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Do Central Bank Forecast Errors Contribute to the Missing of Inflation Targets? The Case of the Czech Republic*

Juraj ANTAL – Czech National Bank
Michal HLAVÁČEK – Czech National Bank and Charles University, Prague
(michal.hlavacek@cnb.cz) – corresponding author
Roman HORVÁTH – Czech National Bank and Charles University, Prague

Abstract
This paper is primarily concerned with assessing the bias of the CNB's predictions in relation to undershooting of the inflation target. We conclude that the inflation prediction error has decreased over time. We further point out that GDP growth and interest rates were, respectively, above and below the forecast most of the time, even in a situation of systematic undershooting of the target. Thus, the undershooting cannot be explained with the help of standard demand mechanisms. Positive supply impulses were admittedly underestimated in the past. According to our findings, about half of the apparent target undershooting in 2003 was due to errors in the predictions of exogenous factors (foreign interest rates, GDP, and inflation). As follows from the distribution of the inflation prediction errors across separate price segments, overpredictions of inflation during most of the period under review were due to mistakes in the prediction of food prices and core CPI ex food, while prediction errors in energy prices mostly fostered convergence to the target. The prediction errors in regulated prices acted in both directions.

1. Introduction

Forecasting tools are a highly important element of the inflation targeting regime. Given the forward-looking nature of monetary policy, decision making is based to quite a large degree on predictions of the evolution of inflation and other macroeconomic variables. Good predictions can contribute to implementation of monetary policy objectives. The quality of predictions and prediction tools can be assessed using various methods. The focus can, for example, cover general methodology aspects, verification of the prediction model calibration, the optimal combination of predictions drawn from various models or statistical evaluation of the 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 increase in inflation above the target at the beginning of 2008.[1] Our analysis approaches the CNB's model toolkit as a "black box," i.e., it deals primarily with the resultant numerical predictions for selected macroeconomic variables and with their linkages[2], and does not attempt to provide a more detailed review of the method

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according to which the predictions were developed (for a description of prediction development, see (Coats et al., 2003), and for forecasting quality and the success rate through the lens of the CNB's prediction model, 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 the reasons for prediction errors (such as inaccurate calibration within the model or failure to include relevant variables in 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 the introduction of the 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 the introduction of the QPM).[4] The one quarter ahead predictions from the QPM are unbiased for all variables under review, except for oil. For the one-year horizon, we find that the predictions of inflation, GDP growth, the 3M PRIBOR, and oil are systematically biased (while the predictions for the other variables are unbiased).

GDP growth was above the forecast and interest rates were below it most of the time, even in a situation of systematic undershooting of the target. The undershooting thus cannot be 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 the negative output gap closing, whereas the 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 the inflation prediction errors across separate price segments, the overpredictions of inflation during most of the period under review were due to mistakes in the prediction of food prices and core CPI ex food, while the prediction errors in energy prices mostly fostered convergence to the target. The prediction errors in regulated prices acted in both directions. Over the period 2002–2003 (and also in 1999 and in 2007), lower-than-expected growth in regulated prices contributed to the undershooting of overall inflation, and thus also to

[1] An assessment of the CNB's predictions can also be found in (Babecký, Podpiera, 2008) and (Kotlán, 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 with other financial institutions, while limiting themselves to the success of inflation predictions or the explanation thereof based on exchange rate prediction errors. Kotlán and Navrátil (2003) analyze the CNB's predictions through the lens of a loss function.

[2] We observe prediction bias for variables that may be deemed significant for the Czech economy: inflation (and certain elements thereof), GDP growth, the CZK/EUR exchange rate, the 3M PRIBOR, foreign inflation and GDP growth, the 1Y EURIBOR, and oil prices. Predictions for some of the variables are, however, unavailable for the initial phase of the period under 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), and (Kotlán, Navrátil, 2003), as well as various strategic documents on the CNB's monetary policy, such as the 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.

the undershooting of the inflation target. At the end of 1998, in 2001, and in 2006, on the other hand, unexpectedly high growth of regulated prices fostered convergence to predicted headline CPI inflation.

According to our findings, about half of the apparent target undershooting in 2003 was due to errors in predictions of exogenous factors (foreign interest rates, GDP, and inflation), in line with the conclusions arrived at by Antal, Hlaváček, and Holub (2008). In other years, errors in exogenous variable predictions added more or less insignificantly to the target undershooting (up to approximately 10 % of the total undershooting). Errors in the 1Y EURIBOR predictions, when compared to errors in the exchange rate predictions, indicate that the assumption of uncovered interest rate parity used in the QPM is unlikely to be very realistic. For a larger part of the period, monetary policy tended to respond to anti-inflationary shocks (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, however, are comparatively significantly affected by a low number of observations. This fact, *inter alia*, made it impossible to conduct any full-fledged econometric analysis based an assessment of the impact that the errors in endogenous variable predictions had on inflation undershooting, while the analysis results need to be taken with caution even for the exogenous variables.

The structure of the paper is as follows. Section 2 compares analyses of the prediction tools of other central banks with our analysis. Section 3 examines the size and bias of the 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 size and bias of the prediction errors for selected macroeconomic variables taken from the QPM. Section 6 considers the extent to which the exogenous variable prediction errors contributed to the undershooting of the inflation target. Section 7 concludes.

2. Overview of Analyses of the Prediction Tools of Foreign Central Banks

Certain foreign central banks have published quality assessments of their forecasting tools.[5] On the one hand, such assessments include more general, methodological approaches, e.g., evaluation of the benefits of calibration compared to the estimation of parameters; the pros and cons of statistical and structural models; and optimal combinations and aggregations of different prediction models. On the other hand, central banks have paid attention to evaluating the statistical performance of forecasts, carried out mainly by measuring forecast accuracy with the help of the size of the average error or by testing whether the predictions show 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, which are built on microeconomic foundations and tell an economic story,

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

and statistical vector autoregressive models, which often possess a potential for more accurate and less biased forecasts, especially over short time spans. The above study also promotes an approach adopting a suitable combination of parameter calibration and estimation, and describes key factors of such an optimum combination. The study recommends that the results of a larger number of prediction models be used in order to have diversification of methodological approaches and forecasts.

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

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, Ranchhod, 2004). The study establishes that inflation predictions have been downward biased since 1994 (i.e., actual inflation was higher than forecasted). The contributing factors were underestimation of aggregate demand and overestimation of the economy's potential. Unexpected behavior of the nominal exchange rate (stronger than forecasted) was identified as the main source of inflation prediction 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) output are the key to improved inflation forecasting.

The Fed, in its study (Gavin, Mandal, 2002), examines the GDP and inflation forecasting performance since 1979, with a particular focus on the accuracy of forecasts of the Federal Open Market Committee (FOMC) as compared to the accuracy of another 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 Fed experts. The study points out that the level and variance of inflation have been decreasing dramatically since 1979, which has contributed to improved accuracy of the forecasts. It continues, however, by pointing out that all the approaches showed prediction failures with regard to turning points of trend changes. The average forecast error for 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 even for the one-year horizon.

The study further points out that the FOMC was unable to make use of the dynamic correlation between GDP growth and inflation for obtaining an improved inflation forecast. In spite of that, the FOMC forecasts were more accurate than those of the analysts. On the other hand, they were less accurate than inflation forecasting by the Fed's specialists.

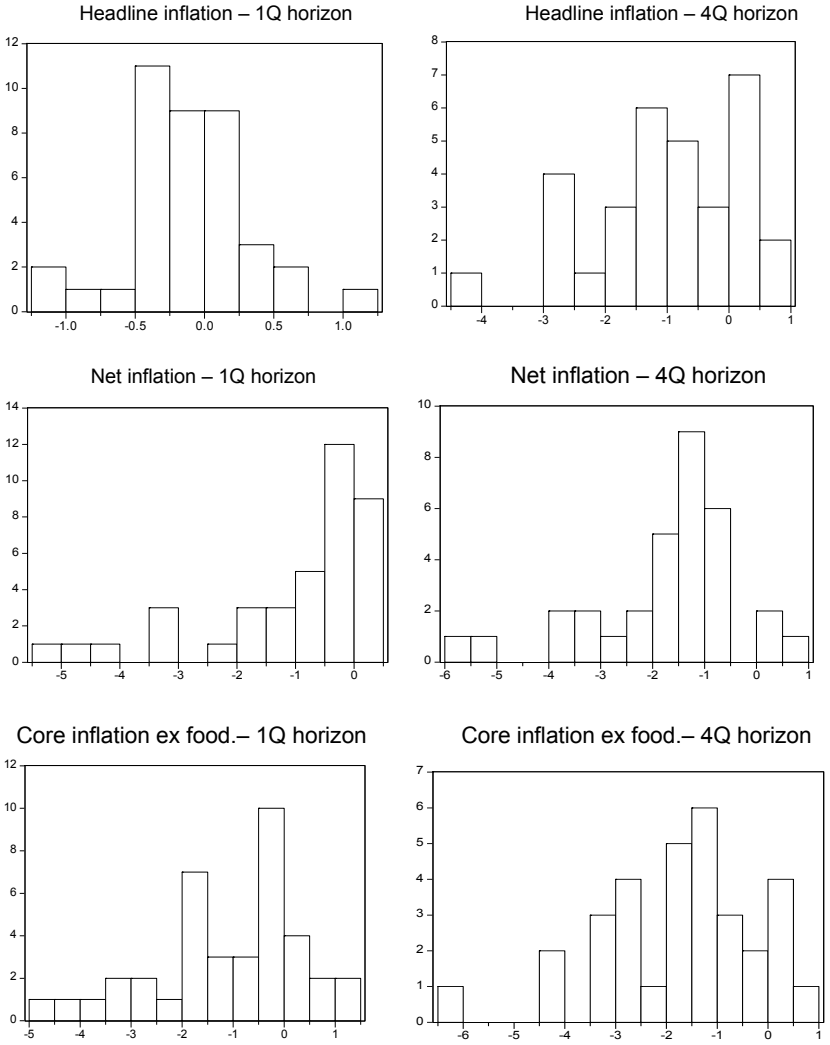
3. Distribution of Prediction Errors of Headline Inflation, Net Inflation, and Core CPI Ex Food Inflation, 1998–2007

This section of our paper discusses an assessment of the predictions for headline, net, and core CPI ex food inflation in 1998–2007. For the 1998–2002 period, the predictions for these variables are taken from the situation reports available from the following web link: http://www.cnb.cz/cs/menova_politika/br_zapisy_z_jednani. For the period 2002Q2–2007Q3, the data are taken from the baseline scenarios of the CNB's core prediction model (the Quarterly Prediction Model, QPM, an internal database). The predictions of inflation and its elements differ somewhat for each of the above two periods included in the review. In 1998–2002, a conditional forecast was used; this assumed constant interest rates at the level existing at the time the prediction was prepared. In 2002Q2–2007Q3, the prediction was prepared as an unconditional forecast, which includes modeling of the monetary policy response, i.e., an estimation of the future evolution of interest rates. The comparability of the inflation prediction errors for the two periods is therefore rather questionable. 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 the introduction of inflation targeting) with shorter prediction horizons. At the same time, the predictions under the QPM core prediction model include a wide range of variables, as reflected by the wider scope of our analysis discussed in Section 5.

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

In *Figure 1*, we present the histograms of the prediction errors computed as the difference between the variable's actual value and its prediction for the 1Q and 4Q horizons. An analysis of the prediction at the 1Q horizon may be of interest for two reasons. First, the new forecast always overwrites the old one because of the quarterly periodicity of macroeconomic forecasting, hence an error in a 1Q prediction to some extent reflects new information or the amount of "surprise" for monetary-policy decision making (if the 1Q prediction error were zero, the new prediction would presumably be similar to the old prediction even for a longer horizon). Second, inflation forecasts might have been especially uncertain at the outset of inflation targeting during the Czech economic transition, while monetary-policy decision

FIGURE 1 Histograms of Prediction Errors (actual – prediction), 1Q and 4Q horizons, 1998–2007



making might also have been taking short-term predictions into account (see Horváth, 2008), with more or less identical fit of both the backward and forward-looking monetary policy rule. We therefore considered it legitimate to include both the 4Q and 1Q horizons. The 4Q horizon reflects the lower part of the monetary policy horizon, within which changes in the monetary policy settings should already be revealed.

The horizon reflects the monetary policy lag and is assumed to be 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 the QPM, and 14

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: *, **, *** denote significance at the 10, 5, and 1 per cent levels, respectively.

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

as opposed to 11 for 1998–2002). *Table 1* nevertheless shows that the correlation between the prediction errors at the 4Q and 6Q horizons is comparatively high for the majority of such variables, meaning the results of our analysis would be unlikely to change dramatically if the 6Q horizon was considered.

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 the introduction of the QPM (for the results after the introduction of the QPM, see the next section). The trend becomes even more apparent in the prediction for the following quarter (0.36 pp in 1998–2007 and 0.24 pp after the introduction of the QPM). A similar view may also be formed based on *Figures 2–4*, which show the development of the prediction errors for headline, net, and core inflation ex food over time. Clearly, the absolute errors of the 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.

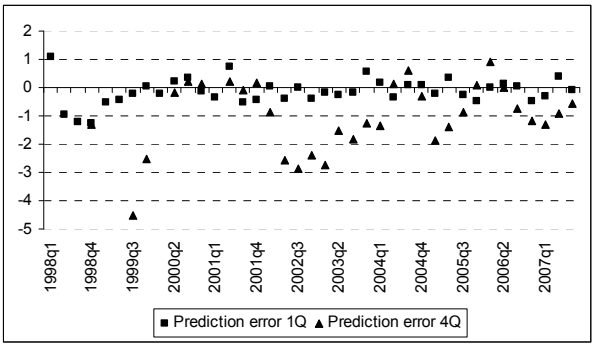
We continue by testing the bias of the predictions, i.e., whether or not the prediction error is non-zero on average. The null hypothesis therefore states that the average of the error in the predictions is $\mu = 0$. The alternative hypothesis is $\mu \neq 0$. The resulting *t*-statistics are computed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

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

where $\bar{\mu}$ is the average error of the predictions within the relevant data sample, s is

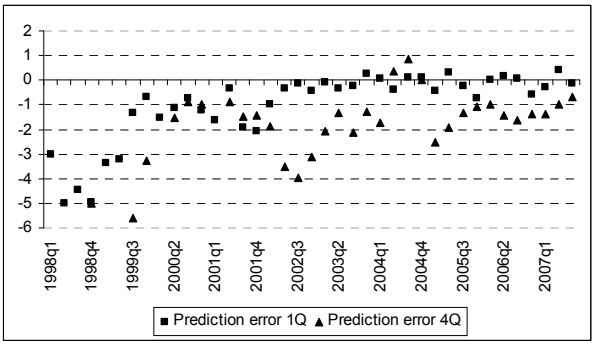
[6] The monetary policy horizon is estimated at as long as 8Q in some economies. However, since the Czech economy is a small open economy, it can be expected to manage somewhat accelerated transmission through exchange rate changes.

FIGURE 2 Prediction Errors of Headline Inflation (actual – prediction), 1Q and 4Q horizons, complete period 1998–2007



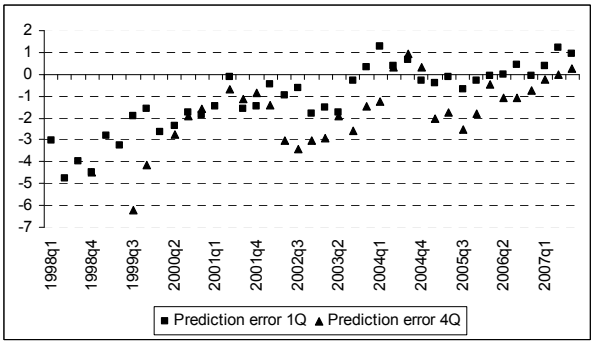
Note: 4Q prediction errors were not available for 1998Q1, 1998Q2, 1998Q3, 1999Q1, 1999Q2, 2000Q1 and 2001Q1.

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.

an unbiased estimate of the standard deviation for the relevant prediction errors, and N is the number of observations. The t-statistics are arranged using a t-distribution with N - 1 degrees of freedom. As far as the bias test results in *Table 2* are concerned, while the 1Q prediction of headline inflation narrowly "passed" the unbiased test (t-statistic 1.94), all the other predictions are statistically significantly biased.

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 differences between actual and predicted inflation according to the CNB's official prediction at a prediction horizon of 4 quarters. Comparing the deviation in the predicted price increase and the actual values for separate price segments enables us to identify which part of the price index contributed most to the headline inflation prediction error and subsequently to the missed inflation target in separate periods.

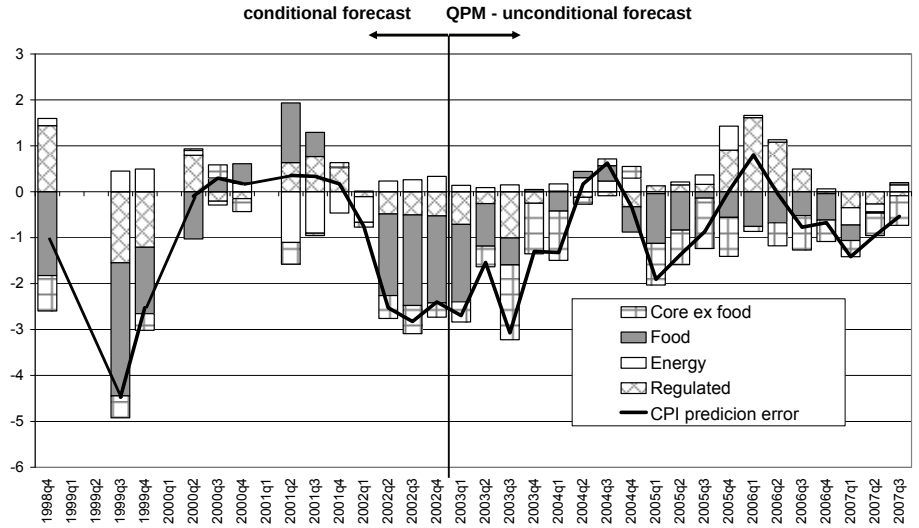
Given the above-mentioned shift from a conditional to an unconditional forecast it is nevertheless somewhat difficult to interpret the evolution of the total error over time, and it is practically impossible to compare the prediction errors between the two periods. During the initial stages of inflation 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 monetary policy response.[7] As already noted, however, the QPM core prediction model in use since 2002 is unconditional (in terms of the evolution of interest rates). 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.

The observed elements of inflation include core inflation ex food, food price inflation, energy price inflation, and regulated price inflation. We obtain the contributions of the separate inflation elements to the total error in the inflation prediction by computing the actual and forecasted value difference for the separate inflation elements and then multiply the differences by their weights in the consumption basket. The results are presented in *Figure 5*. As may be seen from the figure, headline inflation was overpredicted mainly due to 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. The prediction errors in regulated prices acted in both directions. Over the period 2002–2003 (and also in 1999 and

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

[8] This, in fact, does not always apply. Given that monetary policy provides no ex-ante responses to the 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.

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.

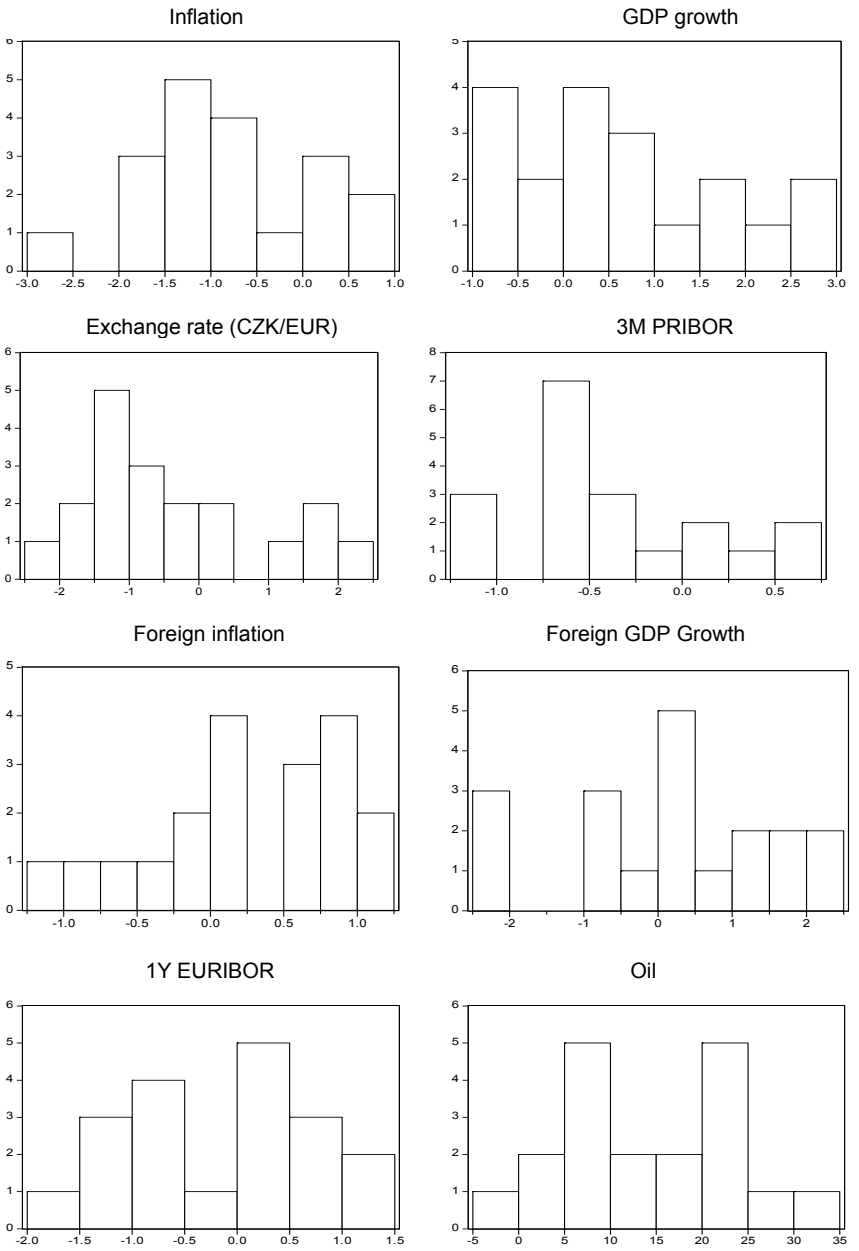
in 2007), lower-than-expected growth in regulated prices contributed to the undershooting of headline inflation, and thus also to the undershooting of the inflation target. In 2006, on the other hand, actual core inflation ex food and food price inflation were once again significantly overpredicted. However, the error was "offset" by unexpectedly steep growth of regulated prices. Had it not been for these higher--than-expected regulated prices in 2006, core inflation and food prices would have pushed headline inflation below the forecast in that period, too. Similarly, the unexpectedly sharp increase in regulated prices fostered convergence to the headline inflation prediction at the end of 1998 and in 2001. The impact of energy prices on the headline inflation prediction error was minor most of the time (thanks to the weight – approximately 3–4 % – of energy prices in the consumption basket) and typically acted in the direction of higher-than-expected inflation.

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

5. Distribution of the Prediction Errors from the QPM, 2002Q2–2007Q3

This section presents an analysis of the errors in the predictions for selected macroeconomic variables taken from the QPM. The prediction error for each variable is computed as the difference between the variable's actual value and its prediction

FIGURE 6 Histograms of Prediction Errors (Actual – Prediction), 4Q horizon, 2002–2007



tion for the 1Q and 4Q horizons. *Figure 6* contains histograms of the prediction errors from the QPM for 4 quarters ahead, while *Figure 8* (in the *Appendix*) provides a histogram of the prediction errors from the QPM for 1 quarter ahead.

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

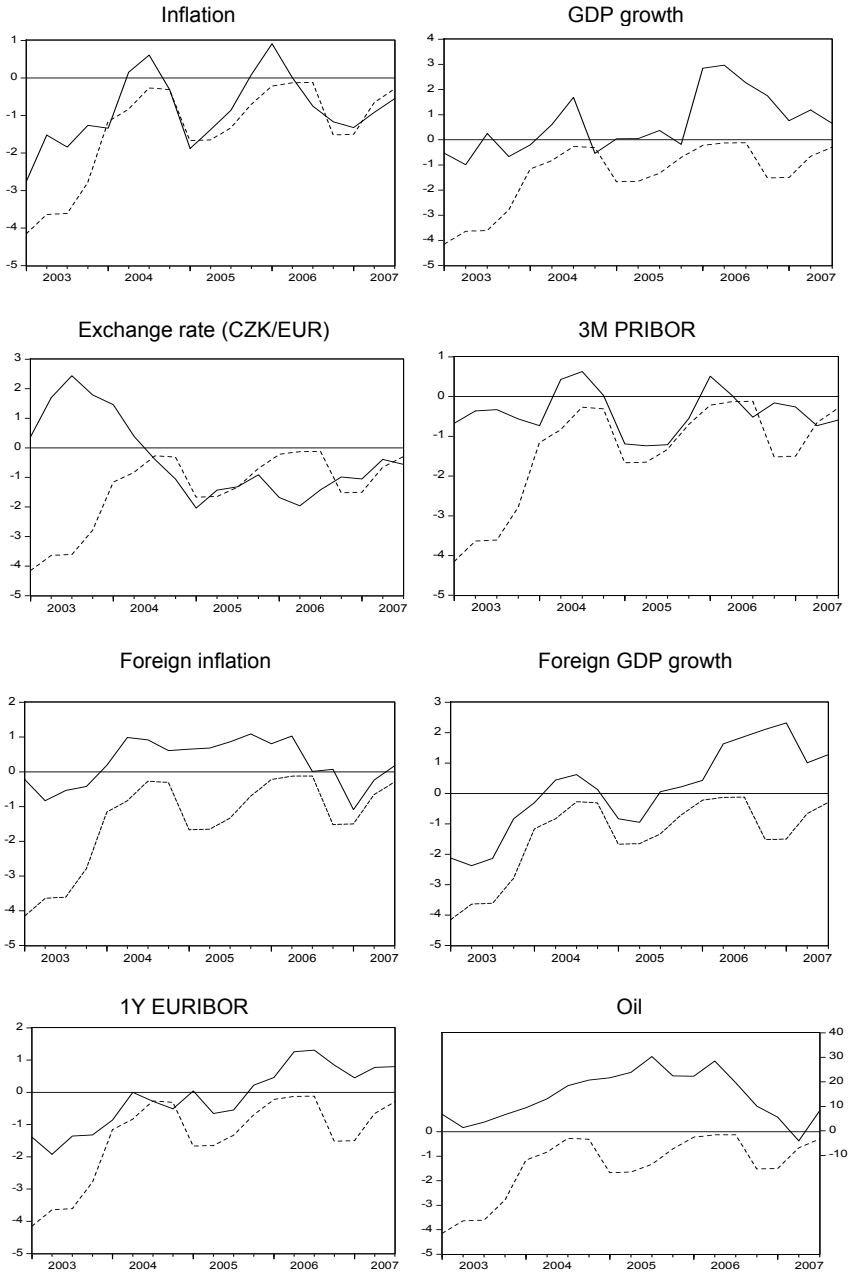
Figure 6 shows the histograms of the prediction errors at the 4-quarter horizon. It is obvious in the case of inflation and domestic interest rates that they were overpredicted compared to the observations. The exchange rate appreciated more strongly than the model prediction forecasted. It is clear from the histogram of the oil prediction errors that actual oil prices were often located higher than predicted. Foreign interest rates were on average somewhat overpredicted compared to the outcomes. The estimates of domestic and foreign GDP growth [9] appear visually unbiased. A moderate underprediction tendency prevails in foreign inflation.

Table 3 presents the results of the prediction bias test, i.e., whether or not the difference between prediction and outcome was systematically different from zero.[10] While certain predictions may seem visually biased (see *Figures 6* and *8)*, we identify a statistical bias in only 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 with increasing prediction horizon. With the 1 quarter ahead prediction, we find that only the oil price prediction is biased, whereas in the case of the 4 quarter ahead prediction, the predictions for inflation, GDP growth, the 3M PRIBOR, and oil prices are all biased.

[9] In the case of domestic and German GDP, these are so-called real time data, i.e., the data available when the forecast was prepared (i.e., not revised data). The real-time data are compared with the prediction. In the 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 GDP growth. From the monetary policy perspective, the output gap is more meaningful as an economic activity indicator than GDP growth, specifically over the periods of extensive changes on the supply side of the Czech economy, which resulted in increased growth of potential output. 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.

[10] The prediction bias test applied works well only for stationary time series. The time series we used reflect the difference between the predicted and actual values and should therefore be stationary, otherwise the prediction would have had to worsen or improve distinctly. 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 time series used at the 5% significance level.

FIGURE 7 Prediction Errors (Actual – Prediction) at the 4Q Horizon and Target Undershooting



Note: The 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.

Table 3 also presents the average absolute errors at the prediction horizons of 1 and 4 quarters. We can see from the table that, for example, 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 the next year prediction recorded an average error of USD 14.6.

In the next step, we present figures that depict the evolution of the prediction errors (at the 4Q horizon) and the 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 the correlation coefficients between the prediction errors and the undershooting. However, as several of the figures presented below will show, the relationship between the prediction errors and the undershooting kept changing over time (for example, the strong exchange rate appreciation in 2002 and its subsequent correction the next year considerably affect the resultant correlation coefficients). The blue dashed line in the prediction error figures indicates the rate of undershooting of the target,[11] while the solid line indicates the forecasting error for the relevant variable. Undershooting of the target is positively correlated with the error in the inflation prediction.[12]

The fact that 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 the undershooting cannot be explained through standard demand mechanisms in this case. It seems that the positive supply impulses acting on potential output 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, whereas the closing was in fact postponed due to enduring low inflation. Repetitions of the phenomenon could lead to target undershooting.

The relationship between the exchange rate prediction error and target undershooting more or less matches the assumption of a positive correlation of these deviations (a stronger exchange rate will mean lower imported inflation and therefore undershooting of the target). The exception is the start of the period under review, approximately at the beginning of 2004, when the exchange rate experienced a higher depreciation vis-à-vis the forecast (by CZK 1–2 to the euro), while inflation was considerably below the target. In this case, the explanation may consist in unexpectedly lower foreign growth and the delayed effects of the appreciation bubble of 2002 (the latter is not visible in the figure, as the figure begins with 003Q1), the adjustment for which led to overprediction of the exchange rate due to the relatively strong backward-looking nature of the exchange rate prediction in that period. As a result, the delayed effects of the overestimated 2002 exchange rate pushed the inflation rate down. Another period during which the deviations of the exchange rate and inflation from the predictions moved in opposite directions was the year 2006, when the target

[11] This series is identical for all figures.

[12] 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* exemption 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 the QPM is longer (4 to 6 quarters).

undershooting rate temporarily decreased. As can be seen, however, from the distribution of the inflation errors across the separate inflation elements (see the discussion of *Figure 5*), the convergence toward the target at that time was considerably supported by an unexpected increase of regulated prices that was unrelated to the exchange rate.

For a larger part of the period under review, the interest rate error was smaller on average than the undershooting of the target (see *Figure 7*).[13] This suggests that real interest rates from the *ex post* perspective were somewhat higher compared to expectations. The foregoing could to some extent confirm the hypothesis of inflation expectations anchored at a level below the target midpoint (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 whether the undershooting of the target was caused by more aggressive than forecasted monetary policy, or whether, on the contrary, monetary policy responded with some delay to the target undershooting or to the lower inflation rate, doing so with lower than predicted rates. A simple look at the figure indicates that, for most of the period, monetary policy was 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 a source of systematic undershooting of the inflation target. An exception could be the year 2003, when lower inflation pressures arising from foreign inflation conveniently matched the already mentioned delayed impacts of the 2002 excessive appreciation. Recently, too, the relationship between foreign and international inflation appears to have been "standard". Similarly to the deviation of foreign inflation, oil prices do not offer much help in explaining undershooting of the inflation target, i.e., the same as fuel prices, which were distinctly higher than expected over the entire period.[14]

In contrast to the somewhat weaker link between foreign inflation and undershooting of the target, an interesting comparatively strong relationship exists between the foreign growth prediction error and target undershooting, in particular until 2006.[15] Weaker foreign growth may have led to a slowdown of foreign inflation and lower imported inflation. It would also have meant weaker demand for Czech exports and also lower inflationary pressures. It is, however, impossible to find the two links completely reflected in the "GDP growth" and "Foreign inflation" figures (see above). The errors in the 1Y EURIBOR predictions indicate, as compared to the errors in the exchange rate predictions, that the assumption of uncovered interest rate parity used in the prediction is unlikely to be very realistic (since approximately 2004, foreign interest rates have been underpredicted and, on the con-

[13] It can also be 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 compared to target undershooting or inflation.

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

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

trary, domestic interest rates have been overpredicted, while the exchange rate has been stronger relative to the uncovered interest rate parity logic).

6. Have Errors in the Predictions of Exogenous Variables Contributed to Undershooting of the Target?

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

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

where $\left(\pi_t - \pi_t^*\right)$ is the difference between inflation and the inflation target at time *t*, thus showing the rate of inflation target undershooting (for the behavior 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* and *i*=1,…,k, and $E_{t-4}\left(x_{t,k}\right)$ is the prediction of the relevant variable at time *t*-4 (i.e., the 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 the explanatory variables, only those which are considered exogenous from the QPM model perspective were included, i.e., the variables whose predictions are mostly assumed from external sources by the CNB prediction system (Consensus Forecast forecasts were used for the majority of the variables considered).[16] We do not examine the role of endogenous factors, such as food prices or domestic GDP growth, as it is econometrically unviable to successfully apply short time series to differentiate the impact of endogenous variables on the undershooting from the impact of the undershooting on the endogenous variables (so-called endogeneity of explanatory variables). Consequently, if we included the endogenous variables in this regression type we would quite likely be estimating equations calibrated directly within the model (e.g., the Phillips curve). The issue is irrelevant for exogenous variables, as domestic undershooting of the target may hardly be expected to affect the evolution of the foreign variables used. Dropping the endogenous variables from the regression of course

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

TABLE 4 Undershooting of the Inflation Target and Errors in the 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 to autocorrelation and heteroskedasticity are given in parentheses below the estimated parameter. *, **, *** denote significance at the 10, 5, and 1 per cent levels, respectively.

does not mean that we do not attempt to estimate the reasons for the undershooting to their full extent, but rather means that we only attempt to find an answer to the question of to what extent such undershooting was driven by external shocks. Despite such a 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 different explanatory variables impact on inflation through various channels and with lags of differing lengths, etc.[17]

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

The estimated constant with a statistically significant coefficient of around -1.5 % indicates that a large portion of the target undershooting cannot be explained by exogenous factors. The regression analysis results imply that the higher-than-expected oil price led 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 the undershooting of the target. Given that both oil prices and inflation and foreign GDP growth were more frequently underpredicted, the two factors on average made no contributions to the undershooting of the target during the period under review. In the case of the EURIBOR, on the other hand, a negative error (overpredicted actu-

[17] Another limitation imposed on this analysis is certainly the assumption that the CNB Bank Board never departs from the forecast, as well as the fact that we do not consider *ex ante* exemptions from inflation target fulfillment.

al values) was typical and EURIBOR overshooting could thus have contributed to the 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 at the result that errors in the EURIBOR predictions contributed to the undershooting of the target to the extent of just above 0.1 pp.[18] Since the target was undershot on average by approximately 1.4 pp during the period 2003–2007, it is apparent that the exogenous factors explain 10 % of the total undershooting at most. If the estimated coefficient in column (5) were used, the effect of the prediction error would be marginal for explanation of the undershooting of the target. The negative coefficient of the exchange rate in column (4) is statistically significant, but with the opposite sign, contrary to expectations. This is due to the already mentioned impact of the 2002 appreciation bubble on subsequent inflation, which resulted in 2003 in a weaker-than-expected exchange rate accompanied by a low rate of inflation. In equation (5), the exchange rate appears statistically insignificant (once again due to multicolinearity).

It is interesting to look at the considerable inflation target undershooting in 2003. It is apparent from *Figure 7* that the EURIBOR, foreign inflation, and GDP growth were lower than expected (e.g., the EURIBOR was in fact 2 pp lower than expected). That should have created pressure for exchange rate appreciation (lower foreign interest rates), hence it can be stated, to a certain degree, that there were exogenous factors behind the undershot target. If we were to quantify the "net" effect of the prediction errors in the case of the above exogenous variables (leaving aside their second-round effects on the other variables), we would get a contribution of around 1.75 pp,[19] i.e., approximately half of the total rate of undershooting of the target in 2003. However, as noted above, given the small number of observations there is unquestionably substantial uncertainty as to the size of such estimated effects.

7. Conclusion

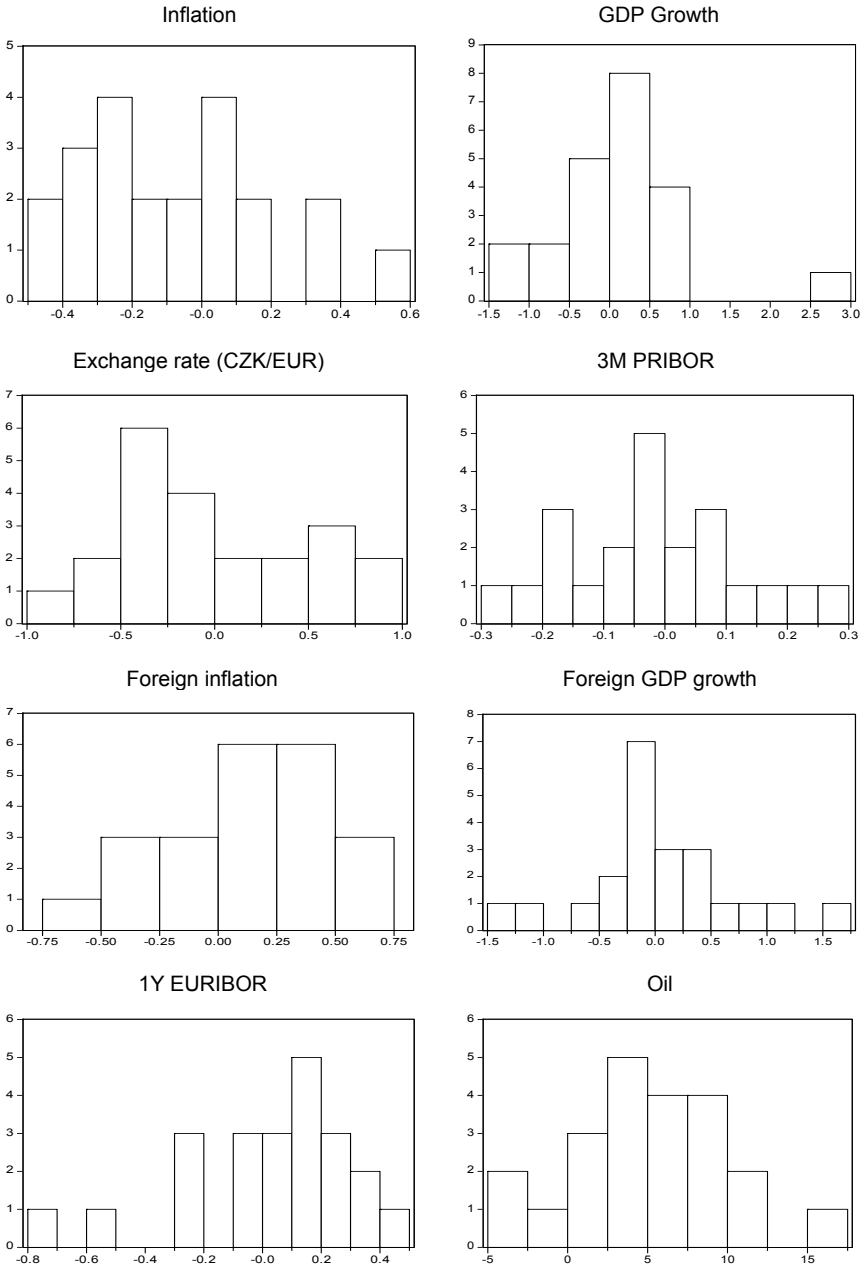
This paper is primarily concerned with analyzing the bias of the CNB's predictions in relation to undershooting of the inflation target. The key conclusions of the paper are as follows. The inflation prediction error decreases over time. Positive supply shocks were admittedly underestimated in the past.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

[18] The simple average error in the EURIBOR predictions is 0.14 pp times the estimated coefficient of approximately 0.9, giving a value above 0.1 pp.

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

APPENDIX

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



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