forecast errors fully as they do not know the entire reality yet. However, at the horizon between one and two years (three to four lags) a reversion occurs; institutions learn from their past errors (they already know the full set of actual realisations), which results in lower current forecast errors.

Next, in order to assess whether there is a change in forecasting accuracy over time, a dummy is added equal to 1 for the period 2004–2007. Negative and significant values of time dummy imply that average deviation of the forecasting errors decreases; this is the case of the CAAFE. For the CARFE, the time dummy is insignificant, signalling that forecast biasedness did not improve over time on average (but the majority of institutions produced unbiased forecasts – after controlling for learning and exchange rate forecast errors).

Table 2: Conditional average forecast errors – relative (left) and absolute (right) – Eq. (2) estimated over 2002–2007

	Dependent variable: *RFE*				Dependent variable: *AFE*		
	Method: Pooled Least Squares				Method: Pooled Least Squares		
	Observations: 17				Observations: 17		
	Institutions: 16				Institutions: 16		
	Total observations: 213				Total observations: 213		
	Variable	Coef.	Std. Error		Variable	Coef.	Std. Error
		-					
	RFE_ER	0.089***	(0.024)		AFE_ER	0.167***	(0.022)
	D_04_07	0.049	(0.244)		D_04_07	-0.414**	(0.209)
	RFE(-1)	0.192***	(0.070)		AFE(-1)	0.231***	(0.059)
	RFE(-2)	0.432***	(0.073)		AFE(-2)	0.312***	(0.065)
		-				-	
	RFE(-3)	0.231***	(0.079)		AFE(-3)	0.238***	(0.072)
	RFE(-4)	-0.139*	(0.077)		AFE(-4)	-0.128*	(0.075)
1	ABN-AMRO	0.269	(0.302)	1	ABN-AMRO	0.289	(0.290)
2	Komerční banka	0.270	(0.379)	2	WOOD	0.311	(0.308)
3	Raiffeisen	0.327	(0.492)	3	Komerční banka	0.369	(0.339)
4	WOOD	0.376	(0.362)	4	Volksbank CZ	0.394	(0.278)
5	Patria-Finance	0.419	(0.332)	5	Patria-Finance	0.426	(0.296)
6	HVB	0.435	(0.355)	6	Živnobanka	0.439	(0.298)
7	Volksbank CZ	0.441	(0.316)	7	HVB	0.451	(0.306)
8	Živnobanka	0.475	(0.343)	8	Raiffeisen	0.465	(0.414)
9	**Colloquia_average**	0.488	(0.332)	9	**Colloquia_average**	0.491*	(0.292)
10	Česká spořitelna	0.509	(0.329)	10	Liberální institut	0.499	(0.304)
11	**MoF CR**	0.509	(0.389)	11	Česká spořitelna	0.508*	(0.291)
12	ČSOB	0.515	(0.331)	12	**MoF CR**	0.522	(0.339)
13	**CNB**	0.537*	(0.323)	13	ČSOB	0.532*	(0.290)
14	Newton	0.553	(0.357)	14	**CNB**	0.555*	(0.300)
15	Citibank	0.722*	(0.390)	15	Newton	0.587*	(0.310)
16	Liberální institut	0.744**	(0.352)	16	Citibank	0.710**	(0.344)
	R^2		0.463		R^2		0.610
	Adjusted R^2		0.403		Adjusted R^2		0.567
	F-statistic		7.826		F-statistic		14.244
	Prob(F-statistic)		0.000		Prob(F-statistic)		0.000
	Durbin-Watson stat		2.371		Durbin-Watson stat		2.237

*Notes: ***, ** and ** denote the statistically significant parameters at the 1%, 5% and 10% levels.*

Estimated variables – the relative inflation forecast error (RFE) and the absolute inflation forecast error (AFE) –are regressed on exchange rate forecast errors, the dummy variable taking the value of 1 for the period 2004–2007, past inflation forecast errors and institution-specific constant terms.

Comparing inflation forecasts of the Ministry of Finance (one of the most successful inflation forecasters) and the CNB, one can notice that both institutions are quite similar (have close ranking) in terms of the CARFE, CAAFE and ARFE. However the difference between these two institutions is pronounced in the case of the AAFE, the Ministry of Finance being characterised by lower average absolute forecast error compared to the CNB. Moreover, the Ministry of Finance's inflation

forecasts are unbiased, while the CNB's forecasts are marginally biased (at the 10% significance level).

Furthermore, comparing the CNB with the Colloquia Average in terms of the conditional forecast errors, the results suggest that the Colloquia Average is unbiased while the CNB turns out to be marginally biased towards inflation over prediction. In terms of the size of the average deviation, the CNB appears to be similar to the Colloquia Average (both exhibit marginally significant average deviation). Nevertheless, given the fact that after controlling for errors in exchange rate forecasts (see CARFE, Table 2), the majority of the institutions produce unbiased forecasts (contrary to the CNB), one can argue that the CNB was not a leader in inflation forecasts during 2002–2007. This conclusion is further confirmed by the results of the conditional average absolute forecast error (CAAFE).

So far, we have interpreted the results in terms of the significance of the forecast errors compared to zero (bias or size of average deviation). In terms of the relative significance of the average forecast errors across forecasters, we conclude that differences in performance of the majority (practically all) of forecasters can not be mutually distinguished on conventional statistical significance levels.

4. CONCLUDING REMARKS

In this paper we performed a comparison of the CNB's accuracy of inflation forecasts with other institutions predicting inflation in the Czech Republic. We used a unique data set of the Macroeconomic colloquia managed by the Czech Ministry of Finance and evaluated the average relative and average absolute forecast errors.

The results suggest that while it is not possible to statistically distinguish among forecasters and the unconditional average forecast errors are significant for all forecasters, some forecasters do perform better in terms of unbiasedness and average deviation of conditional (on exchange rate forecast error and learning) forecasts than others. In particular, the CNB performs slightly worse than majority of professional forecasters by exhibiting a marginally significant bias and statistically significant average deviation in inflation forecasts. So called "herd behaviour" (see Giavazzi and Mishkin, 2006) could be one possible reason making difficult a differentiation of forecast accuracy among the institutions.

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CHAPTER 7

EVALUATION OF THE QUALITY AND SUCCESS RATE OF FORECASTS – A HISTORIC OVERVIEW

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JAN VLČEK

1. INTRODUCTION

This paper sets out to contribute to the debate about the fulfilment of past inflation targets by evaluating the quality and success rate of forecasts as the basis for monetary policy decisions. Furthermore, it strives to identify and sum up the factors underlying deviations from reality in past forecasts. The terms "success rate" and "quality" refer to the degree of fulfilment of the individual forecasts for key macroeconomic variables[1] and thus also of their stories.

The paper deals solely with forecasts produced by the CNB and does not compare them with those produced by other institutions. Therefore, we talk here only about higher or lower success rates of particular CNB forecasts based on comparisons between them. It is up to the reader to decide whether the forecasts can be deemed truly successful or unsuccessful from the external point of view.

The CNB's Monetary and Statistics Department regularly identifies the factors underlying the non-fulfilment of its forecasts and uses such analyses to adjust the forecasting mechanism and its tools. Evaluations of 18-month-old forecasts are contained in an internal document entitled *Evaluation of Inflation Target Fulfilment*. Conclusions from that document are regularly published in the *Inflation Report* in the section "Fulfilment of the inflation target".

The evaluations of the quality and success rate of forecasts submitted here are based on the individual historical *Evaluations of Inflation Target Fulfilment* and involve an overall assessment of the full set of forecasts from the beginning of 2004 until mid-2006[2].

The paper has the following structure. Following a summary of the most important results, the fulfilment of historical forecasts is evaluated. That is done first by simply comparing the forecasts with the actual developments. Next, adjusted forecasts based on knowledge of all factors are discussed and an evaluation of the fulfilment of the historical forecasts is presented in chronological order, year by year. The main part of the text is supplemented with two appendices. Key terms and methodology relating to the creation of adjusted forecasts are described in Appendix 1. Appendix 2 contains a description of the deviations of the original and adjusted forecasts from reality.

2. SUMMARY OF RESULTS

In terms of deviations from reality, the forecasts produced in the period under review deviate on average towards higher inflation, lower real growth and a less appreciated nominal exchange rate. Consistent with that, the implied interest rate path in the forecasts is also, on average, higher than the actual path. The deviations of key macroeconomic variables increase as the forecast horizon lengthens. However, the deviations gradually decrease over time, being largest for the forecasts produced in 2004. By contrast, they are lower in the case of the latest reviewed forecasts dating from 2006.

[1] The paper deals solely with CPI inflation, the growth rate of GDP (or the output gap as the cyclical component thereof), the nominal exchange rate against the euro and nominal interest rates.

[2] Forecasts performed prior to 2004 are not included in the evaluation. At that time, the forecasts resulted from a complex process of integration of medium-term and short-term forecasting methods complemented with expert adjustments. Deducting from such forecasts and identifying errors is not easy and goes beyond the scope of this paper.

Based on an evaluation of the forecasts from 2004 until mid-2006, we have identified three basic sets of factors which have most frequently contributed to the overvaluation of the historical forecasts.

The first set comprises the influence of the settings of equilibrium variables. This set of factors is the one that has contributed most to the deviations of the forecasts from reality in the past. From the *ex-post* point of view, incorrect estimations of non-inflationary output growth and of the rate of equilibrium appreciation of the exchange rate (undervaluation in both cases) and a high past level of equilibrium interest rates caused the deviations in the forecasts. Setting the long-term trends in the forecasts is, and probably will remain, of key importance to their fulfilment. These long-term trends are determined by structural factors and are therefore hard to predict.

The second set consists of the non-fulfilment of some exogenous assumptions and the influence of unexpected shocks. First and foremost is an assumption overestimating the first-round impact of certain tax changes on inflation. Lower actual inflation was also fostered by bumper harvests of some agricultural commodities in 2004 and 2005 and by strong competition among retail chains.

The last set of factors is represented by the miscalibration of some behavioural relationships within the model system, which is the core prediction tool. Based on analyses performed during the period under review, modifications of the model equations resulted mainly in a reduction of the pass-through of energy prices and regulated prices to inflation expectations, which, in turn, led to a reduction in the inflation forecast errors.

3. EVALUATION OF THE FULFILMENT OF HISTORICAL FORECASTS

This chapter deals with the evaluation of the success rate of the forecasts in terms of forecast fulfilment by assessing the predictions for key variables such as inflation, interest rates, exchange rates and real economic activity as described by the output gap. We concentrate our evaluation on the medium-term horizon of 4–6 quarters[3].

The evaluation of the success rate of historical forecasts can be performed by assessing the deviation of the forecasted variables from reality. This evaluation is significantly simplified and does not offer complete information from the forecasters' point of view. A simple comparison of a forecast with the actual outcome of a given variable does not clearly identify the factors underlying non-fulfilment of the forecast. However, such information is important for the development, revision and modification of prediction tools. As part of the forecasting process, procedures have been developed within the CNB to help analyse past forecasts and identify the factors underlying their non-fulfilment. For more details, see *Evaluation of Inflation Target Fulfilment* in Appendix 1.

The factors underlying forecast non-fulfilment are either exogenous or endogenous to the forecasting process. Purely exogenous factors enter the forecasts in the form of assumptions, which are adopted in a relatively mechanical manner. They include in particular external variables such as foreign inflation, interest rates and real economic activity, but also domestic factors, such as assumptions about the development of regulated prices and indirect taxes. The impact of those exogenous factors on forecast non-fulfilment can be described using adjusted forecasts that take into account the actually observed evolution of those factors (see Appendix 1 and the description of the simulation techniques). These forecasts are a standard part of the internal document *Evaluation of Inflation Target Fulfilment* and have been assembled for the entire period under review (see Appendix 2).

[3] The reason for this is the assumption applied when creating the forecasts that there is a lag in the transmission of monetary policy decisions to inflation.

The other group comprises forecast assumptions that are endogenous to the forecasting process. They consist primarily of the settings of the initial conditions of the forecasts and the trends in equilibrium variables over the forecast horizon. As in the case of the exogenous factors, their impact can be evaluated using adjusted forecasts, which this time contain our current view regarding their evolution.

Such an evaluation of the factors underlying the non-fulfilment of forecasts may seem very simple at first glance. Past forecasts are complemented with the actual outcomes of the exogenous variables and the current view about the historical development of cycles and trends. We thus obtain an evaluation of their effect on the non-fulfilment of forecasts. In reality, however, it is impossible to simply compare the adjusted forecasts – based on knowledge of all (exogenous and endogenous) factors – with the actual outturns. This is mainly because of the unconditional nature of the forecasts[4] and the assumption of perfect knowledge of all exogenous variables at the forecast horizon.

The unconditional nature of the forecasts means that monetary policy will always respond to steer inflation towards the target amid the given inflation pressures. If we assume that the adjusted forecast correctly describes, *ex post*, the inflation pressures and that monetary policy responds to keep inflation on target, then the interest rate path, like the forecasts for inflation and other variables, may differ from reality. The reason may be a different *ex-post* rate response compared to the historical *ex-ante* path.

This unconditionality is joined by another major assumption used in the adjusted forecasts – that all changes in factors are fully expected. Such an assumption is unrealistic in reality. If we had known, for example, the present oil price inflation rate or international interest rates last year, the response of the economy, and thus of monetary policy, would have been different.

Therefore, the adjusted forecasts help us evaluate the contributions of individual factors, but they cannot be simply compared with the actual outturns. They allow us to identify the factors underlying the non-fulfilment of forecasts, but they need to be complemented with a detailed knowledge of the story of the forecast.

The historical forecasts, along with a knowledge of their structure and their evaluation, and the adjusted forecasts reveal that a significant proportion of the deviations of the forecasts from reality was due to *ex-post* erroneous assumptions concerning the determination of the trends in the equilibrium real exchange rate, equilibrium real interest rates and equilibrium output as compared with the contemporary view. From the point of view of the forecasting process, therefore, it was due to endogenous factors.

The non-fulfilment of the forecasts was also partly due to exogenous factors, or to assumptions about exogenous variables. Taking into account the actual development of all the exogenous factors entering forecasts, the degree of overvaluation of the inflation forecast at the horizon of 4 to 6 quarters decreases significantly. Knowledge of the actual development of those variables thus significantly assists in enhancing forecast quality as regards the overvaluation of inflation. Also,

[4] The forecast is unconditional in the sense that it includes the reaction of interest rates. It is therefore conditional not on an exogenous assumption about their development, but on the path that is consistent with future inflation at the target horizon.

knowledge of the actual changes to indirect taxes and the actual development of regulated prices would result in higher forecast accuracy.

The following sub-sections deal in more detail with the identification of the factors underlying forecast non-fulfilment. They are based on the internal documents *Evaluation of Inflation Target Fulfilment* and on situation reports describing the individual forecasts. The sub-sections are further broken down by individual years and their conclusions have been generalised. The following sections also contain figures comparing the actual and assumed development of selected variables at the six-quarter horizon. The horizon moves according to when the relevant forecast was produced. In the case of unobservable variables, such as the output gap or equilibrium trends, the January 2008 estimates are shown. Those estimates were made using the forecasting techniques applied by the Monetary and Statistics Department when preparing the January forecast and are consistent with its assumptions. The manner of identification of the individual unobserved variables in the forecasting process is described in the *Inflation Reports*[5] and in *The Czech National Bank's Forecasting and Policy Analysis System* (CNB, 2003).

3.1 Forecasts published in 2004

The inflation forecasts compiled in this period assume growth in inflation pressures and are higher than the actual outcomes. Thus, they imply a need to raise interest rates that is greater *ex-post* than the path consistent with fulfilment of the target (see Appendix 2). According to these forecasts, inflation was to rise as a result of changes to indirect taxes and regulated prices and their pass-through to inflation expectations. In particular, food price inflation was expected to rise as a result of the tax changes. Moreover, these changes were coming at a time of a turnaround in real economic activity into expansion, with the forecasts predicting sharp growth in the output gap. Moreover, the Monetary and Statistics Department was recommending an interest rate rise and communication to prevent a rise in inflation expectations associated with accession to the EU.

Table 1: Assumed/estimated contribution of tax changes to overall inflation in p.p.

	Q1 2004	*Q2 2004*	*Q3 2004*	*Q4 2004*	*Q1 2005*	*Q2 2005*	*Q3 2005*	*Q4 2005*	*Q1 2006*	*Q2 2006*
January 2004	1	0.26	0.13							
April 2004	0.82	0.29	0.05	0	0.05					
July 2004	0.73	0.19	0.19	0	0.3	0.23	0.02	0	0.21	0.21
October 2004	0.73	0.19	0.19	0	-0.02	0.20	0.24	0	0.27	0.25
Estimate	0.73	0.19	0.5	0.03	0	0	0	-0.2	0.25	0.08

The forecasts for inflation, real economic activity, the exchange rate and thus interest rates did not materialise. This was mainly due to lower impacts of the changes to indirect taxes (see the table above) and to faster growth of the supply side of the economy in the form of faster growth in equilibrium output and faster appreciation of the real exchange rate.

As a result of the lower impacts of the changes to indirect taxes, inflation dropped below the inflation target in 2005 and thus ended up well below the forecast. However, the forecasts in that period assumed significant pass-through effects of the changes to indirect taxes and regulated prices

[5] For example, the January 2007 *Inflation Report* with the box "The extension of the core prediction model to include the effect of real wages", the October 2005 *Inflation Report* with the box "Potential output in the CNB's forecasting system", and the January 2005 *Inflation Report* with the box "Inflation expectations in the CNB's modelling system".

to inflation via inflation expectations (see Figure 3). In the case of taxes this pass-through was reduced during 2004, but it took some time before the second-round effects in the forecast were fully eliminated. Based on analyses performed in the period under review, the pass-through of energy prices and regulated prices to inflation expectations was lowered in several steps. This had a major anti-inflationary impact on the inflation forecasts.

Figure 1: Output gap in %

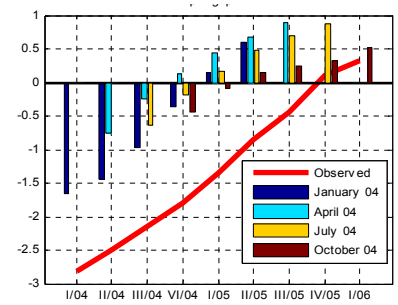
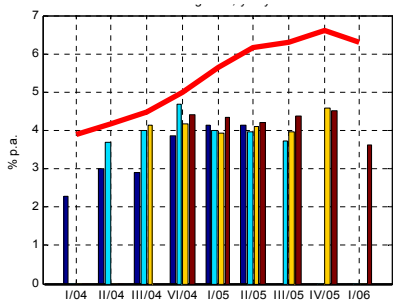


Figure 2: Real GDP growth, y-o-y in %



The overvaluation of the forecast was also due significantly to an erroneous projection of the phase of the business cycle (see Figures 1 and 2). The forecasts made at the time correctly expected an upswing in the growth of real economic activity, but rather through growth in demand, i.e. via the output gap. The growth of the output gap in turn implied significant inflationary pressure at the forecast horizon. In reality, however, inflation did not increase at the forecast horizon, even given relatively high observed real GDP growth. This situation is reflected in a change in the contemporary view regarding the development of the output gap. With the benefit of hindsight, we believe that the output gap had an anti-inflationary effect at the forecast horizon. Given the high real growth, there was thus rather an improvement in the supply side of the economy, i.e. faster growth in equilibrium output. In addition, we observed faster equilibrium real exchange rate appreciation.

Figure 3: Regulated price inflation, y-o-y in %

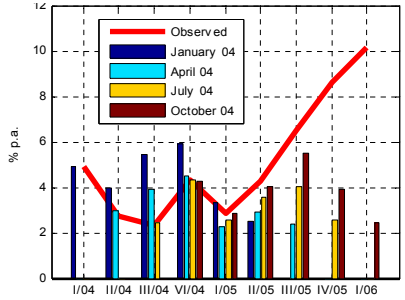
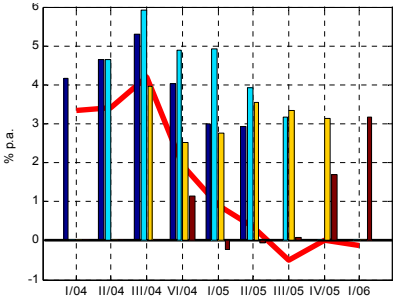


Figure 4: Food price inflation, y-o-y in %



The last significant factor contributing to the forecast error at that time was an *ex-post* incorrect assumption of faster food price growth (see Figure 4). A good harvest, the deferral of a cigarette price hike and, in particular, competition among retail chains kept food price inflation relatively low.

3.2 Forecasts published in 2005

The 2005 forecasts are assessed in relation to the evolution of key macroeconomic variables primarily in 2006. The forecasts for the most closely observed variables, i.e. inflation and interest rates, were fulfilled. The only exception is the final forecast in October 2005, which is well above the outturn. However, if we consider only the first three forecasts that year, their average error is close to zero. There were even forecasts that underestimated inflation.

The fulfilment of the forecasts is consistent with inflation, which was close to the centre of the point target in 2006. Similarly, the evaluation of real economic activity is in line with the contemporary view, although the forecasts for real GDP continued to lag behind the outturns (see Figure 5). Equilibrium output growth (on the supply side) was higher than expected and, as in 2005, correctly assessing and determining the long-term trends remained a problem.

Figure 5: Real GDP growth, y-o-y in %

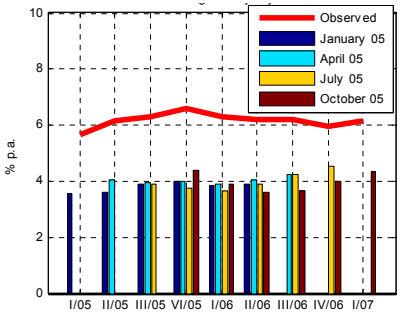
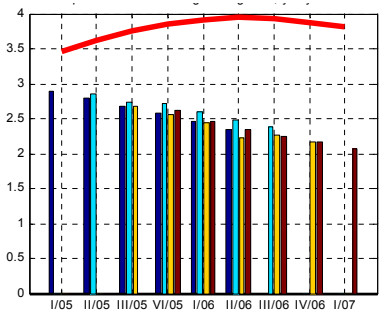


Figure 6: Equilibium real exchange rate growth, y-o-y in %



The assumptions regarding the evolution of economic activity also had implications for the setting of the real equilibrium exchange rate appreciation (see Figure 6). Although the forecasts from this period may seem to be fully in order, they contain a partial error in the exchange rate forecast. The forecasts again did not expect such a sharp appreciation of the exchange rate. Looking at the overall picture, and as regards the recommendations, the forecasts turned out well, as unexpected growth in regulated prices offset the negative contribution to inflation stemming from a downturn import prices and low food price inflation, which had not been envisaged in the forecast (see Figures 7 and 8).

Figure 7: Food price inflation, y-o-y in %

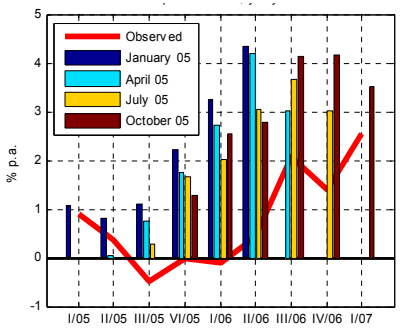
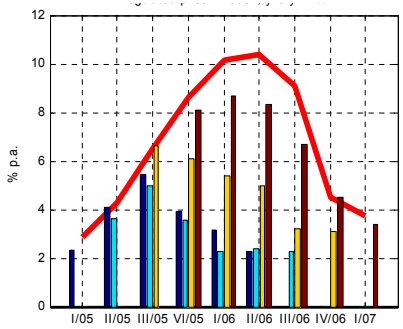


Figure 8: Regulated price inflation, y-o-y in %



The October 2005 forecast is probably the most overvalued forecast in the entire period under review. One possible reason is that this forecast for the first time disaggregated the impacts of the equilibrium real exchange rate appreciation on the components of inflation. It also took into consideration the tradability/non-tradability of each component. Taking into account all of the factors entering the forecast, the overvaluation of the October inflation forecast remains relatively high.

3.3 Forecasts published in 2006

This section only assesses the first two forecasts of 2006, i.e. the January and April ones. At the time of writing, no evaluation had been produced for the remaining forecasts in the form of an *Evaluation of Inflation Target Fulfilment*.

The forecasts from the period under review assumed that inflation would stay close to the point target. In reality, however, inflation dropped significantly in the fourth quarter of 2006 (see Figure 9). In particular, adjusted inflation excluding fuels stayed very low in 2007, while the nominal exchange rate appreciation remained faster than forecasted (see Figure 10).

The nominal exchange rate was thus again the main factor underlying the non-fulfilment of the forecasts. It was accompanied by a significant revision of the impact of changes to indirect taxes on tobacco products. They were substantially lower in 2007 than originally assumed.

The original inflation forecasts, however, are not fully comparable with the observed values, as the weights of the components of the consumption basket, as published by the Czech Statistical Office, were changed in 2007. Observed inflation, retaining the original weights of the CPI basket, remained slightly higher than the actual official data.

Year 2006 can be identified with major changes to the modelling system in historical terms. As mentioned above, the equilibrium variables were revised in order to eliminate their overvaluing effects on the inflation forecasts.

Figure 9: CPI inflation, y-o-y in %

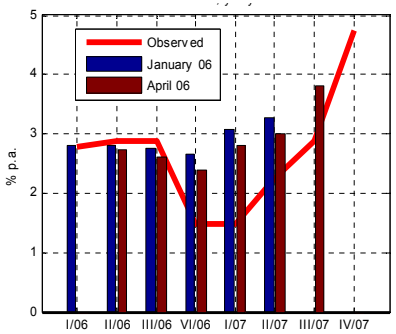
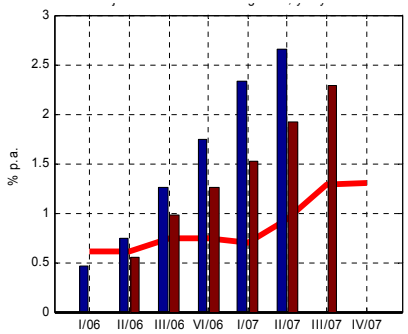


Figure 10: Adjusted inflation exd. fuels, y-o-y in %



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APPENDIX 1: POINTS OF DEPARTURE AND METHODOLOGY

The CNB's official forecasts are produced by the Monetary and Statistics Division, which is responsible for the development, testing, administration, and operation of the overall forecasting system. Since 2004, the main forecasting tool has been a medium-term quarterly cyclical model of a small open economy, the Quarterly Projection Model (QPM)[6]. This model describes the medium-term linkages between key macroeconomic variables such as inflation, the exchange rate, interest rates and real economic activity. It is primarily focused on the transmission process in an inflation-targeting environment.

The forecasts produced by the Monetary and Statistics Division, however, are not created using the QPM alone. They also take into consideration a host of other information going beyond the scope of the model itself. All this information is integrated into the forecasts following detailed deliberations in quite a long and complex process, with discussions taking place between experts of the Section, with the management of the Section, and with members of the Bank Board and their advisers. This is why these forecasts (unlike the pure model forecasts) are referred to as integrated forecasts.

The CNB's official forecasts are updated on a quarterly basis and are described in detail in the situation reports submitted to the Bank Board as an important reference material for its monetary policy decisions. These integrated forecasts are described as historical forecasts in this text. By comparing them with the actual outturns, we calculate the errors in the historical forecasts.

An internal document *Evaluation of Inflation Target Fulfilment* is produced in parallel with the new forecast. This returns to the forecast created six quarters earlier. It is aimed at analysing in detail the causes of (non-)fulfilment of the inflation target. Since monetary policy-making affects the future, rather than the current, course of inflation, the forecasts – in particular of inflation – are the most important criteria for monetary policy decisions. Consequently, a key part of the *Evaluation of Inflation Target Fulfilment* is an evaluation of the quality of the forecasts, where we strive to identify the sources and pinpoint the causes of any deviations of the original forecasts for key variables from the observed outturns.

The final historical integrated forecast is based on a huge number of differing assumptions and settings, or factors. These factors need to be consolidated into several groups for practical reasons. The appropriate consolidation method depends on the circumstances in which the forecast was made. The most important include the forecasting system and the model version, and also the specific hypotheses we want to test. As a result, the groups of factors in the decomposition of the overall changes in the individual forecasts may differ. When drafting the *Evaluation of Inflation Target Fulfilment*, the historical forecasts created 18 months before are modified to include these factors, grouped most often as follows:

- adjustments made to the modelling system between the creation and evaluation of the forecast;
- the actual development of external variables at the horizon of the original forecast (interest rates, inflation, GDP, oil, USD/EUR cross rate);

[6] A detailed description of the QPM, along with the CNB's forecasting and analytical system, is contained in *The Czech National Bank's Forecasting and Policy Analysis System* (CNB 2003).

- new estimates of the equilibrium variables at the horizon of the original forecast (domestic and external real interest rates, real exchange rate appreciation, risk premium, non-inflationary domestic and external output growth, real wage growth);
- the actual impact of changes to indirect taxes at home and abroad at the horizon of the original forecast;
- new assumptions about the effect of fiscal policy on the real economy at the horizon of the original forecast;
- the actual development of regulated prices at the horizon of the original forecast.

Those factors enter the forecast creation process as exogenous variables and monetary policy cannot influence them. However, since they are important for future inflation, assumptions about their evolution are made or forecasted using information from other institutions.

Our methodology applies the core QPM to break down the overall deviation in the forecast according to the effects of the individual groups of factors – artificial forecasts are simulated based on various assumptions about the development of these factors. Unlike with the creation of the forecast proper, replication of the actual forecasting process using various techniques, models and expert knowledge to evaluate the effects of each group of factors is practically impossible and the simulation is performed in a mechanical manner. The results, therefore, must be interpreted with great caution, taking into account the actual content of the relevant historical forecast.

In practice, the evaluation of the impact of the individual groups of factors on the forecast is performed by means of model simulations in which more and more groups of updated factors are added. The method of cumulative changes is thus used. We start with the original historical forecast and incorporate changes in the factors group by group until all of the factors have been fully updated. Under this approach, the effect of changes to a group of factors depends on the changes to the factors made in the previous simulations. Therefore, the sequence of the changes is important when evaluating their impact on the forecast.

By incorporating the changes to all relevant factors into the historical forecasts we arrive at the adjusted (integrated) forecast. The difference between the adjusted forecast and the outturn is referred to the adjusted forecast error.

To express the aforementioned methodology more formally, the forecast of any variable F is a function of a vector of factors (or information subsets) $z = (z^1, \ldots, z^n)$ which form the complete information set used to make the forecast: $F(z)$. The contributions K to the change in the forecast pertaining to the changes in the groups of factors are then:

$$\Delta F = F(z_1) - F(z_0) = \sum_{k=1}^{n} K_k,$$

where $z = (z_i^1, \ldots z_i^n),\ i = 0,1$, with subscripts 0 and 1 denoting the original and updated information subset for the individual groups of factors. $F(z_0)$ therefore denotes the original historical forecast and $F(z_1)$ the resulting adjusted forecast.

Let us assume that the groups of factors are indexed according to the order in which they are updated in the simulations. If we use superscript $-k$ to denote the vector of all variables except the variable with the k-th superscript, we get the following equation for the change in the prediction for variable *F*:

$$\Delta F = F(z_1^1, z_0^{-1}) - F(z_0) + F(z_1^1, z_1^2, z_0^{-1,2}) - F(z_1^1, z_0^{-1}) + \ldots + F(z_1) - F(z_1^{-n}, z_0^n) = \sum_{k=1}^{n} K_k,$$

where

$$K_k = F(z_1^1, \ldots, z_1^k, z_0^{k+1}, \ldots, z_0^n) - F(z_1^1, \ldots, z_1^{k-1}, z_0^k, \ldots, z_0^n).$$

The advantage of the cumulative approach to evaluating the effect of groups of factors on the forecast is that the quantitative impact of the changes in the individual factors sums exactly to the overall change in the forecast without any need to linearise the model. The disadvantage is its above-mentioned dependence on the order of the simulations, which means that the decomposition is not clear and thus makes it more difficult to interpret the results.

From the practical point of view, it is better to start off the decomposition with simulations assessing the impact of changes in the most non-linear factors, such as changes in the modelling system, and then continue with factors whose changes – given the model used – are linear or "almost linear". For subsequent determination of the order, it is more sensible to replicate the order used during the creation of the original forecast, where – for example – the estimate of the domestic initial conditions depends on assumptions regarding external developments.

In seeking the causes of (non-)fulfilment of inflation targets, the adjusted forecasts are objectively a better source of information than the historical forecasts because they are based on the actual development of factors exogenous to monetary policy. The adjusted forecast error eliminates from the original historical forecast error the part which pertains to the deviation of the forecasts for exogenous variables from the outturn. Therefore, the core elements of the adjusted forecast error are:

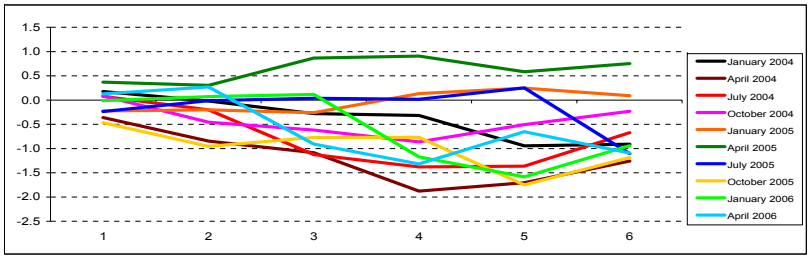
- the omission or incorrect description of key economic processes in the modelling system;
- imperfect capture of ongoing changes in economic elasticities or linkages;
- erroneous *ex-post* identification of economic shocks affecting the economy, leading to incorrect determination of the initial assumptions of the forecasts;
- unexpected economic shocks causing deviations of inflation and other economic variables (in the event of certain unexpected strong shocks, fulfilment of the inflation target is in fact objectively unrealistic);
- adjusted forecast errors also include monetary policy errors (not only in interest rate settings, but also in correct communication of monetary policy to the public).

Yet another factor affecting the size of the adjusted forecast errors is the way in which the *ex-post* model simulations are performed to quantify the effects of deviations of the forecast assumptions from reality. Those simulations assume that the expected evolution of exogenous variables was exactly equal to their *ex-post* observed values. In reality, however, the information set of economic agents changes over time, resulting in a gradual revision of expectations in line with new shocks. Executing all the historical model simulations based on the new information sets in each quarter would be so time-consuming in the current modelling system that it would exceed the time frame of the present study.

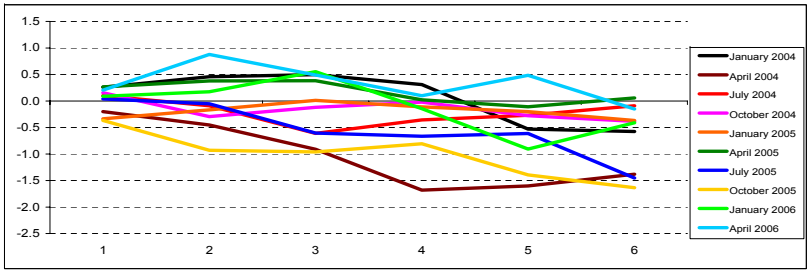
APPENDIX 2: DEVIATIONS OF THE FORECASTS FROM REALITY

FORECASTED AND ACTUAL INFLATION

Inflation y-o-y, Deviations of historical forecasts



Inflation y-o-y, Deviations of adjusted forecasts



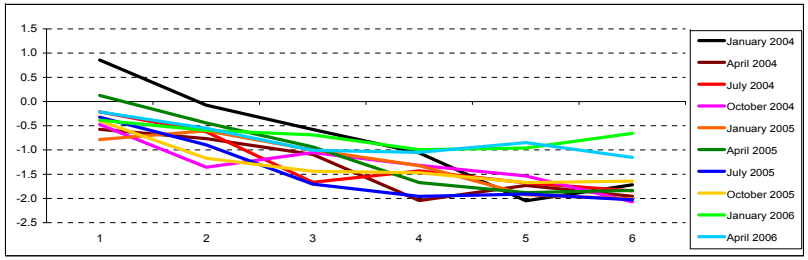
For the inflation forecasts, a relatively good predictive ability can be identified in the first two to three quarters, when the errors of both the historical and adjusted forecasts are close to zero with small standard deviations. As for the forecasts from four to six quarters, the means of both forecasts become more negative. The standard deviation rises in the fourth quarter, but remains almost constant for the rest of the forecast. This is connected with increasing future uncertainty and also with the unconditionality of the forecasts.

The historical forecast deviation chart shows that inflation forecasts deviate slightly upwards, particularly at the end of the forecast horizon. However, the adjusted forecast deviation chart does not show that the inflation estimate deviates systematically over the entire forecast horizon – there are forecasts that are lower than actual inflation and fluctuating around the outturn. In addition, one can identify adjusted forecasts that are higher than the outturn over the entire horizon (the April 2004 and October 2005 forecasts). Despite some deviations, the adjusted forecasts are capable of capturing the dynamics of the development and changes in overall annual inflation.

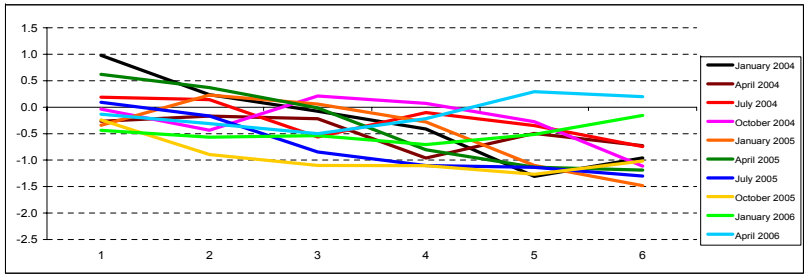
In terms of the size of the integrated forecast error, the April 2004 and October 2005 forecasts can be regarded as the least successful. If we remove those forecasts, we get a significant reduction in the negative deviation (as measured by the mean forecast from the second quarter of the prediction) and a reduction in the standard deviation for both the historical and adjusted forecast errors.

FORECASTED AND ACTUAL EXCHANGE RATE

Exchange rate CZK/EUR, Deviations of historical forecasts



Exchange rate CZK/EUR, Deviations of adjusted forecasts

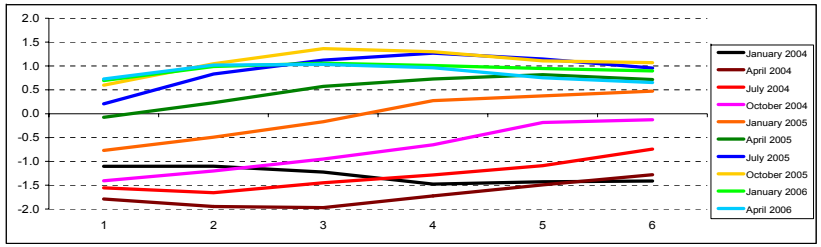


In all the observed historical forecasts, the forecasted exchange rate appreciation deviated unilaterally from the outturn, or – more accurately – the observed rate of appreciation of the nominal CZK/EUR exchange rate was systematically higher than we expected. The largest average difference occurs between the third and the fourth quarter forecasts. In subsequent quarters it declines slightly. The adjusted forecasts show a significant reduction in errors over the entire horizon under review. The adjusted forecast error chart surprisingly shows significant growth in both the average error and the standard deviation for the fifth quarter of the forecast.

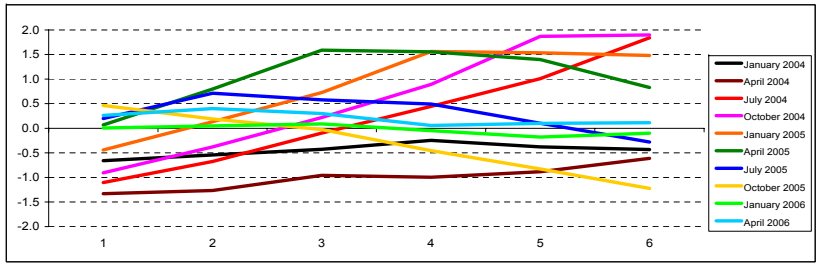
A comparison of the actual outturns and the adjusted forecasts reveals that the forecasts are capable of capturing changes in the rate of appreciation, but are not able to estimate the size of that rate. The latter was significantly higher in reality. The exchange rate forecasts were significantly affected by the assumptions made about the equilibrium real exchange rate appreciation paths and the equilibrium real interest rate levels.

FORECASTED AND ACTUAL OUTPUT GAP

Output Gap, Deviations of historical forecasts



Output Gap, Deviations of adjusted forecasts



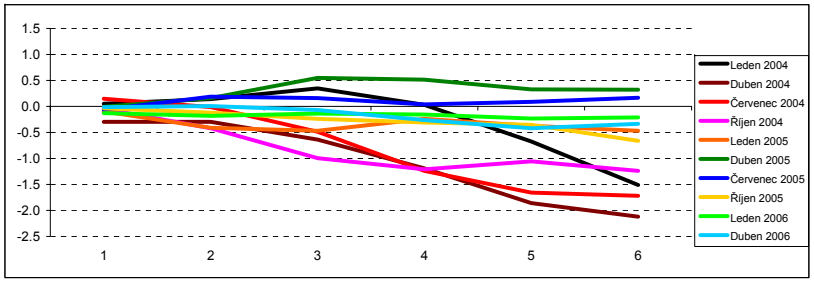
Analysing the output gap is more difficult because we do not know its actual course. We only have more recent estimates, which we believe better reflect the true phase of the business cycle. The output gap now represents the inflation pressures arising from production costs and is one of the two components of real marginal costs. The other is the real wage gap.

The historical forecast deviation chart shows only a moderate downward diversion of the average deviations. The forecast is, therefore, slightly higher than the actual estimate. Ignoring the less successful forecasts in terms of inflation (the April 2004 and October 2005 forecasts), the average forecast error is even lower, while the standard deviation is roughly constant. A comparison of the historical forecasts with the current view regarding the development of the output gap reveals that the forecasts produced until the first quarter of 2005 are above the current estimate of the output gap. In the subsequent period, the forecasted output gaps are mostly lower than the current estimate.

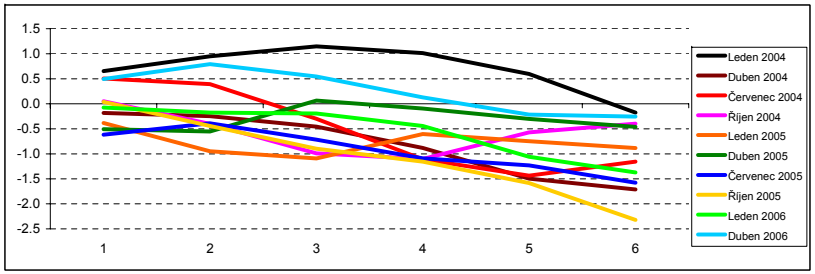
More valuable information is offered by the adjusted forecast analysis. A comparison of the paths of the individual forecasts (excluding the least successful ones) gives a positive mean error. The slower closure of the output gap results from a restrictive fiscal effect in 2004 and 2005 and, on the contrary, an expansive effect in 2006.

FORECASTED AND ACTUAL INTEREST RATE

3M PRIBOR, Deviations of historical forecasts



3M PRIBOR, Deviations of adjusted forecasts



Evaluating the deviations of nominal interest rates from the outturns is no easy task. As mentioned above, monetary policy is endogenous to the forecasting framework and responds to the inflation forecast. Therefore, it works solely with the information contained in the reviewed forecast. In reality, the historical path of rates reflects a gradual process of adjustment to new information and shocks.

As far as errors relating to historical forecasts of interest rates are concerned, there is a clear trend towards negative deviation starting with the second quarter of the forecast. This fact is confirmed by the chart showing the adjusted forecast deviations. Most of the forecasts are higher than the actual interest rates over the entire forecast horizon. This is consistent with the higher inflation forecasts, as higher inflation pressures at the forecast horizons implied a need for a greater tightening of interest rates.

The higher negative deviations of the historical forecasts, especially in the 2004 and 2005 forecasts, were probably influenced by the – from the current viewpoint – incorrect settings of certain model equilibria. The path of equilibrium real rates was at that time assumed to be at higher levels than the economic reality, which meant a higher politically neutral interest rate and consequently also a higher implied path of monetary policy rates. The politically neutral interest rate in this case acts as the equilibrium rate to which the forecasted rate converges (this effect manifests itself at the forecast horizon).

CHAPTER 8

THE HISTORY OF INFLATION TARGETING IN THE CZECH REPUBLIC THROUGH OPTIC OF A DYNAMIC GENERAL EQUILIBRIUM MODEL

JAREK HURNÍK
ONDRA KAMENÍK
JAN VLČEK

1. INTRODUCTION

The inflation targeting regime was effectively introduced by the Czech National Bank (CNB) from January 1998. While, during the first six months of that year, inflation had been staying at the values above the first inflation target published for the end of the same year, it then dropped well below the target during autumn 1998 and CNB subsequently undershoot also its targets declared for year-ends of 1999 and 2000. The first actually hit inflation target was that for the end of 2001. Even introduction of the continuous target since January 2002 failed to bring any clear improvement in its effective fulfilment. Holub and Hurník (2008) report that from January 2002, when the continuous target was introduced, till the end of 2007, inflation moved below its midpoint for some 90% per cent of the period and even below its lower tolerance interval for 51% of the time.

The Czech economy was not the only one among the developing economies that experienced disinflation following introduction of the inflation targeting regime[1], but was probably the only one where inflation moved below the declared inflation targets most of the time once the inflation targeting regime has been introduced. Undershooting of inflation targets was undoubtedly due to many reasons and this paper does not attempt to identify all of them. Instead, it discusses in more detail only one of the possibilities. Or, to put it more precisely, it strives to describe the role that may have been played by monetary policy itself.

Using a dynamic general equilibrium model we therefore analyze monetary policy with respect to its publicly declared inflation target. We base ourselves on a simple assumption that monetary policy may be essentially analysed only with the help of an economic model that itself contains monetary policy, while it holds at the same time that parametrisation of such economic model is independent of monetary policy (Lucas, 1976).[2] A structural economic model, encompassing the central bank behaviour and certain sets of observed economic variables, should be therefore used in order to understand historical development of monetary policy properly. Both the economic model and set of observed economic variables are then used to estimate economic (structural) shocks, including also the monetary policy shock. The heart of the method used thus consists in explaining, with the help of the economic model, the observed dynamics of the economic variables by economic shocks. Such shocks will include e.g. changes in technology, consumer preferences, exchange rate shocks and, also, monetary policy shocks.

Apparently, the course of monetary policy shocks and their impact on the nominal interest rates and inflation are of main interest if monetary policy is evaluated. If any part of the observed realization of nominal interest rates is to be attributed to a monetary policy shock, we conclude that the central bank set the interest rates either above or below the level that would be consistent with the observed state of the economy and published inflation target. An error in monetary policy setting (i.e. a monetary policy shock) occurs whenever the central bank misinterprets the observed state of economy, or, sets the interest rates otherwise than would be consistent with the observed state of economy and inflation target.

With certain lag we then identify an impact of the monetary policy shocks on inflation deviations from the inflation target. That does not mean, of course, that whenever e.g. a positive monetary policy shock may occur, observed inflation would necessarily with some lag appear below the

[1] Battini, Kuttner and Laxton (2005) have documented successes in decreasing inflation in numerous developing economies that introduced inflation targeting at the end of the 1990s or early after 2000.
[2] This condition gains even more on importance when a hypothesis cannot be excluded that monetary policy did actually something else than what it publicly committed itself to.

inflation target. In practice, inflation might as well hit precisely the target or even get above it, as a result of other shocks' impact. The virtue of the method we have applied is that even in such case we are able to estimate impacts of monetary policy shocks and document whether or not monetary policy was set consistently with the declared inflation target. Another advantage of the method consists in the fact that, in order to identify monetary policy shocks, it makes no difference based on what analyses the central bank was actually making decisions. The resulting identification of monetary policy shocks, while subject to specification of the used economic model, is independent of the analytical framework used within the central bank.

It definitely applies on the other hand that identification of monetary policy shocks in itself provides only information as to when the central bank set the nominal interest rates below or above the level consistent with the observed state of the economy and inflation target, without actually revealing why the central bank did so. Certain, however to quite a degree only *weak* conclusions on the reasons may be arrived to through the analysis of other shocks identified at the same time as the monetary policy shock, or, prior or after such a time. If, for example, we identify a strong monetary policy shock together with a counteracting effect of an exchange rate shock both effecting the observed interest rates, we may be able to judge of a slow response of monetary policy vis-à-vis the exchange rate shock. An isolated presence of a monetary policy shock may then actually represent a sign of incorrectly directed interest rates.[3]

Whatever the reason of occurrence of monetary policy shocks, their very existence (in particular if their realization went rather one way) could lead other economic subjects to perceiving the central bank as an institution targeting other inflation target in practice than the declared one. In such case, economic subjects may not perceive the central bank as an institution that makes mistakes when it tries to achieve its inflation target but as an institution that is presumably pursuing another target and that in fact does not make mistakes. Under such circumstances, the inflation target may be qualified as an unobserved variable and estimated along a similar method applied to other unobserved variables.

The rest of the paper is structured as follows: Section 2 contains a more detailed description of the used economic model and estimation method. Section 3 follows up with a description of the estimated results, i.e. an analysis of deviation of nominal interest rates and inflation from their respective long-term values in response to different shocks. Section 4 presents an estimate of the inflation target in the absence of monetary policy shocks and Section 5 summarises all results.

2. THE MODEL AND THE ESTIMATION METHOD

As indicated above, the basic principle of our method consists in identifying economic shocks (directly unobserved) using a structural model of the Czech economy and information contained in the observed variables, where the link between the observed and unobserved variables is represented by the economic model itself. Criteria for the model selection are then defined by the questions we attempt to answer. In our case, analysing the economy under the inflation targeting regime requires that the model includes endogenous monetary policy and fairly reflects its transmission mechanism. The point is that if the monetary policy were absent in the model, expectations of economic subject could not be accurately described (Lucas, 1976). The model should at the same time have a sufficiently rich supply (production) structure to enable its own

[3] Incorrect directing should be understood to also include leaving interest rate at its current level in a situation requiring their change.

calibration based on the observed data and to enable use of information contained within the GDP components.

2.1 Structure of the model

The economy is described using a dynamic general equilibrium model, which was initialy described in Beneš, Hlédik, Kumhof and Vávra (2005), while the version we use, including parametrisation and features, is discussed in detail by Andrle, Hlédik, Kameník and Vlček (2008). In this paper we therefore provide only a verbal description of the key features of the model. The model includes the sectors of households, intermediaries in the financial market, domestic producers of intermediate good, importers of intermediate good, producers of consumption final good, exporters and producers of capital good. Parts of the model are also the central bank and government.

Households consume the final good basket and accumulate capital, lend the capital and supply differentiated labour force to the domestic producers of intermediate good. Further, households directly trade in domestic bonds and, through the financial market intermediaries, also in foreign currency denominated bonds. Households own all firms and, accordingly to their investments, share in the firms' profits. In addition to the corporate profits, households are recipients of government transfer payments. Households wage contracts are rigid, i.e. households cannot re-optimise their wage contracts at each period. Those households that are not enabled to optimise their wage contracts then index their wages to the last observed increase of wages. Finally, households move within the competitive insurance market (Yaari, 1965) that ensures for heterogeneous wages to have no impact on distribution of wealth among the households. This enables to use the representative household concept. During accumulation of capital, i.e. during their investment activity, households face adjustment costs associated with required capital level (Kim, 2003).

Financial market intermediaries operate on the perfectly competitive financial market and their operations are expected to always cover two periods. During their first period, intermediaries obtain funds from households and invest them in the international financial market; in the second period, they close their positions and return invested funds to the households. There are always two intermediary groups in each of the periods, one of them in the first stage of the financial operation and the other one in the second stage. When investing intermediaries face certain transaction costs, which existence is necessary for achieving model stationarity (Schmidt-Grohé and Uribe, 2003). The transaction costs are one of the government revenues.

Domestic producers of intermediate goods hire capital and labour force from households and, while operating on the monopolistically competitive market, each of them produces one type of an intermediate good. For production they use identical technology that involves labour augmenting technological progress. Producers maximise their profit under constraints represented by used technologies, costs of production factors and the non-zero probability that they will be unable to optimise their product price at every period. Differentiated intermediate goods are then combined with no additional costs for a composite intermediate good that is sold to the sector of final consumer and export good producers and sector of government consumption good producers.

In addition to the sector of domestic intermediate good producers, there is also the sector of intermediate good importers included in the model. Each importer combines its imported intermediate good from various foreign goods, prices of which are derived from prices of those goods in respective currencies and the nominal exchange rate. Similarly to domestic intermediate good producers importers of intermediate good face the non-zero probability that they will be

unable to optimise their product price at every period. Imported intermediate good is then sold to the sector of consumer, export and capital good producers.

Final consumption good producers also operate on the monopolistic market and use domestic and imported intermediate goods as production inputs. The proportion in which both types of intermediate good are used is determined by production technology with constant elasticity of substitution. Rigid nominal prices exist in this sector like in other sectors, i.e. producers are unable to optimise their price at each period.

Exporters, too, use both domestic and imported intermediate goods for production, while the proportion of the goods use is again determined by production technology with constant elasticity of substitution. Exporter prices are rigid, like in other sectors, in the foreign currency though. Exports from the local economy compete with exports from various other countries and share imports of the foreign economy. Foreign demand for domestic export goods then may be expressed as a certain share in foreign imports, while the proportion is determined by the relative price of export goods to the price of foreign goods. With respect to the export sector, several different technology trends are additionally adopted and are discussed in more detail in the next section.

Capital good producers use only imported intermediate goods for production. This specification is based on high import share on investment expenditures as well as on our effort to avoid quick overflow of an increased capital accumulation into production of the domestic value added. Likewise in other sectors, producers in this one are unable to optimise their prices every period.

The last production sector includes government consumption good producers. Similarly to the capital good sector, in this sector producers use only a single production input, specifically a domestic intermediate good. Once again, producers are unable to optimise their production price at each period.

The government and central bank represent another two economic subjects present in the model. With respect to the government's revenues side, taxes and transaction costs arising in the financial market and at accumulation of capital are expected to flow in, while on the expenditure side, the government makes transfer payments and purchases government consumption good. The government may accumulate the debt but must guarantee its intertemporal solvency. This is achieved by applying a fiscal rule that adjusts the flow of the government transfer payment in a way ensuring governmental intertemporal solvency. Government consumption is then coupled with household consumption. The central bank is expected to carry out credible monetary policy under the inflation targeting regime. In order to achieve its inflation target, the bank manipulates the nominal interest rate around its neutral value, taking into consideration the current value of the interest rate and responding to expected inflation deviations from the inflation target. Specifically, the central bank responds to deviations of the year-on-year consumer price index growth from the inflation target at a year horizon. Potential impacts of different specification of the monetary rule on the recorded results are discussed in Section 2.4.

2.2 Technology trends and long-term growth

It is important for our method to avoid any ad hoc de-trending of observed time series. Therefore, the model structure is extended for both nominal and technology trends so as to enable direct use of the observed nonstationary time series.

While the nominal trend is a single one and it is determined by targeted inflation, six different real technology trends have to be used for replication of the observed data. Among them, the most important include general labour augmenting technology that enters the production function in the domestic intermediate good producer sector; specific technology of the export sector that maintains competitiveness of exporters in foreign markets; and, specific technology of the investment sector that helps to explain an increase (decrease) in investment share in the gross domestic product.

In addition to the above mentioned real trends, the model employs also a specific trend in labour supply that enables to explain long-term changes in the participation rate; specific technology trend in government consumption good production that helps to explain changes in share of government consumption in the gross domestic product; and, specific technology trend describing changes in quality of export goods. The latter helps to explain observed increase in the share of domestic exports in foreign imports taking place despite no observed change in relative prices of domestic export to foreign prices.

Use of all of the above trends is driven both by economic logic and need to explain observed data of a converging economy. It holds that real variables do not grow necessarily at an identical growth rate, while nominal shares of components of the gross domestic product keep constant.[4] Trend growths of technologies, as well as shocks hitting those growths, are estimated as unobserved variables jointly with an estimate for all other structural shocks.

2.3 Calibrating and testing

Andrle, Hlédik, Kameník and Vlček (2008) discuss in detail the calibration methods and tests of the model based on the data sample for the period from the first quarter of 1996 to fourth quarter of 2007. The main idea followed in model calibration is the 'minimal econometric approach' as suggested by Geweke (1999) and the used methods involve analysis of impulse responses; forecast error variance decomposition; analysis of model properties in time and spectral domains (King and Watson, 1996); and, recursive forecast. Andrle, Hlédik, Kameník and Vlček (2008) report inter alia on the ability of the model to forecast inflation in a 2-year horizon.

2.4 Estimation method

The first step at identifying structural shocks is to solve the model for its reduced form (Blanchard and Kahn, 1980 or Uhlig, 1995), which involves substitution of forward looking (non-predetermined) variables with a linear combination of past shocks. However, given non-linear nature of the used model, its equations have to be log-linearised first.

A reduced-form of the model serves as a starting point for the estimation of structural shocks based on the method of Kalman filtration. The Kalman filter applies a reduced-form of the model extended for measurement equations that map observed variables to the unobserved. Together they represent the 'state description of model'. The form is as follows:

$$y_t = Zx_t + \varepsilon_t \quad (1)$$

$$x_t = Tx_{t-1} + \nu_t \quad (2)$$

[4] Fore more detailed discussion, see Andrle, Hlédik, Kameník and Vlček (2008).

wherein x denotes the vector of unobserved state variables, y vector of observed (measurement) variables, ε is a random vector we call process noise, and v is measurement noise. At that, we assume a Gaussian distribution of random vectors and of x state vector's initial state.

Based on the state form of the model and using observed variables, the Kalman filter identifies all unobserved variables that are part of the model, i.e. including also structural shocks. For linear systems it represents an optimum estimate in terms of the least squares criterion (Hamilton, 1994). Application of the filter itself takes on the recursive algorithm form, wherein the conditional probability density of state variables gets updated based on observed variables. Variables used as observed in estimation are set out in Table 1.

Table 1: Observed variables for structural shock estimates

CPI (index)	Foreign 3M interest rates (EURIBOR)
Regulated prices (index)	Nominal exchange rate (CZK/EUR)
Net inflation (CPI adjusted for regulated prices, index)	Nominal wage (average wage in business sector)
Consumption deflator (index)	Real consumption (index)
Investment deflator (index)	Real investment (index)
Export deflator (index)	Real exports (level)
Import deflator (index)	Real imports (level)
Government consumption deflator (index)	Real government consumption (level)
Foreign prices (PPI, euro area, index)	Foreign demand (real imports of euro area, level)
3M interest rates (PRIBOR)	

The first step of the algorithm under the Kalman filtration is the prediction step. During the step, equation (2) is used to estimate the predictive probability density of states at time t based on the previous conditional probability density at time $t-1$. This probability density is however inexistent in the first period of the data sample and is therefore substituted with a random vector with a mean value and the unconditional variance of state variables as described by the equation (2). Due to the presence of trends within the model and resultanting non-stationarity of certain variables, the unconditional variance does not have a finite value and that is why a diffuse Kalman filter is applied (De Jong, 1991).

The filtration step follows after the prediction step, representing an update of the predictive probability density based on information contained in the observed data. The measurement equation (1) is used for that purpose. Additional information drawn from the observed data enables a refined estimate of state variables, also including estimate of shocks. In addition to the above Kalman filter steps, we use also a smoothing step of the filter which, as apposed to the prediction and filtration steps, uses complete information from the observed data (Harvey, 1989).

Application of the Kalman filter results in identification of unobserved state variables, i.e. including structural shocks. In the next stage the estimated realisations of different shocks are used for historical simulations of the model, with help of which we quantify exact impacts of different shocks on nominal interest rate and inflation. At historical simulation, we therefore simulate impact of each particular estimated realization of shocks (such as the exchange rate shock, shock in regulated prices etc.) on the deviation of nominal interest rates and inflation from their long-term values. While different shocks naturally have different impact directions and strength in particular periods of the data sample, we obtain actually observed realizations of nominal interest rates and inflation by summing up impacts of all shocks.

Hence, a solved structural model with endogenous monetary policy is used to identify structural shocks including monetary policy shocks. Using a particular type of the central bank reaction function may raise doubts as to the robustness of our results with respect to the form and calibration of the central bank's reaction function. In reality, there is no such issue. If we assume that given the structural form of the model we are able to identify absolutely correctly all structural shocks except for the monetary policy shock, then, irrespective of any concrete form of the monetary policy rule, it is the monetary policy shock remaining as the only one to replicate observed data. That is why this shock is determined unambiguously, despite a concrete form of the monetary policy rule.

3. BASIC DECOMPOSITION OF MONETARY POLICY

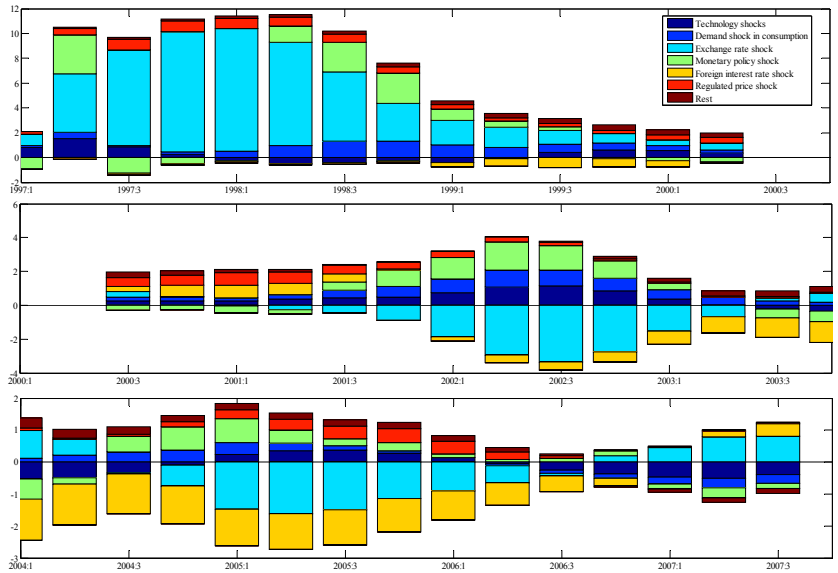
This section provides a detailed description of the historical decomposition of monetary policy, wherein the observed realizations of nominal interest rates and inflation are analysed by impact of different economic shocks. More precisely, we do not analyze effects of shocks on the nominal interest rate and inflation levels but effects economic shocks have on the deviation of nominal interest rate and inflation from their long-term levels. This is what follows from the key assumption of our analysis - that only economic shocks cause deviation of any variable from its respective long-term level. Such long-term level is represented by the inflation target in case of inflation and by the sum of the equilibrium real interest rate and inflation expectations (or, inflation target in the long run) in case of nominal interest rates.

Figure 1 shows the decomposition of nominal interest rates to the contribution of estimated shocks in the period from the beginning of 1997 to third quarter of 2007.[5] Table 2, in order to facilitate orientation, then sets out brief interpretations of those shocks, while Table 3 contains exact numbers for monetary policy shocks. It follows from Figure 1 that the exchange rate shocks were the key determinant for the nominal interest rate setting (its deviation from the long-term level). The other determinants are shocks in foreign interest rates and monetary policy shocks. The latter are crucial for the purpose of our analysis. The monetary policy shock appears in the figure whenever nominal interest rate setting was not fully consistent with the observed state of the economy and inflation target. It also applies that whenever such shock is positive, nominal interest rates were set higher than ideally consistent with the observed state of the economy and inflation target, and vice versa.

The first period following introduction of inflation targeting for which we identify a sequence of positive monetary policy shocks starts as from the second quarter of 1998 and ends with third quarter of 1999. The highest contribution of the monetary policy shock is estimated for the third and fourth quarter of 1998. As a result, we may note that especially in the course of the second half of 1998, monetary policy was set more restrictive than would correspond to the observed state of the economy and inflation target. At the same time, behaviours of the other shocks seem to suggest that the monetary policy shock occurs due to an insufficiently quick response by the central bank to fading pro-inflationary effect of the exchange rate shock. We may but speculate on the reasons for such slow response.

[5] In order to obtain a more robust estimate, we use the data since 1996.

Figure 1: Decomposition of interest rates (deviation from the long-term level in pp)



Source: Own calculation.

Table 2: Basic interpretation of shocks

Technology shocks	Sum of shocks identified in all technology trends.
Demand shock in consumption	Shock identified in household consumption.
Exchange rate shock	Shock identified in the exchange rate equation (the uncovered interest rate parity)
Monetary policy shock	Shock identified in the monetary policy rule.
Foreign interest rate shock	Shock identified in foreign interest rates.
Regulated price shock	Shock identified in the regulated price development.
Rest	Sum of all other identified shocks (such as foreign demand, investments and government consumption).

Table 3: Impact of monetary policy shocks on the deviation of nominal interest rate from its long-term level (in pp)

1997Q1	-0.91	2000Q4	-0.25	2004Q3	0.49
1997Q2	3.13	2001Q1	-0.38	2004Q4	0.74
1997Q3	-1.24	2001Q2	-0.26	2005Q1	0.76
1997Q4	-0.49	2001Q3	0.48	2005Q2	0.40
1998Q1	-0.01	2001Q4	0.95	2005Q3	0.21
1998Q2	1.35	2002Q1	1.26	2005Q4	0.25
1998Q3	2.38	2002Q2	1.68	2006Q1	0.12
1998Q4	2.43	2002Q3	1.44	2006Q2	0.07
1999Q1	0.92	2002Q4	1.02	2006Q3	0.12
1999Q2	0.51	2003Q1	0.36	2006Q4	0.15
1999Q3	0.30	2003Q2	-0.02	2007Q1	-0.13
1999Q4	-0.09	2003Q3	-0.52	2007Q2	-0.31
2000Q1	-0.27	2003Q4	-0.61	2007Q3	-0.17
2000Q2	-0.34	2004Q1	-0.63		
2000Q3	-0.30	2004Q2	-0.19		

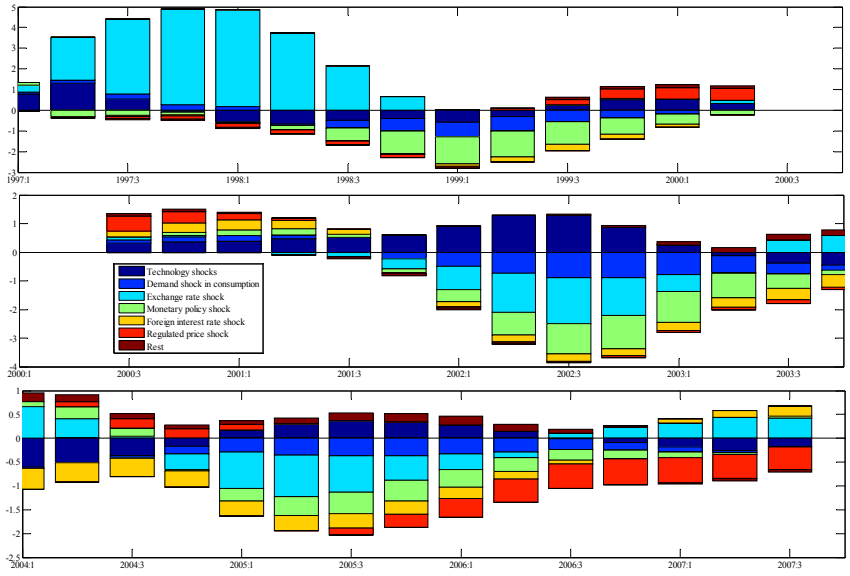
Source: Own calculation.

An explanation may be suggested by considering the monetary policy risk aversion at the inflation targeting regime launch. At that time, monetary policymakers dealt with numerous uncertainties represented by the estimates of equilibrium trends, power of the transmission channel, as well as an inefficient banking sector and underdeveloped financial market. They were probably also aware that had declared disinflation been unsuccessful, any subsequent attempt would have been much more costly. Therefore, the decision to decrease the interest rate more slowly than would be otherwise optimal might have been motivated by the risk aversion that led the monetary policymakers to transferring into the present time a portion of the expected costs of future disinflation attempts.

Figure 2 and Table 4 consistently describe monetary policy as a significant and comparatively long-term factor of a negative deviation of inflation from the inflation target. The above discussed monetary policy shock itself pushes inflation below the inflation target during the period from the second quarter of 1998 to second quarter of 2000, i.e. over the first two years of the new monetary policy regime.

During the second half of 1999 and then until the second half of 2001, we identify no marked monetary policy shocks and even if so, negative ones prevail. We may therefore note that, during that period, nominal interest rates were set consistently to the inflation targets and to the observed economic development.

Figure 2: Decomposition of inflation (deviation from the long-term level in pp)



Source: Own calculation.

However, as may be seen from Figure 1, the situation begins to change in the second half of 2001, during which a marked exchange rate shock hit the economy, followed in addition by another shock of falling foreign interest rates. A positive monetary policy shock arises concurrently to a negative exchange rate shock. This may indicate that the reason behind the monetary policy shock might have been an insufficiently quick response by the central bank. The size of the monetary policy shock rises gradually, while the central bank succeeds in damping the tendency as late as in the third quarter of 2002 when the absolute amount of the monetary policy shock gets decreased, despite the culminating exchange rate shock.[6] The described monetary policy shock then adds to the pressure on inflation decrease below the inflation target, as may be seen from the inflation decomposition in Figure 2 and Table 4. The shock itself ebbs away in the second half of 2003, however its impact on inflation is present until the end of that year.

The period from the third quarter of 2003 to second quarter of 2004 is the time of negative monetary policy shocks. Nominal interest rates were kept lower during the period than would have been consistent with the observed state of the economy and inflation target. We identify the most marked negative shock in the first quarter of 2004, during concurrent effects of a positive exchange rate shock.[7] In the third quarter of 2004, a positive monetary policy shock however appears once again and survives, albeit very modestly, until the first quarter of 2006. Identically to the previous

[6] The interest rates were decreased by 0.75 pp in July 2002. During the first half of 2002, CNB was additionally making efforts to stop the exchange rate appreciation by interventions in the foreign exchange market.

[7] In the first quarter of 2004, a temporary depreciation of the koruna peaked, recording the average 32.90 CZK/EUR in that quarter.

example, the positive monetary policy shock is accompanied by a negative exchange rate shock. As opposed to the previous period, exchange rate shocks rather tend to follow after a monetary policy shock. As may be seen in Figure 2, while a positive monetary policy shock occurs in the third quarter of 2004, a negative exchange rate shock follows only in the fourth and subsequent quarters. That might suggest that the central bank itself could possibly partly contribute to the exchange rate shock occurrence as the foreign interest rate caused a strong pressure on the low level of domestic interest rates during that period.[8] It is therefore possible that the observed state of the economy was not entirely accurately assessed in the made analyses or monetary policy decision, or, that monetary policy setting was adjusted at the point of time that was already unsuitable for that.

Table 4: Impact of monetary policy shocks on the deviation of inflation from its long-term level (in pp)

1997Q1	0.14	2000Q4	0.12	2004Q3	0.17
1997Q2	-0.31	2001Q1	0.20	2004Q4	-0.03
1997Q3	-0.24	2001Q2	0.23	2005Q1	-0.26
1997Q4	-0.12	2001Q3	0.11	2005Q2	-0.40
1998Q1	-0.04	2001Q4	-0.12	2005Q3	-0.45
1998Q2	-0.20	2002Q1	-0.42	2005Q4	-0.43
1998Q3	-0.61	2002Q2	-0.77	2006Q1	-0.37
1998Q4	-1.09	2002Q3	-1.04	2006Q2	-0.29
1999Q1	-1.29	2002Q4	-1.16	2006Q3	-0.23
1999Q2	-1.27	2003Q1	-1.08	2006Q4	-0.19
1999Q3	-1.08	2003Q2	-0.85	2007Q1	-0.12
1999Q4	-0.79	2003Q3	-0.51	2007Q2	-0.03
2000Q1	-0.47	2003Q4	-0.17	2007Q3	0.04
2000Q2	-0.20	2004Q1	0.11		
2000Q3	0.00	2004Q2	0.25		

Source: Own calculation.

Looking more closely at the recorded results, one cannot leave unnoticed the fact that the impact of monetary policy shocks on inflation is more persistent than the very existence of the shocks. Out of 39 observed periods (counted from the first quarter of 1998), monetary policy acted more anti-inflationary during 30 periods (and, to a comparatively limited extent at three out of these observations, i.e. less than 0.1 pp) that would have been consistent with the observed state of the economy and inflation target.

Whatever the reasons for the behaviour, an argument may be certainly made that the economic subjects, based on their own observations, might gradually begin to perceive the central bank as asymmetric in terms of meeting the published inflation target. In such case, economic subjects, instead of feeling about the central bank as an institution that, while making mistakes, nevertheless keeps on following its declared inflation target, would perceive it as an institution that in fact pursues another target without actually making many mistakes. In the next section, we therefore discuss the inflation target estimate as an unobserved (state) variable under the circumstances where the central bank monitors the state of the economy and avoids mistakes at monetary policy setting, while perceived as such by other economic subjects.

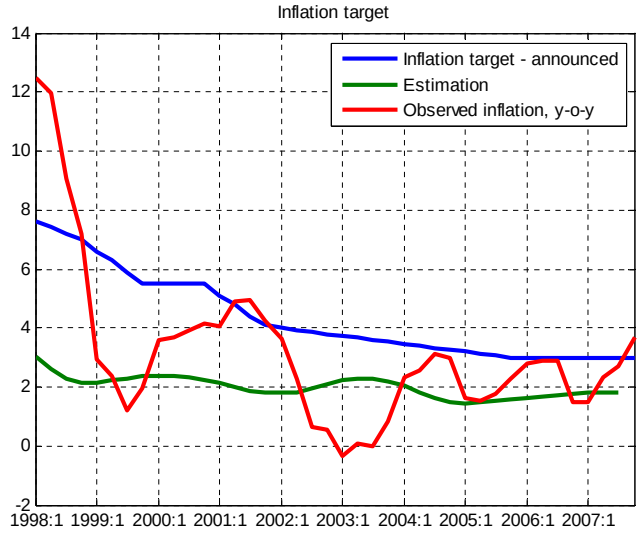
[8] In August 2004, the interest rate was increased by 0.25 pp. The decision to increase it followed the July forecast that was consistent with an rising trajectory of interest rates (See the Inflation Report of July 2004).

4. INFLATION TARGET AS AN UNOBSERVED VARIABLE

Prior to entering the discussion of the estimate, we should however repeat that an inflation target estimated using the above described methodology represents a target perceived by the economic subjects as the central bank's real target, while it is at the same time also the target truly pursued by the central bank. Obviously, an ideal approach would be to estimate an implicit inflation target understood by the economic subjects as the one followed by the central bank, while the bank would in fact follow the formally declared target, while mistakes (monetary policy shocks) would be allowed. The present economic literature on heterogeneous expectations and information, however, has been making its first strides and is so far unable to provide a sufficiently robust toolkit for practical application with real data.

Figure 3 presents the inflation target estimate together with the declared target and inflation. The estimate robustness is at the same time derived from the stability of estimates for other unobserved variables (technology trends, in particular), compared with the situation where the target is observed and monetary policy mistakes are allowed. In other words, the robustness and reliability of the estimate is derived from an identical estimate of the business cycle.

Figure 3: Inflation, declared inflation target and its estimate (in %)



Source: Own calculation.

It may be seen at once that the estimated target moves below the declared target level throughout the period under review, while the absolute difference between the two is decreasing over time. The beginning of the estimate may be naturally affected by quite quick observed disinflation during 1998 and 1999 as well as by our approximation of the inflation target, as the target was in fact

declared for net inflation, for the respective year-ends and as a corridor in addition to that.[9] Since 2002, when an explicit continuous trajectory of the inflation target came into existence, the estimated target moves within the band of 2 and 3%. The estimated inflation target may be interpreted as an explanation for the central bank behaviour at the same estimation of the business like in previous case and in the absence of mistakes in monetary policy implementation.

5. CONCLUSIONS

The inflation targeting regime was effectively introduced by the Czech National Bank since the beginning of 1998 and, already during the autumn of that year, observed inflation fell markedly below the inflation target published for that year-end. Inflation targets defined for respective year-ends were repetitively undershoot also in 1999 and 2000. Holub and Hurník (2008) further report that from January 2002, when the continuous target was introduced, till the end of 2007, inflation moved below the target for some 90% per cent of the period and for 51% of the time even below its lower tolerance interval.

The above outline history of fulfilling the inflation targets necessarily evokes the question of reasons for their undershooting, including obvious emphasis on the role of monetary policy itself. This paper has attempted to provide an answer to the question from the perspective of a dynamic general equilibrium model, designed and calibrated to fit the Czech economy data.

The strong conclusion of our analysis consists in the estimation of structural economic shocks that indicates more restrictive monetary policy during three periods since the beginning of 1998 than would have been consistent with the observed state of the economy and declared inflation target. The first period lasted from the second quarter of 1998 to first quarter of 1999, the second period from the third quarter of 2001 to the second quarter of 2003 and the third period from the third quarter of 2004 to the end of 2005. For one period, we identify more relaxed monetary policy, specifically from the third quarter of 2003 to the second quarter of 2004.

The weak conclusion is represented by our view that, in the first instance, the most probable reason was a slow response to an already fading previous pro-inflationary shock, and, in the second instance, a slow response to an exchange rate appreciation shock in progress, and, in the third instance, erroneous directing of interest rates during a period that was no longer justifying such a step.

Given comparatively frequent observations of the positive monetary policy shocks in the past, it is conceivable that the inflation target as perceived by the economic subjects deviated from the inflation target declared by the central bank. While the latter hypothesis cannot be tested following an entirely correct approach, our experiment with an unobserved inflation target may provide certain degree of approximation. The inflation target oscillating between 2 and 3% in the period since 2002 is conveniently suitable for explaining the central bank behaviour though such an optic.

[9] Detailed description of the history of the CNB's inflation targets may be found in Kotlán and Navrátil (2003) or, more recently, in Holub and Hurník (2008). The approximation of the inflation target in headline inflation prior to 2002 is based on the targets published for net inflation. To the midpoints of these targets (the targets were declared as a corridor), 1 pp is added as an estimated average contribution made by regulated prices to the headline inflation, while the targets are interpolated to individual quarters using a linear trend (the targets were declared for the year-ends).

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CHAPTER 9

ASYMMETRIC MONETARY POLICY IN THE CZECH REPUBLIC?

ROMAN HORVÁTH

1. INTRODUCTION

One of the reasons for undershooting inflation targets may be in the application of the asymmetric monetary policy. The central banks, which perform inflation targeting, usually define *de iure* their inflation targets in a symmetric manner, i.e., the intensity of the monetary policy response is independent of whether the deviation of inflation from the target has been positive or negative. Nevertheless, there are several reasons why the monetary policy may be *de facto* asymmetric. For example, after the introduction of the inflation targeting regime, particularly under higher initial inflation rate (i.e., the case faced by the CNB), the central banks may justifiably fear difficulties with the anchoring of inflation expectations (risk of a credibility loss), which may lead them to apply asymmetric handling of inflation targets. Such asymmetry would in practice mean that the central banks would "increase their rates more if their inflation forecasts were 1 percentage point above the target, rather than reducing them if the inflation forecasts were 1 percentage point below the target".[1]

Asymmetric monetary policy is typically quantified by an estimation of the monetary policy rule (see e.g., Cukierman and Muscatelli (2008), Petersen (2007) or Taylor and Davradakis (2006)), i.e. by a test of whether the rule differs in relation to whether such inflation forecasts were above or under inflation targets (i.e., a test of the existence of so-called non-linear monetary policy rule). This paper estimates the CNB monetary policy rule, making use of the data relating to 1998Q1–2007Q3, and it provides an quantitative analysis of whether the monetary policy *ceteris paribus* responded with more aggressively with interest rates if the model inflation forecasts exceeded the target (i.e., there was the risk of non-anchoring of inflation expectations) that when the inflation forecasts were under the inflation target.[2]

The estimates of the monetary policy rule indicate that – following the introduction of inflation targeting – the CNB responded in a more aggressive manner to forecasts of inflation above the target. Such asymmetry, however, is not visible if the estimates of the monetary policy rule are carried only with the application of more contemporary data (approx. 2002–2007). Therefore, it can be claimed that currently symmetric handling of inflation targets prevails.

As shown by estimates of monetary policy rules performed by other central banks, asymmetric monetary policy does not seem to be so exceptional. Quantitative evidence on this topic show that, e.g., the monetary policy applied by Fed in the Grenspan era was asymmetric in that the Fed would apply a more aggressive response to inflation development if the inflation rate should exceed a certain threshold. A similar asymmetry has been identified also in the behaviour of the Bank of England in the 1990's, which responded in a more intense manner to the development of inflation, as long as its forecast was significantly higher than the inflation target.[3]

The paper is structured as follows. Section 2 describes the econometric model, data, and related literature. Section 3 presents the estimates of the monetary policy rule. The conclusion follows, as well as an annex containing a derivation of the monetary policy rule.

[1] Alternatively, it would be possible to assess whether a central bank responds faster or with a higher probability.
[2] We also make an assessment of whether the monetary policy responded in an asymmetric manner to interest rate forecasts.
[3] See e.g., Petersen (2007) for the Federal Reserve Bank, and Taylor and Davradakis (2006) for the Bank of England.

2. DATA DESCRIPTION AND MODEL

We use data from 1998Q1 to 2007Q3 (i.e., 39 observations) for the following variables: inflation forecasts and interest rates, model inflation target derived form QPM[4], the CZK/EUR exchange rate, the output gap, 3M PRIBOR and 1Y Euribor. In the period of 2002Q2–2007Q3, inflation forecasts come from the baseline QPM scenarios, while forecasts relating to the period of 1998Q1–2002Q1 come from estimates presented in the then current CNB Situation Reports, which are available on the CNB web site (see http://www.cnb.cz/cs/menova_politika/br_zapisy_z_jednani). The other data have been drawn from the baseline QPM scenarios (an internal CNB database).

Non-linearity of the monetary policy rules is tested as follows:

$$i_t = (1-\rho)\left[\alpha + \beta_1 \pi_{above} + \beta_2 \pi_{below} + \gamma X_t\right] + \rho i_{t-1} + \varepsilon_t \qquad (1)$$

where π_{above} is defined as: $\pi_{above} = \pi^f_{t/t+4} - \pi^*_t$, if $\pi^f_{t/t+i} > \pi^*_t$, otherwise $\pi_{above} = 0$. Inflation forecasts in time *t* for 4 quarters ahead (the choice of such horizon reflect the CNB monetary policy horizon for 4–6 quarters and data availability) is marked as $\pi^f_{t/t+4}$ and π^*_t denotes the QPM model inflation target. Similarly, π_{below} is defined as follows: $\pi_{below} = -(\pi^f_{t/t+i} - \pi^*_t)$, if $\pi^f_{t/t+i} < \pi^*_t$, otherwise $\pi_{below} = 0$. Deducting $\pi_{above} - \pi_{below}$, we get a time series of the differences of inflation forecasts from the target ($\pi^f_{t/t+4} - \pi^*_t$). Thus, it is a simple decomposition of the difference of the inflation forecasts from the target into two parts: inflation forecasts above the target (π_{above}) and inflation forecasts under the target (π_{below}). These two variables are shown in Figure 1.

X_i represents all other variables (the exchange rate, output gap, and foreign interest rates, i.e., those variables, which have been most often incorporated in estimates of the monetary policy rules in the empirical literature), i_t denotes 3M PRIBOR, α can be interpreted in certain specifications of monetary policy rules as a policy neutral rate, and ε_t represents a residuum.[5] If neither the exchange rate nor foreign rates are included in vector *X* in Equation 1 (thus, only the output gap, or no variable at all is inserted), this coefficient can be interpreted as a policy neutral rate. If the central bank conducts monetary policy in an asymmetric manner, Equation (1) implies that $\beta_1 \neq \beta_2$. More formal derivation of the monetary policy rule can be found in an annex to this paper.

We are aware of the issues related to changes from conditional forecasts to unconditional forecasts in 2002, when – in the latter case – long-term inflation always is directed to the target thanks to the built-in response of the monetary policy. Contrary to unconditional forecasts, conditional forecasts do not contain any monetary policy response and it is presumed that the interest rates are fixed at

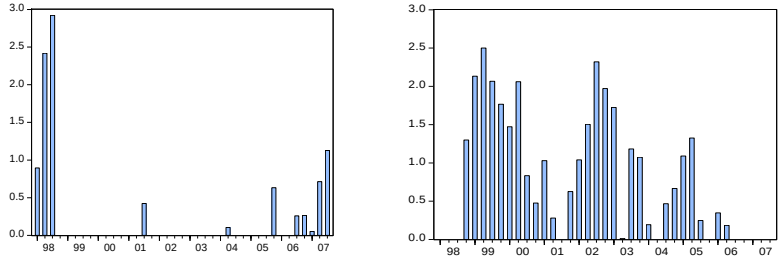
[4] QPM – Quarterly Projection Model – is the main forecasting model applied by the CNB, made use of since 2002Q2. For a detailed description of the model see Coats *et al.* (2003).
[5] The current empiric records of estimates of monetary policy rules for the Czech Republic can be identified in the following papers: Horváth (2008) and Podpiera (2008). The issue of no-linear monetary policy rules is discussed in detail in Cukierman and Muscatelli (2008).

the current level. That indicates the possibility of a major difference between inflation forecasts and inflation targets along the monetary policy horizons. Still, even following the change to unconditional forecasts, Figure 1 shows that inflation forecasts in the horizon of 4 quarters differ from inflation targets, which is caused to a certain extent by the application of the institute of exemptions (they are mainly shocks on the supply side). This is why the paper further presents two sensitivity analyses, where – one – we apply forecast horizon 1Q instead of forecast horizon 4Q, which has not been affected by the change from conditional forecasts to unconditional forecasts, and – two – we estimate the reaction function with forecast interest rates. Yet another argument in support of such sensitivity analyses may be that the public did not distinguish enough between conditional and unconditional forecasts, and that inflation forecasts at the more distant forecast horizons might have been especially uncertain at the beginning of inflation targeting in the course of transition of the Czech economy.

In view of the fact that forecasts performed in transitional economies may be more uncertain than in more stable macroeconomic environments, it also would be of interest to note here exactly what role has been played by uncertainty in monetary policy decisions. Brainard (1967) claims that higher uncertainty in forecasting would rather support cautious monetary policy characterised by a greater degree of interest rate smoothing. On the other hand, Srour (1999) presents a model, which shows that in case of several uncertain parameters in the forecasting apparatus it is difficult to say whether a monetary policy response should be more aggressive or more cautious. For more details about relationships between uncertainty and monetary policy, please, see Šmídková (2003).

Figure 1: Inflation forecasts above target (π_{above}) and under target (π_{below})

π_{above} = forecast – target, if forecast > target, otherwise 0. *π_{below} = – (forecast - target), if forecast < target, otherwise 0.*



Notes: π_{above} shows by how many percentage points inflation forecasts were above the targets in the given quarter (e.g., the left part of the figures shows that the 1998 inflation forecast was approx. 1–3 percentage point above the target). If forecasts were not above the target then the value of π_{above} equals zero. Similarly, π_{below} shows by how many percentage points the forecasts were below the targets (e.g., in 1999, it is obvious that the forecast was approx. 1.5–2.5 percentage point below the target). If forecasts were not below the target lower then the value of π_{below} equal zero. All in all, Figure 1 shows that inflation forecasts for 4 quarters ahead were more often below the (model) inflation target.

Other authors in this stream of literature estimate similar rules and model the Taylor Rule as asymmetric, either in inflation (e.g., Dolado et al., 2004, Bec et al., 2002), or in output, or in both of the varaibles at the same time, (e.g., Surico, 2007, Boinet and Martin, 2008). Some other authors capture asymmetry by adding, e.g., squared variables (e.g., Dolado et al. 2004), or they assume that the coefficients may differ within the monetary policy rules, depending on some threshold values, e.g., whether the economic growth was positive or negative, (Surico, 2007, Boinet and Martin, 2008, Bec et al. 2002).

Probably the most similar methodology as applied in this paper can be found in Davradakis and Taylor (2006), Bec et al. (2006), and Gredig (2007). It can be pointed out that the empirical methodology contained in this paper represents a special case of Davradakis and Taylor (2006). Davradakis and Taylor (2006) model the Taylor Rule using three regimes. One, if inflation is close to the target, the interest rate is not changed. Two, if inflation is sufficiently above the target, the central bank increases the rates. Three, if inflation is sufficiently below the target, the central bank reduces the rates. Contrary to Davradakis and Taylor (2006), our rule would not include the first regime (i.e., the changes would not occur if inflation is close to the target) and we take into consideration only the remaining two regimes. It is worth pointing out that Davradakis and Taylor (2006) apply data from the United Kingdom and their number of observations is three to six times higher, which in principle allows them to identify a higher number of regimes. Similarity between our methodology and that applied in Bec et al. (2002) is primarily based on the assumption of a known threshold value (Bec et al., 2006 assumes whether an economy was hit by recession or not, while our thresholds value (threshold) assumes whether inflation forecasts were above or under the target). Gredig (2007) estimates the asymmetric Taylor Rule, which to a large extent is identical with our methodology; the difference is in that our methodology would allow for an asymmetric response towards inflation, the Gredig model facilitates asymmetric response to inflation, the output gap, as well as to the interest rate smoothing (if asymmetric response to the output gap and the interest rate smoothing is not allowed, both models would be almost identical). Gredig (2007) estimates this rule in the case of Chile, based on monthly data relating to the years 1991–2007 (the disadvantage of this approach is, understandable, in the construction of the output gap on a monthly basis although the GDP data are available only on a quarterly basis).

Equation (1) has been estimated by the least squares. The least squares approach can be generally applied if the explanatory variables are not endogenous. In the opposite case, the parameters based on the least squares estimation would not be consistent. The least squares then can be applied to the Taylor rules if the value of the explanatory variables have been known before the monetary policy meeting (i.e., inflation forecasts and output gap in real time, lagged interest rates) or if the explanatory variables are exogenous (foreign interest rates for a small open economy), see Orphanides (2001). The output gap variable, unfortunately, is not available in real time (its regular reporting did not begin until mid-2002, following the introduction of the QPM), and therefore it may be endogenous, same as the exchange rates. Since the methods of instrumental variables is known that it can exhibit large small sample bias (see e.g., Ramalho, 2005), we lagged the output gap and the exchange rate by one period.

An alternative manner of evaluation of the asymmetric monetary policy may also be represented by an analysis of responses of monetary policy to interest rate forecasts and how those responses differ when such interest rate forecasts have headed higher or lower than the previous forecasts (i.e., whether the impact of reassessment of interest rate forecasts has been symmetrical). This is why we estimate Equation (2), which tests whether the monetary policy responses depend on the direction of reassessment of the level of interest rates (towards higher or lower rates):

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \beta_1 i_{above} + \beta_2 i_{below} + \varepsilon_t \qquad (2)$$

where i_t denotes 3M PRIBOR, i_{above} is defined as: $i_{above} = i^f_{t/t+i}$, if $i^f_{t/t+i} > i^f_{t-1/t+i-1}$, otherwise $i_{above} = 0$. The interest rate forecasts in time *t* for *i* quarters ahead is denoted as $i^f_{t/t+i}$ (in this analysis, *i* equals either 1Q or 4Q). Similarly, i_{below} is defined as follows: $i_{below} = i^f_{t/t+i}$, if $i^f_{t/t+i} < i^f_{t-1/t+i-1}$, otherwise $i_{below} = 0$. Thus, this is a simple decomposition of the interest rate forecasts into two parts, which reflect the direction of reassessment of the interest rates. A sum of $i_{above} + i_{below}$ gives back the time series of the forecasts of rates, $i^f_{t/t+i}$. Equation (2) has been estimated by the least squares because all explanatory variables are known prior to monetary policy meeting.

3. RESULTS

The results of the estimates of the monetary policy rule are reported in Table 1. The coefficient of variable π_{above} is larger in all four specifications than the coefficient of variable π_{above}, and – with the exception of one single specification – we reject the zero hypothesis of equality of the coefficients ($\beta_1 = \beta_2$) of those variables. Therefore, the results indicate that the responses to the monetary policy were more aggressive if inflation forecasts were heading above the target than when the forecasts were heading under the target.

The sensitivity of results is assessed by the inclusion of other explanatory variables (the exchange rate, output gap, and foreign rates). We find that the output gap is not significant. According to the results in column (3), the appreciation of the exchange rate has been associated with lower interest rate. Similarly, lower foreign interest rate contributes lower domestic interest rate. Of course, it is not possible to interpret the statistical significance of the two last mentioned variables as if the CNB monetary policy responded directly to the development of the exchange rates and foreign interest rate, it rather means that those variables affect in significant manner inflation forecasts, which enter the reaction function of the CNB. A policy neutral rate (coefficient α in columns 1 and 2) usually fluctuates around 3%, which is the value that approximately complies with the QPM values as well as the estimates contained in Horváth (2008). The estimated degree of interest rate smoothing in the amount between 0.5–0.8 has been slightly higher that the QPM and the estimates contained in Horváth (2008), which estimate the smoothing parameter around 0.4.

Table 1: Estimates of the non-linear monetary policy rule, 1998–2007

Do the CNB interest rates respond more if the inflation forecasts are above target than if they are below target (i.e., is the coefficient of π_{above} higher than the coefficient of π_{below} ?)

	(1)	(2)	(3)	(4)
3M PRIBOR (t-1)	0.50*	0.80***	0.71***	0.46
	[0.27]	[0.05]	[0.30]	[0.30]
α	3.28***	2.99***	-22.7***	-0.21
	[0.89]	[0.69]	[4.95]	[1.19]
π_{above}	4.69***	2.58***	2.41***	4.35***
	[0.84]	[0.57]	[0.38]	[0.71]
π_{below}	0.47	1.13*	0.82**	0.61
	[0.73]	[0.92]	[0.633]	[0.68]
Output gap (t-1)		-0.22		
		[0.25]		
Exchange rate (t-1)			0.51***	
			[0.07]	
1Y EURIBOR				1.02**
				[0.40]
$\beta_1 = \beta_2$ [F-statistics]	33.3***	1.78	7.02**	41.8***
[p-value]	[0.00]	[0.18]	[0.00]	[0.00]
No. of observations	39	39	39	39
Adj. R^2	0.60	0.66	0.97	0.61

*Notes: Standard errors robust to autocorrelation and heteroskedasticity shown in brackets below the estimated parameters. *, **, *** denotes significance at 10, 5 and 1 level. The lower part of the table presents of the result of the test of the null hypothesis $\beta_1 = \beta_2$, i.e., whether the monetary policy has been symmetric.*

As an additional sensitivity analysis we present in Table 2 the estimates of the rule with inflation forecasts for 1 quarter ahead (instead of 4 quarters). Our conclusions relating to asymmetry of monetary policy does not seem to be affected by the change of the forecasting horizon. Carrying out such sensitivity analysis is relevant in particular due to the change from conditional forecasts to unconditional forecasts in 2002. It can be presumed that the resulting inflation forecasts for 1 quarter would be affected by such change to a substantially lesser extent that forecasts for 4 quarters (short-term forecasts do not have a built-in monetary policy response, which would have contributed to the return of the inflation back to target). Moreover, if we compare adj. R^2 for the rule with 4Q forecasts vs. 1Q forecasts (see Tables 1 and 2), we can see that adj. R^2 has been higher for the rule with 1Q. Therefore, the rule with forecasts for 1Q seem to represent a legitimate sensitivity analysis.

Table 2: Estimates of non-linear monetary policy rule, 1998–2007, sensitivity analysis (forecast horizon 1Q instead of 4Q)

Do the CNB rates respond more if inflation forecasts are above target than if they are below target (i.e., is the coefficient of π_{above} higher that the coefficient of π_{below} ?)

	(1)	(2)	(3)	(4)
3M PRIBOR (t-1)	0.34*	0.75***	0.66***	0.29
	[0.21]	[0.06]	[0.06]	[0.21]
α	3.12***	3.19***	-8.05**	-0.54
	[0.55]	[0.51]	[3.46]	[0.70]
π_{above}	3.37***	2.00***	1.72***	3.20***
	[0.56]	[0.26]	[0.13]	[0.50]
π_{below}	0.24	0.26	0.32**	0.41
	[0.33]	[0.44]	[0.12]	[0.27]
Output gap (t-1)		-0.03		
		[0.17]		
Exchange rate (t-1)			0.36***	
			[0.11]	
1Y EURIBOR				1.02***
				[0.19]
$\beta_1 = \beta_2$ [F-statistics]	30.5***	14.1***	43.5***	38.2***
[p-value]	[0.00]	[0.00]	[0.00]	[0.00]
No. of observations	39	39	39	39
Adj. R^2	0.83	0.98	0.98	0.86

*Notes: Standard errors robust to autocorrelation and heteroskedasticity shown in brackets below the estimated parameters. *, **, *** denotes significance at 10, 5 and 1 level. The lower part of the table presents of the result of the test of the null hypothesis $\beta_1 = \beta_2$, i.e., whether the monetary policy has been symmetric.*

In this regard, another hypothesis comes up, namely, whether monetary policy asymmetry would change in time, i.e., the CNB might rather perceive the risk of unanchored inflation expectations as relevant after the introduction of inflationary conduct than at present. To evaluate any potential changes in asymmetry over time, we remove consecutively the first four observations in our sample (i.e., we perform so-called regression of the 1998–2007, 1999–2007, 2000–2007, 2001–2007, and 2002–2007 data)[6] and we also perform estimates using the data relating to the years 1998–2002. As far as this issue is concerned, we opt for an estimate of a very simple monetary policy rule (due to the low number of observations):

$$i_t = \alpha + \beta_1 \pi_{above} + \beta_2 \pi_{below} + \nu_t \qquad (2)$$

[6] Alternatively, recursive estimates of the parameters of the monetary policy rule have also been examined, nevertheless, standard errors in estimates were too large to assess any potential changes in asymmetry over time. The same applies also in the event of estimates of model with time-varying parameters.

This rule would thus assume that the central bank responds explicitly only to inflation. Although this rule may seem to be simplified at the first glance, we need to be aware that an absence of any other macroeconomic values needs not necessarily mean that they would be ignored. Those values enter into the rule at least indirectly because they affect the inflation forecasts (Taylor, 2001). An advantage of this rule, understandably, is a lower number of estimated parameters required; a disadvantage may be in a weaker relationship to the actual conduct of monetary policy (e.g., missing interest rate smoothing).[7]

The results of the estimates of such monetary policy rule from Equation (2) are presented in Table 3. Statistically significant asymmetry can only be noted in connection with the data from 1998–2007, if we ignore the first year of observations in the time series, the asymmetry cannot be identified any further. In order to assess the sensitivity of the results, we also estimate the given monetary policy rule in respect of the data from 1998–2002, which confirms that asymmetric monetary policy can be noted only in the period immediately after the introduction of inflation targeting. Similarly, the resulting values of R^2 show that asymmetry was present only in the initial years of inflation targeting. While R^2 has been relatively high for the estimates relating to the years 1998–2002 and 1998–2007, the R^2 value considerably decreases for any other specifications. That means that our non-linear/asymmetric monetary policy rule captures the behaviour of variables relatively well for the data belonging to the beginning of inflation targeting while afterwards the fit of the monetary policy rule worsens. In view of the low number of observations, uncertainty naturally prevails as regards the robustness of the results; still, it is possible to sum up that asymmetric handling of inflation targets has been relevant only at the beginning of the period following the introduction of inflation targeting (approx. 1998–2002).

The results in Table 3 also show estimates of a policy neutral rate (coefficient α). That rate has fluctuated moderately under 3% if data relating to the years 1998–2007 were applied. If only the 1998–2002 data were applied, the results indicate higher rates, namely around 6.3%. This visible decline of a policy neutral rate in time complies with the estimates in the QPM and Horváth (2008), which apply different methods in the estimation of a policy neutral rate.

An estimate of Equation (2), which assesses potential asymmetric handling of the interest rate forecasts, is presented in Table 4. In order to facilitate the assessment of sensitivity of the results, we present our basic specifications of Equation (2), which differs in relation to whether we include lagged interest rate (i_{t-1}) and in relation to the forecast horizon of the interest rate forecast (1Q vs. 4Q). The results rather support the hypothesis of symmetric handling of the rates forecasts, even though two specifications indicate that it would be more important for the monetary policy in the interest rate forecasts were reassessed in direction to lower rates, rather than vice versa. Although the difference between the coefficients reflecting the effect of the direction of such re-assessment may be statistically significant (see equality test $\beta_1 = \beta_2$ in Table 1, columns 1 and 3), this seems to be marginal from the economic point of view. Moreover, if we also include the lagged interest rate, there is no different response identified even from the statistical point of view in respect of any reassessment of the rates. Therefore, the results suggest that monetary policy responses to the direction of reassessment of the interest rate forecasts are probably be symmetric, which supports our previous conclusions, namely, that the handling of inflation targets was symmetrical in the 2002–2007.

[7] Although a vivid debate exists in literature about the extent of the interest rate smoothing. Several authors (e.g., Rudebush, 2006) recently stressed that the extent of the interest rate smoothing has been low and many empirical approaches tend to overestimate its extent.

Table 3: Estimates of the simplified monetary policy rule: Asymmetry in time?

Do the CNB rates respond more if inflation forecasts are above target than if they are below target (i.e., is the coefficient of π_{above} higher than the coefficient of π_{below} ?)

Period	1998–2007	1999–2007	2000–2007	2001–2007	2002–2007	1998–2002
α	2.40***	2.54***	2.91***	2.77***	2.18***	6.33***
	[0.76]	[0.64]	[0.64]	[0.50]	[0.13]	[1.67]
π_{above}	4.58***	0.75	0.21	0.42	0.77***	3.49***
	[0.56]	[0.70]	[0.59]	[0.40]	[0.20]	[0.73]
π_{below}	1.48**	1.19**	0.43	0.18	0.39**	0.38
	[0.64]	[0.59]	[0.41]	[0.26]	[0.16]	[1.04]
$\beta_1 = \beta_2$ [F-statistics]	11.6***	0.67	0.16	0.37	1.79	18.5***
[p-value]	[0.00]	[0.41]	[0.69]	[0.55]	[0.19]	[0.00]
No. of observations	39	35	31	27	23	20
Adj. R^2	0.48	0.23	0.05	0.01	0.11	0.56

*Notes: Standard errors robust to autocorrelation and heteroskedasticity shown in brackets below the estimated parameters. *, **, *** denotes significance at 10, 5 and 1 level. The lower part of the table presents of the result of the test of the null hypothesis $\beta_1 = \beta_2$, i.e., whether the monetary policy has been symmetric.*

Table 4: Asymmetric monetary policy depending on direction of reassessment of interest rate forecasts?, 2002–2007

	(1)	(2)	(3)	(4)
i_t		0.18*		0.55***
		[0.10]		[0.06]
i_{above}	0.94***	0.78***	0.39***	0.31***
	[0.06]	[0.11]	[0.07]	[0.11]
i_{below}	1.01***	0.80***	0.49***	0.32***
	[0.06]	[0.13]	[0.08]	[0.13]
$\beta_1 = \beta_2$ [F-statistics]	5.51**	0.65	4.88**	0.21
[p-value]	[0.03]	[0.43]	[0.04]	[0.65]
No. of observations	21	21	21	21
Adj. R^2	0.90	0.92	0.57	0.93

*Notes: Standard errors robust to autocorrelation and heteroskedasticity shown in brackets below the estimated parameters. *, **, *** denotes significance at 10, 5 and 1 level. The lower part of the table presents of the result of the test of the null hypothesis $\beta_1 = \beta_2$, i.e., whether the monetary policy has been symmetric. Columns (1) and (2) based on the interest rate forecasts for horizon 1Q, columns (3) and (4) for horizon 4Q.*

4. CONCLUSIONS

This paper deals with the topic of asymmetric handling of inflation targets by estimating of the monetary policy rule. The results indicate that, following the introduction of inflation targeting, the CNB responded in a more aggressive manner to inflation forecasts heading above the target. That asymmetry, however, is vanishing if we estimate the monetary policy rule only using the contemporary data (approx. 2002–2007). Therefore, inflation target handling has been deemed as symmetric over the several past years.

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APPENDIX: DERIVATION OF THE MONETARY POLICY RULE [8]

The initial step in the formal derivation of the monetary policy rules is represented by an assumption that the central bank targets to set the nominal interest rate in line with the state of the economy , as in Equation (1):

$$i_t^* = \alpha + \beta\left(E\left\{\pi_{t+i}\middle|\Omega_t\right\} - \pi_{t+i}^*\right) + \gamma E\left\{x_t\middle|\Omega_t\right\} \qquad (3)$$

i_t^* denotes the target interest rate, α is a policy neutral rate, π_{t+i} represents a forecast of the year-on-year inflation rate of the central bank for *i* periods ahead, π_{t+i}^* means the inflation target of the central bank, x_t represents the output gap, $E(.)$ is the expectation operator, and Ω_t denotes the information set, which is available at the time of the monetary policy decision. This is why Equation (1) connects the target nominal interest rate and the constant (i.e., interest rate – policy neutral rate –, which occurs if the expected inflation hits the target and there is a zero output gap), the difference between the expected inflation and the inflation targets and the output gap.

Nevertheless, it is often claimed that Equation (3) has been too restrictive because it does not consider the interest rate smoothing. Clarida *et al.* (1998) assume that the central bank would adjust step by step its interest rates to the target value due to several reasons. For example, the central bank may worry about the financial stability in the event of any major changes of the interest rates, or uncertainty has often been underscored in relation to the impact of changes of interest rates on the real economy.

Instead of explicit incorporation of all potentially relevant factors of interest rates smoothing, Clarida *et al.* (1998) assume for the sake of simplicity that the actual monetary policy rate represent a combination of their lagged and target values, as shown by Equation (4).

$$i_t = \rho i_{t-1} + (1-\rho) i_t^* + \nu_t \qquad (4),$$

where $\rho \in [0,1]$. In line with Clarida *et al.* (1998), we would substitute Equation (4) to Equation (3) and eliminate unobservable forecast variables, and thus we arrive at Equation (5):

$$r_t = (1-\rho)\left[\alpha + \beta\left(\pi_{t+i} - \pi_{t+i}^*\right) + \gamma x_t\right] + \rho r_{t-1} + \varepsilon_t \qquad (5)$$

It is interesting to note that ε_t denotes a combination of forecast errors, and that it thus is orthogonal towards all available information in time *t* (Ω_t). Since Equation (5) has not been estimated by GMM but with the least squares method, we would keep inflation forecast instead of an actual future inflation. The standard form of the monetary policy rule, therefore, is as follows:

$$i_t = (1-\rho)\left[\alpha + \beta\left(\pi_{t+i}^f - \pi_{t+i}^*\right) + \gamma x_t\right] + \rho i_{t-1} + \varepsilon_t \qquad (6)$$

[8] For further information regarding monetary policy rules, please, see – e.g., Horváth (2008) and Podpiera (2008).

where i_t denotes 3M PRIBOR, α is a politically neutral rate, π^f_{t+i} represents year-on-year inflation rate forecast by the central bank for *i* period ahead, π^*_{t+i} is the inflation target of the central bank, x_t represents the output gap, and ε_t denotes residuum. Let us denote $k = \left(\pi^f_{t+i} - \pi^*_{t+i}\right)$. We would define π_{above} as: $\pi_{above} = \pi^f_{t/t+i} - \pi^*_t$, if $\pi^f_{t/t+i} > \pi^*_t$, otherwise $\pi_{above} = 0$ and $\pi_{below} = -(\pi^f_{t/t+i} - \pi^*_t)$, if $\pi^f_{t/t+i} < \pi^*_t$, otherwise $\pi_{below} = 0$. Then k can be decomposed into two parts, π_{above} and π_{below}, as follows: $k = \pi_{above} - \pi_{below}$. If the monetary policy is symmetric, it will be valid that $\beta k = \beta_1 \pi_{above} + \beta_2 \pi_{below}$ (i.e., $\beta_1 = \beta_2 = \beta$). A simple asymmetry test is then to examine whether $\beta_1 = \beta_2$.

CHAPTER 10

REASONS OF UNDERSHOOTING THE INFLATION TARGET IN THE CZECH REPUBLIC: THE ROLE OF INFLATION EXPECTATIONS

ROMAN HORVÁTH

1. INTRODUCTION

The inflation targeting regime was introduced in the Czech Republic 10 years ago and there has been still a comparatively limited number of empirical studies explicitly attempting any evaluation as to whether and how such monetary policy regime has actually contributed to anchoring of the inflation expectations.[1] The key purpose of this article is to estimate an extent to which the CNB's inflation target and monetary policy have been impacting the inflation expectations, particularly in relation to frequent undershooting of the inflation target.

The "hypercredible" inflation target hypothesis, under which a 1 pp reduction would induce a decrease of inflation expectations by more than 1 pp in the long term, represents one of the inflation target undershooting options. Lower inflation expectations of economic subjects would then contribute to inflation stabilisation at the values below the inflation target. The inflation target, according to our econometric analysis, is a major determinant of inflation expectations, albeit nothing to support the "hypercredible" inflation target hypothesis has been found.[2] Relying on the 1999–2007 data, our estimates have indicated that the 1 pp reduction of the inflation target would be on average accompanied by a 0.4 pp drop of the financial market inflation expectations for the inflation expectations during the 12-month horizon, and, by a 0.6 pp drop for the inflation expectations over the 36-month horizon.

This article also addresses relationships between inflation expectations, the target and other macroeconomic variables over a short-time period, using the impulse response analysis and variance decomposition within the block restriction vector autoregression model.[3] We identify a statistically relevant decrease of inflation expectations in response to the stricter monetary policy and to the lower inflation target. The performed econometric analysis has on the overall indicated the credibility of the CNB's monetary policy. While the key determinant of inflation expectations is represented by the foodstuff prices in the short term, it is the inflation target that impacts the inflation expectations development in the longer term. On the overall, the results indicate that the CNB's monetary policy has anchored the inflation expectations.

The article is structured as follows: Section 2 contains a brief outline of the econometric model and data. Section 3 presents the results and Section 4 summarises the conclusions. An Appendix with additional results follows afterwards.

[1] The empirical literature typically analyzes the inflation target impact on other macroeconomic quantities (such as: development of – expected – inflation and GDP) or their characteristics (such as volatility or persistence of inflation). Mishkin and Schmidt-Hebbel (2006), for example, have analysed an impact of inflation targeting on the level of inflation, as well as intensity of inflation response to various shocks. Levin *et al.* (2004), Vega and Winkelried (2005) and Yigit (2007) have examined if introducing an inflation target has lowered the persistence and volatility of inflation. Johnson (2002, 2003), de Mello and Moccero (2006) and Cerisola and Gelos (2008) have evaluated the inflation target impact on the level of expected inflation. Holub and Hurník (2008) base themselves on the Czech data to examine creation of inflation expectations in general, Holub (2008) addresses the role of the target undershooting in inflation expectations, Babetskii, Coricelli and Horváth (2007) and Franta, Saxa and Šmídková (2007) have inter alia analysed the impact introducing the inflation target on inflation persistence.

[2] Another possible reason why the inflation expectations moved frequently below the inflation target may be seen in building-in of a significant exchange rate appreciation into the inflation expectations for 2002–2003. The foregoing channel is dealt with by the article "Inflation deviations from the CNB's targets – their reasons and impacts on the inflation expectations" in these proceedings.

[3] This restriction, in particular, disables a response of the inflation target to other variables; see the econometric model description in Section 2.

2. ECONOMETRIC MODEL DESCRIPTION

2.1 Vector error correction model

We have employed the vector error correction model (VECM) by Johansen and Juselius to evaluate the existence of a long-term relationship between the inflation target and inflation expectations, and other macroeconomic variables.

In the matrix form, the so-called reduced form VECM has the following form:

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{p} \Pi_i \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

where y_t denotes the vector of variables, ε_t vector of residuals, μ vector of constants and Π_i is the matrix of parameters to be estimated.[4] We estimate several specifications that differ depending on which variables are included in y_t. The simplest specifications include only the inflation expectations, target and actual inflation, while the most comprehensive ones include the following variables: $y_t = \left[\pi_t^*, \pi_t^{com}, \pi_t^{food}, \Delta s_t, \pi_t, \pi_t^{\exp}, i_t\right]$. π_t^* denotes the CNB's inflation target (for the period during which the target was published only as a band, the mean value of the range is considered, while for the period during which the target was set as net inflation, respective values are adopted from the CNB's main prediction model - the QPM), π_t^{com} represents commodity price inflation, π_t^{food} denotes foodstuff price inflation, Δs_t is the exchange rate change, π_t means the CPI inflation, $\pi_t^{\exp}$ denotes the market inflation expectations for 12, or, 36 months forward, and i_t means 3M PRIBOR.

2.2 Vector autoregression model under block restrictions

We have employed block restriction vector autoregression (Zha, 1999, Lutkepohl, 2005) to analyse short-term dynamic relations of the inflation target and inflation expectations – the model is defined as follows:

$$\begin{bmatrix} y_t^1 \\ y_t^2 \end{bmatrix} = \begin{bmatrix} A_{11}^1 & 0 \\ A_{21}^1 & A_{22}^1 \end{bmatrix} \begin{bmatrix} y_{t-1}^1 \\ y_{t-1}^2 \end{bmatrix} + \ldots + \begin{bmatrix} A_{11}^1 & 0 \\ A_{21}^1 & A_{22}^1 \end{bmatrix} \begin{bmatrix} y_{t-p}^1 \\ y_{t-p}^2 \end{bmatrix} + \begin{bmatrix} e_t^1 \\ e_t^2 \end{bmatrix} \qquad (2)$$

where vector $y_t^1 = \left[\pi_t^*\right]$, i.e. the vector includes only the CNB's inflation target, while vector y_t^2 includes the remaining variables, i.e. $y_t^2 = \left[\pi_t^{com}, \pi_t^{food}, \Delta s_t, \pi_t, \pi_t^{\exp}, i_t\right]$. The above block restriction prevents the inflation target from responding to the development of other variables.[5] The block

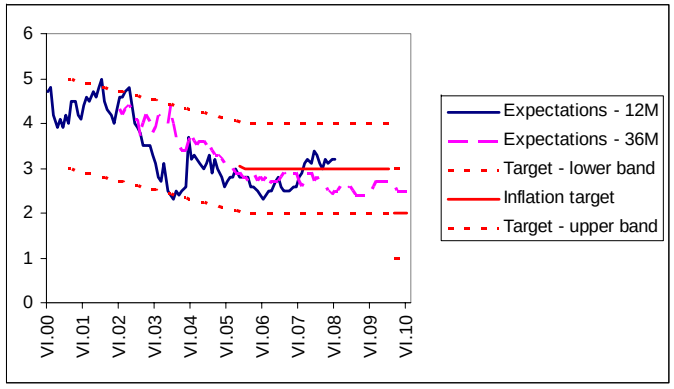
[4] We determine the VECM model lags in a standard manner, using the Schwarz information criterion (SIC). In our case, the number of lags equals 1 or 2, subject to specification of the variable vector.

[5] A similar set of variables has been used by Holub and Hurník (2008) that, too, has addressed the inflation expectations analysis, using a simple vector autoregression model. In our paper, we have additionally introduced an inflation target under block restrictions which enables us to explicitly analyse the inflation target impact on inflation expectations. Since monthly-frequency data are used in the empirical section, no explicitly cyclical element has been included in the variable vector. Otherwise, a quarterly output gap to the monthly frequency would have had to be interpolated in order to set up a time series that would contain 2/3 of "artificially" generated observations, which is particularly problematic in dynamic models of the VAR type, as

restriction consequently means that the other variables within vector autoregression, such as foodstuff inflation in month *t-1* cannot influence the level of inflation target in month *t*. This restriction is motivated by aiming at creating the inflation target exogenous in short-term to all other macroeconomic variables and to have a more realistic VAR model as a result. The advantage of the method consists in its lower demands for the degrees of freedom, as a smaller number of parameters are estimated. A publicly accessible CNB's ARAD database has been used as the data source (see http://www.cnb.cz/cnb/STAT.ARADY_PKG.STROM_KOREN).

For this article, we have employed the monthly data from June 1999 to June 2007 on the financial market inflation expectations over the 12-month and 36-month horizons, from the surveys carried out by CNB.[6] The financial market inflation expectations over 12 and 36 months compared to the inflation target are shown in Figure 3. Obviously, the expectations have moved within the target, or, tolerance band in the long term, however the 36-month horizon expectations have stabilised under the point target. The question naturally is to what extent the inflation expectations held by the financial analysts may be taken as an indicator of the economy-wide inflation expectations. Given a high correlation (see Footnote 9) of the analyst inflation expectations and those of the corporate sector an assumption may be made that our employed expectations are representative of at least the corporate sector. The assumption is further supported by the estimate derived from the two-equation VAR model including inflation expectations of both companies and analysts and indicating that the analyst expectations have a statistically significant impact on the corporate expectations (the results may be obtained upon request).

Figure 1: Inflation expectations (12- and 36-month horizon) and the inflation target



Note: The inflation 12- and 36-month expectations have been shifted forward by 1 and 3 years respectively to compare with the CNB's inflation target.

such "artificially" set up observations would have been regressed for themselves. A procedure like that could induce the spurious regression problem. Industrial production used sometimes in the literature is too much volatile to reflect the cyclical conditions.

[6] No earlier data are available. CNB also carried out quarterly surveys of inflation expectations of firms and households. We do not use the latter data for several below reasons. Firstly, the survey is taken only quarterly which considerably limits the number of observations, econometric results of which would have been certainly adversely affected by that (much higher uncertainty of estimates). What is more, inflation expectations of the corporate sector are tightly correlated with the financial market expectations (the correlation has recorded 0.93 in our data sample). Inflation expectations of the households significantly diverge from reality and their correlation with future real inflation in our data sample was insignificant.

3. RESULTS

A long-term relationship (so-called cointegration vector) of the inflation expectations and other variables is presented in Table 1.[7] It is apparent from the Table that an increase of the inflation target by 1 pp was accompanied by a drop of inflation expectations by approx. 0.3–0.5 pp over 12 months. In the 36-month horizon, the estimate indicates a somewhat higher value, by about 0.6 pp. Further, we can see that a long-term relationship exists of the development of overall inflation and inflation expectations. In addition, Table 1 points to the fact that the exchange rate appreciation was accompanied by lower inflation expectations. It follows from the estimated coefficients that the exchange rate appreciation by 1 pp was accompanied by a drop of inflation expectations by approx. 0.03 or 0.04 pp, a surprisingly low impact. We can also see that the interest rate setting is related to the inflation expectations. Higher rates may be expected during the higher inflation expectation periods (even though the relationship is statistically insignificant for the 36-month horizon expectations). Foodstuff price inflation is not significant for the inflation expectations development in the long-term (while it is significant in the short term, see below). Commodity price inflation, too, appears not highly relevant for the inflation expectation creation in the long-term horizon (the relationship is not statistically significant in one case, while it is significant in another, but the estimated coefficient has the opposite sign), which is not exactly surprising given the variable's volatility.

Table 1: Inflation expectations and the inflation target, a long-term relationship, 1999–2007

	Inflation expectations - 12-month horizon			Inflation expectations - 36-month horizon		
	(1)	(2)	(3)	(4)	(5)	(6)
Inflation target	0.55***	0.32*	0.33**	0.58***	0.58***	0.62***
	[0.16]	[0.18]	[0.15]	[0.02]	[0.03]	[0.15]
Commodity inflation			-0.01**			-0.004
			[0.005]			[0.003]
Foodstuff price inflation			-0.05			0.001
			[0.04]			[0.05]
Rate change			0.03**			0.04***
			[0.01]			[0.01]
Inflation		0.45***	0.21**		0.05**	0.17**
		[0.12]	[0.08]		[0.02]	[0.08]
3M PRIBOR			0.37***			0.12
			[0.11]			[0.10]
Number of observations	94	94	94	94	94	94

*Note: Standard errors in the parentheses below the estimated parameter. *, **, *** denotes the significance at 10, 5 and 1 per cent level.*

[7] Relevant tests have indicated the existence of a single cointegration vector.

Next, we present estimates below for the above described block restriction VAR model, in a standard form of impulse responses and variance decomposition (as noted above, this model, as opposed to the previous model, is better suited to analyse short-term relationships). Figure 2 shows the impulse response by the inflation expectations to the shock caused by the remaining variables within our model. As the results imply, lower inflation target induce the inflation expectations to decrease in a statistically significant manner (see the image top left of the Figure), which suggests that the CNB's inflation target had been anchoring the financial market inflation expectations over the period under review (which supports the conclusions arrived to by Holub and Hurník, 2008).[8] An increase in commodity price inflation has no statistically significant impact on the inflation expectations (confidence intervals are too wide). Higher foodstuff price inflation leads to a short term increase in the inflation expectations (the increase is statistically significant over an approximate 12-month horizon). The VAR model results point also at the significance of the exchange rate fluctuations in creation of the inflation expectations. The exchange rate depreciation leads to higher inflation expectations: the effect is statistically significant approximately 3 or 9 months after the exchange rate shock. According to the results, a CPI inflation increase has initially no significant impact on the inflation expectations, while the inflation increase within approximately 18 months is accompanied by lower inflation expectations. This may reflect the fact that economic subjects expect lower inflation in future due to an expected response of the monetary policy to higher inflation. Similarly, a increase of interest rates is teamed with a significant decrease of the expectations as the market is expecting a drop in future inflation as a response to introducing a more restrictive monetary policy (once again, the response of the inflation expectations is significant after approx. 6 quarters, which presumably reflects perception of the CNB's monetary policy horizon). The foregoing, in addition to the inflation target effect on the inflation expectations, may be interpreted as another evidence of a credible monetary policy. The Appendix presents additional impulse responses (inflation response to the monetary policy shock and to the inflation target). The results indicate that a monetary restriction induces lower inflation, while a lower inflation target is accompanied by lower inflation.

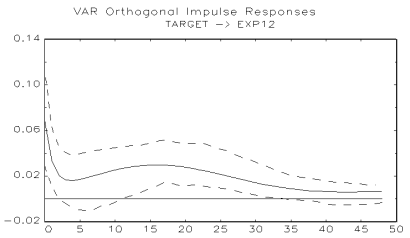
In Figure 3, we present the results with the 36-month inflation expectations (the rest of the model remains unchanged). These results support to quite a degree interpretation of the result in Figure 2 (inflation expectations within the 12-month horizon). The inflation target has a systematic effect on the inflation expectations. The market shows somewhat surprising revaluation of its inflation expectations depending on the foodstuff prices even within the above horizon (although the impulse response is significant in the short term only). Current exchange rate fluctuations are impacting creation of the inflation expectations, exchange rate depreciation leads to a decrease in expected inflation (the effect presumably reflects the expectations of the financial market that the current exchange rate depreciation will result in higher inflation forecast by the central bank and that the bank will then respond by higher interest rates and those will subsequently reduce inflation with a

[8] A cumulative impulse response to the target was computed, too, and it indicates that reducing the target by 1 pp reduced the expectations by 0.35 pp one year after the shock, and, by 0.6 pp two years after. Cumulative responses showed a similarity even when the 36-month inflation expectations were used. Hence, the results do not on the overall support the "hypercredible" target hypothesis. Chow prediction tests were carried out in order to evaluate whether the CNB's migration from the conditional forecast to the unconditional one in mid-2002 caused any structural break in the migration expectations. Resulting tests do not dismiss the null hypothesis for either of the inflation expectation horizons – corresponding bootstrapped values recorded 0.21 and 0.78 respectively – and we have therefore found nothing in support of a structural break. The above VAR models have been estimated also based on the 1999M6–2006M1 data. The results remain practically unchanged vis-à-vis those presented in Figures 2 and 3. A reason of this sensitivity analysis lies in the fact that the inflation target value had not changed since 2006 and consequently had a zero variability.

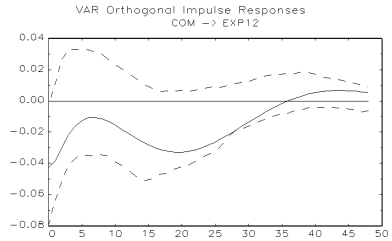
delay and accordingly also the 36-month inflation expectations). The development of current CPI inflation and the interest rate setting does not seem to be so important in terms of their impact on the 3-year ahead expectations.

Figure 2: Inflation expectations (12-month horizon): Impulse responses, Block restriction VAR

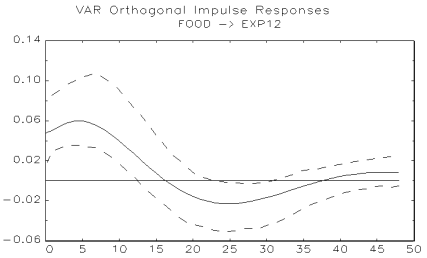
Response of expectations to inflation target



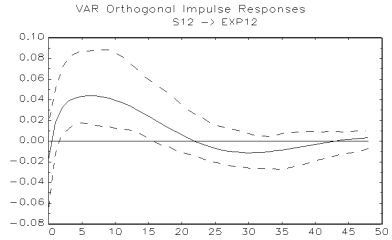
Response of expectations to commodity inflation



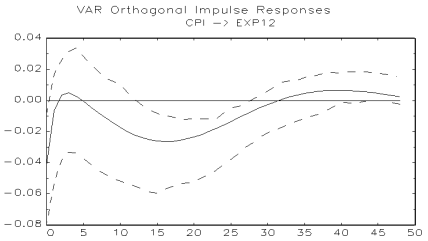
Response of expectations to foodstuff price inflation



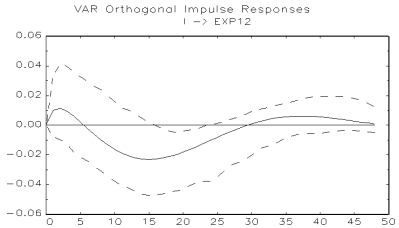
Response of expectations to exchange rate change



Response of expectations to CPI inflation



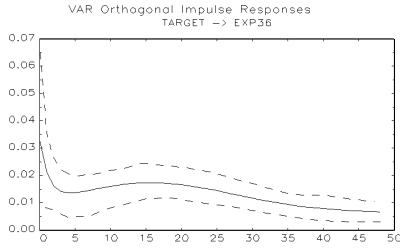
Response of expectations to interest rates



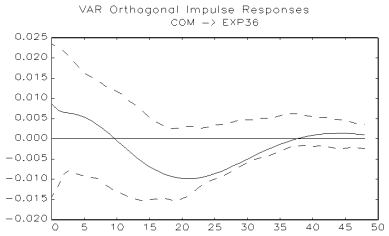
Note: The x axis shows time in months. The full line shows the impulse response, the dashed lines represent a 95% confidence interval computed using the Efron bootstrap method (it may be said then that the inflation expectation response is statistically significant in a given month providing both of the confidence intervals are positioned either below or above the x axis). Identification of shocks uses the Cholesky decomposition.

Figure 3: Inflation expectations (36-month horizon): Impulse responses VAR under block restrictions

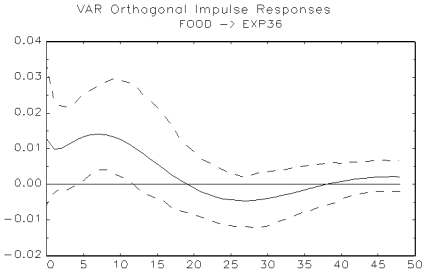
Response of expectations to inflation target



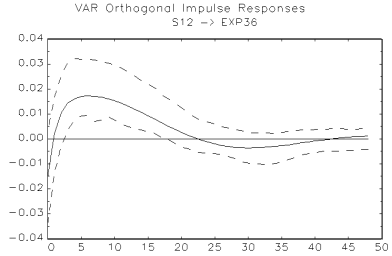
Response of expectations to commodity inflation



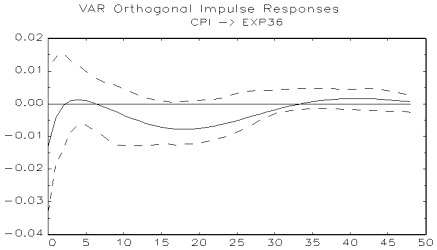
Response of expectations to foodstuff price inflation



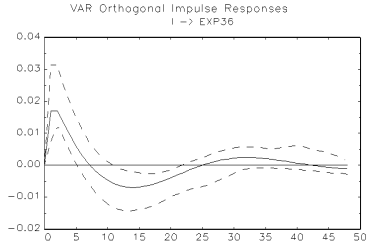
Response of expectations to exchange rate change



Response of expectations to CPI inflation



Response of expectations to interest rates

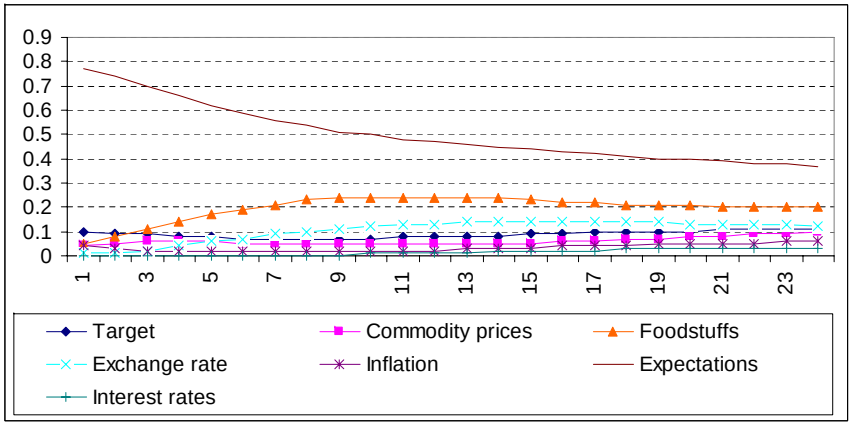


Note: The x axis shows time in months. The full line shows the impulse response, the dashed lines represent a 95% confidence interval computed using the Efron bootstrap method (it may be said then that the inflation expectation response is statistically significant in a given month providing both of the confidence intervals are positioned either below or above the x axis). Identification of shocks uses the Cholesky decomposition.

Figures 4 and 5 present variance decomposition for the inflation expectations within the 12- and 36-month horizon respectively. It follows from Figure 4 that the short-term variability of the 12-month inflation expectations is based on the foodstuff price inflation variability by approx. 20–25%, change of the inflation target by 10% and monetary conditions by 15% (the exchange rate significance exceeds that of the interest rates). A considerable relevance of the foodstuff prices for

creation of the inflation expectations is supported also by the newly available data from the turn of 2007–2008 that show an increase in the inflation expectations in the light of a high increase of the foodstuff prices. The significance of the commodity prices and overall inflation records less than 10%. It may supposed due to the low impact of the commodity prices that the market did not expect any significant second-round effects of the commodity prices on inflation. The residual variability relates to the inflation expectations per se.

Figure 4: Inflation expectations (12-month horizon): Variance decomposition, Block restriction VAR

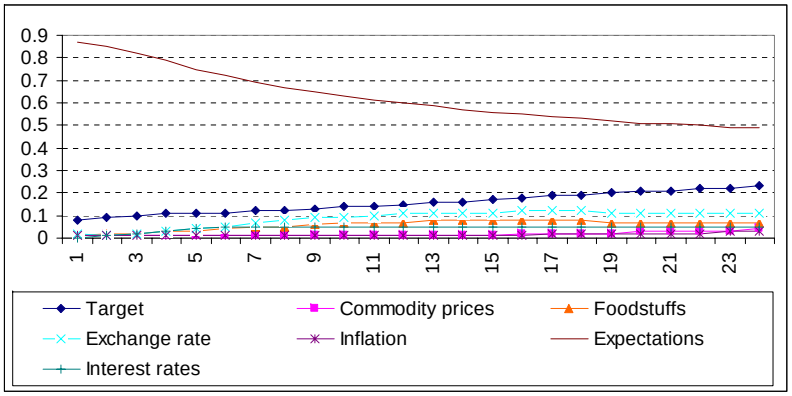


Note: The x axis shows time in months.

With respect to the inflation expectation variability over 36 months, we can see in Figure 5 that the significance of the foodstuff prices has dropped considerably (from the above 20–25% to the values below 10%).

The monetary conditions significance remains more or less unchanged, about 15%, and the same applies to other variables, except for the inflation target. The inflation target significance for the inflation expectations variability has increased from the above 10% to approx. 20%. An increase in significance of the inflation target therefore apparently indicates the credibility of the CNB's monetary policy, since the foodstuff price development has been identified as the most important short-term determinant, while the key longer-term determinant is represented by the inflation target that impacts the inflation expectations revaluation by the financial market. The residual variability, ranging to the high 50%, may be attributed to the inflation expectations per se. This, on one side, refers to the stability of the inflation expectations over the 36-month prediction horizon (the financial market "is not easily tempted to revaluate its view on the inflation development for 3 years forward"), on the other side, it also suggests that our model is apparently somewhat more suitable for an analysis of the 12-month inflation expectations and that we could include additional factors describing the economic cycle into it.

Figure 5: Inflation expectations (36-month horizon): Variance decomposition, VAR under block restrictions



Note: The x axis shows time in months.

4. CONCLUSION

This article initially addresses the role of the inflation target with respect to inflation expectations developments using the vector error correction model (VECM) and block restriction vector autoregression (VAR), based on the monthly data of 1999–2007. The econometric analysis performed has not identified any grounds in support of the "hypercredible" inflation target hypothesis, under which a 1 pp decrease would be accompanied by a decrease of inflation expectations by more than 1 pp. The results however suggest that the inflation target is a major determinant of inflation expectations, its significance for creating the inflation expectations surpassing even that of the current inflation development. Another conclusion is that the inflation expectations show a significant statistical decrease when responding to a stricter monetary policy and to the inflation target decrease. On the overall, the results indicate that the monetary policy has anchored the inflation expectations.

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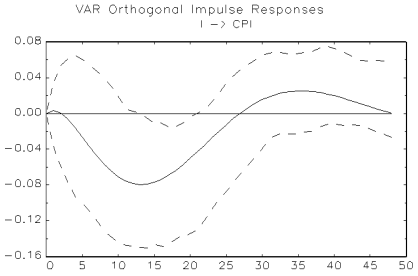
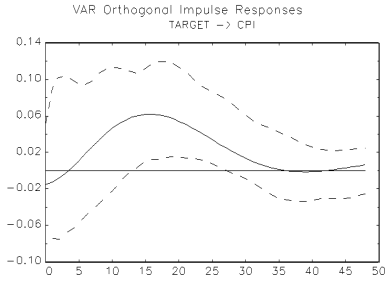
APPENDIX: ADDITIONAL IMPULSE RESPONSES

Inflation expectations (12-month horizon): Impulse responses, Block restriction VAR

Response of inflation to interest rate

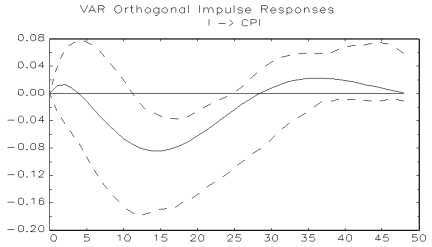


Response of inflation to inflation target

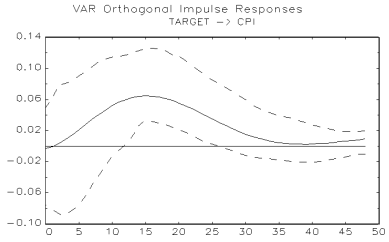


Inflation expectations (36-month horizon): Impulse responses, Block restriction VAR

Response of inflation to interest rate



Response of inflation to inflation target



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