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

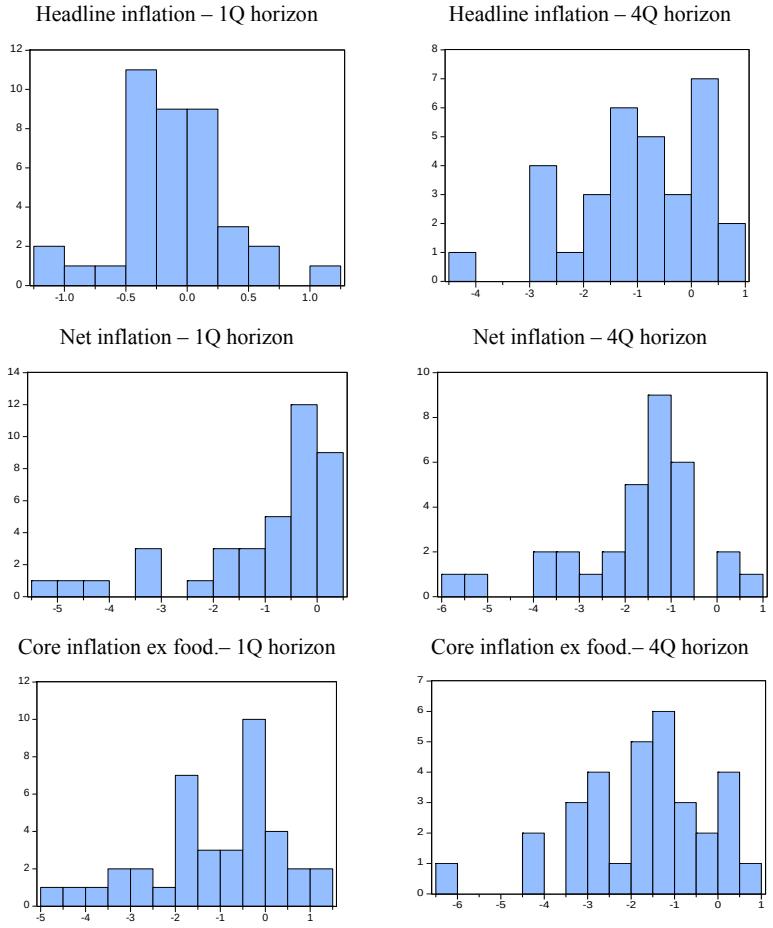
This section of our paper discusses an assessment of predictions of headline, net and core CPI ex food inflation in 1998–2007. For the 1998–2002 period, predictions for these variables are drawn from the Situation reports that are available from the following web-link: http://www.cnb.cz/cs/menova_politika/br_zapisy_z_jednani. 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**

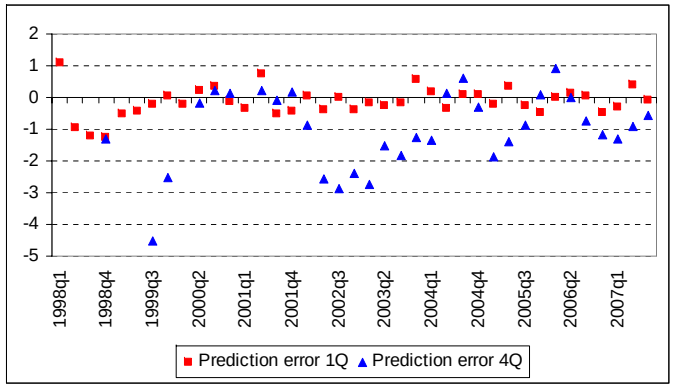
Note: The average error is set out in pp and computed as arithmetic average of prediction errors within the respective time series. The average absolute error is set out in pp (the absolute error for each quarter is computed first and then averaged). ***Bold*** *is used to denote absolute values of t-statistics 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:

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

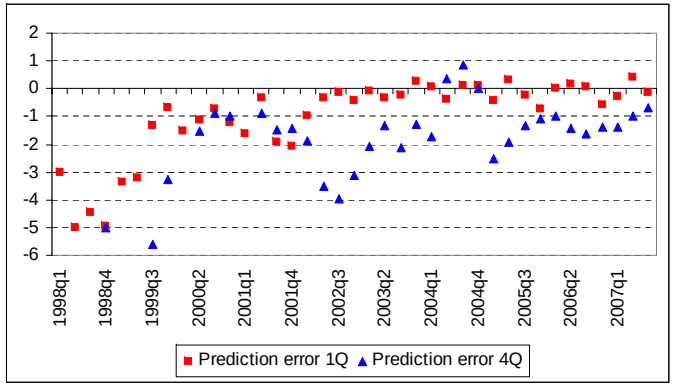
wherein $\bar{\mu}$ is the average error of predictions within the respective data sample, s is a unbiased estimate of the standard deviation for the respective prediction errors, and, N is the number of observations. The t-statistics are arranged using t-distribution with $N-1$ degrees of freedom. As 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



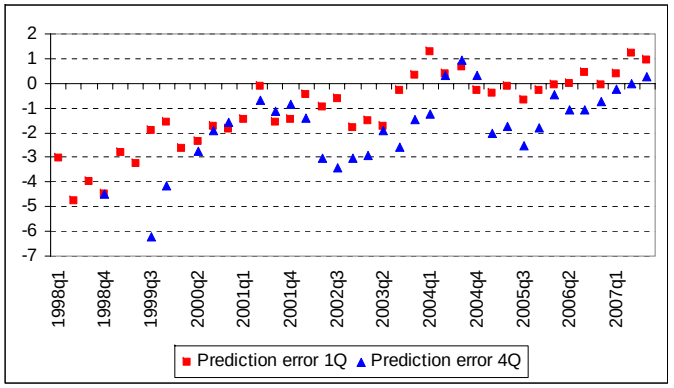
Note: 4Q prediction errors were not available for 1998Q1, 1998Q2, 1998Q3, 1999Q1, 1999Q2, 2000Q1 and 2001Q1.

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.

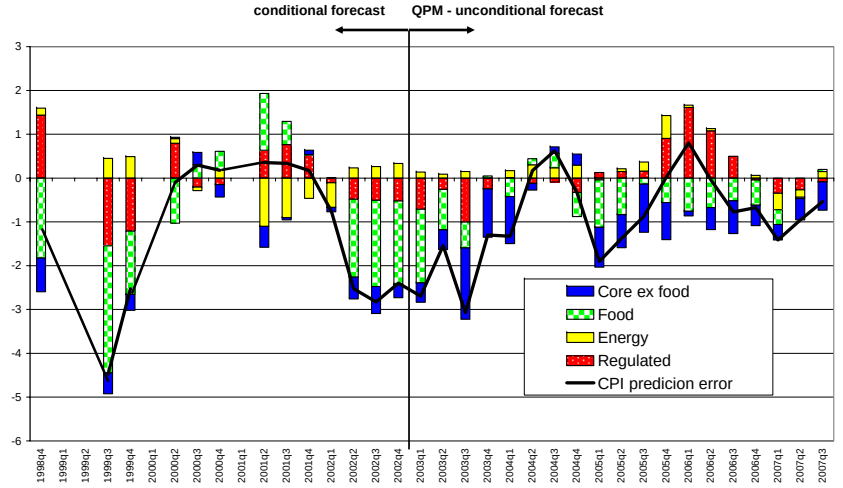
Given the above mentioned shift from the conditional to the unconditional forecast it is nevertheless somewhat difficult to interpret evolution of the total error over time, or, it is practically impossible to compare errors in predictions between the two periods. During the initial stages of inflation 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

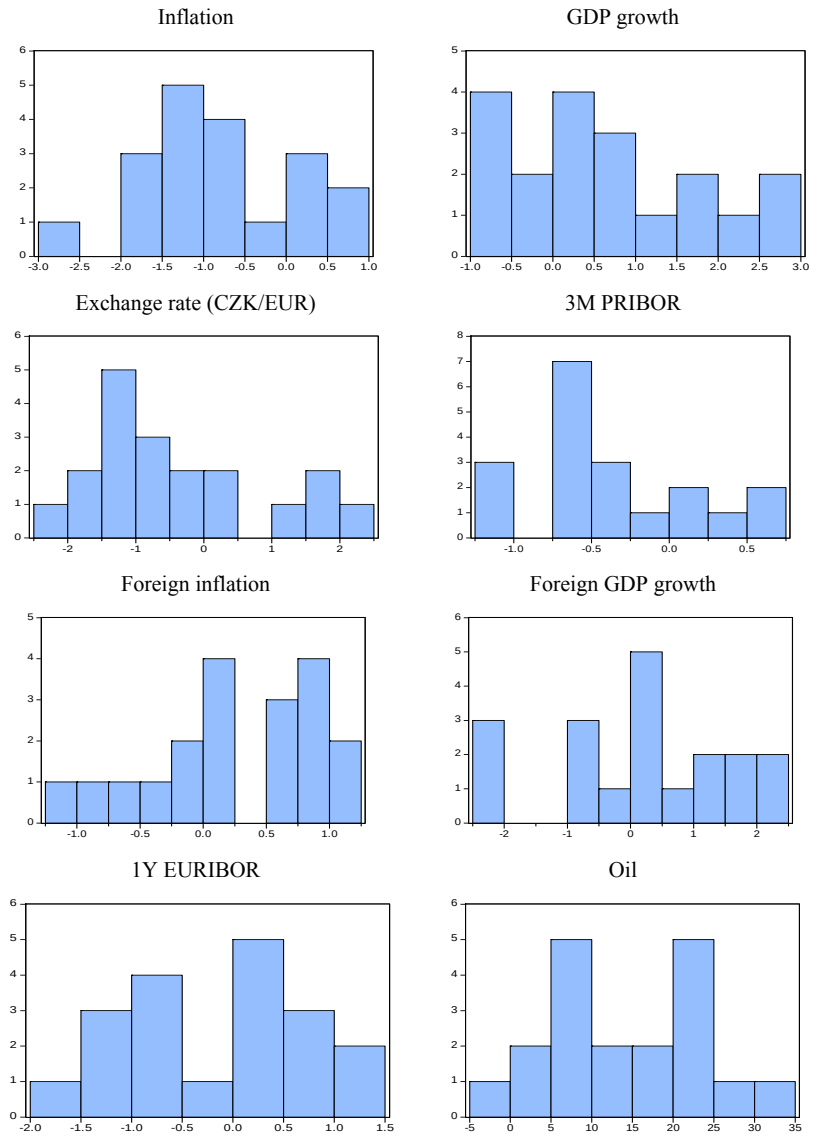


Table 3: Test of prediction bias, 2002–2007

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.

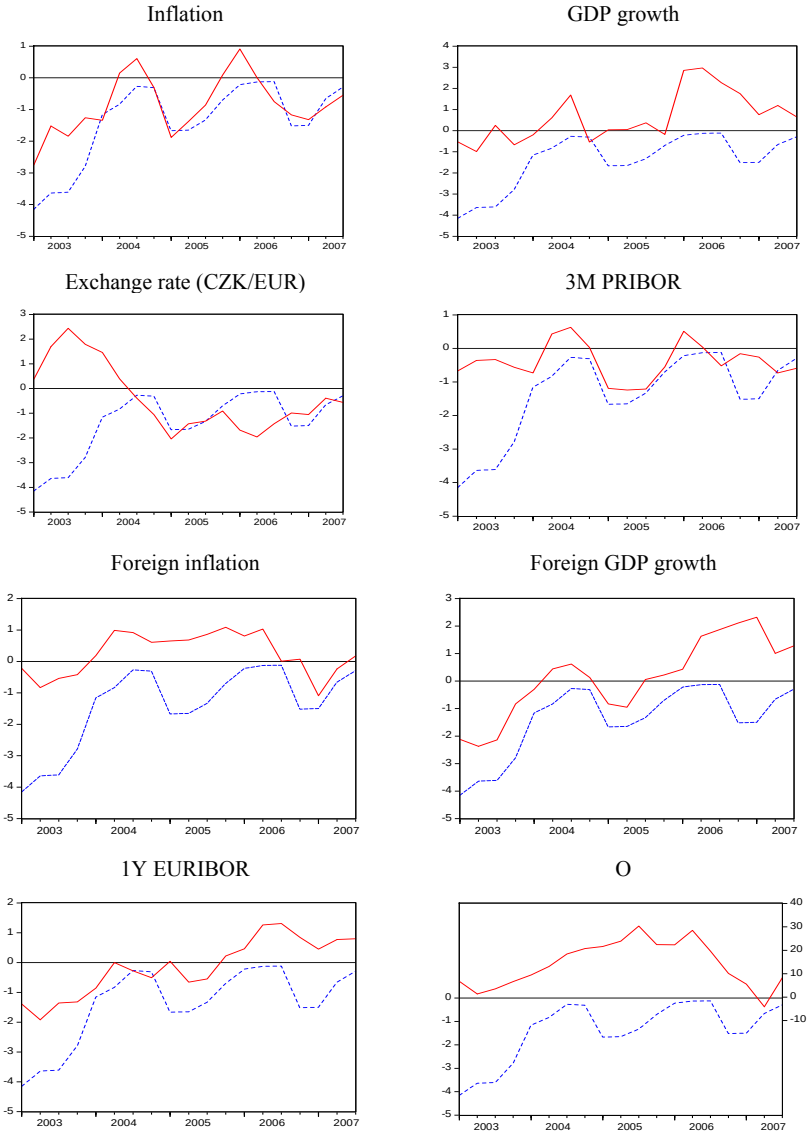
In the next step, we present figures that depict the evolution of prediction errors (at a 4Q horizon) and undershooting of the target over time (see Figure 7). The selected horizon of four quarters reflects the monetary transmission horizon. Another analytical approach would be to compute correlation 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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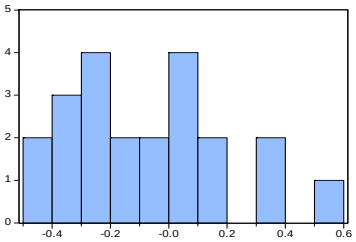
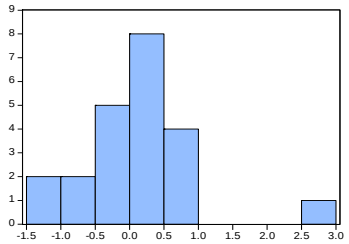
APPENDIX:

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

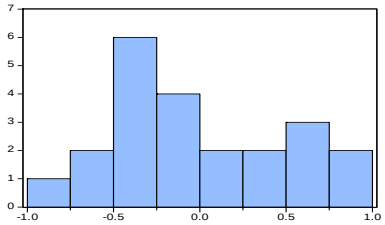
Inflation



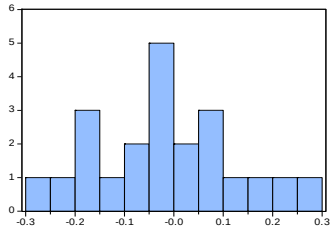
GDPgrowth



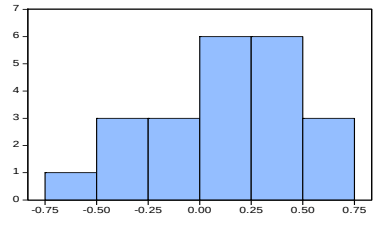
Exchange rate (CZK/ER)



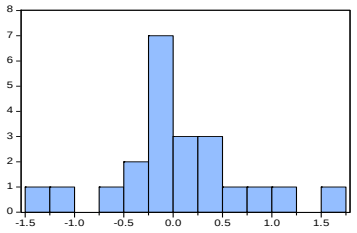
3M PRIBOR



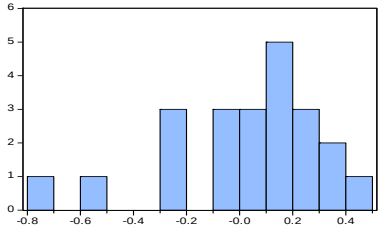
Foreign inflation



Foreign GDP growth



1Y EURIBOR



Oil