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EDITORIAL

Over the past decade, relatively frequent deviations of inflation from the target were typical for inflation-targeting central banks. In the advanced stage of Czech inflation targeting, such deviations were observed in approximately half of cases, in line with the international experience. The frequency of such deviations is a puzzle that attracts researchers around the globe. This issue tries to figure out which deviation factors were important in the Czech case. The presented articles propose several potential suspects: a series of shocks, the forecasting system and the decision-making system. The articles then suggest which methodologies could be used to decipher the deviation puzzle and provide empirical results for the Czech case. These results suggest that deviations of inflation from the target in the past decade cannot be explained by a single factor in the Czech case, and that the role of each factor changed over time. Anti-inflationary shocks are the most frequently identified source of the deviations. In the initial stage of inflation targeting, the forecasting system and the decision-making process also contributed. The analysis of factors contributing to deviations of inflation from the target provides useful lessons for improving the inflation targeting strategy. For example, a less rigid forecasting system seems to be more beneficial than a forecasting system that is changed only very rarely.

Kateřina Šmídková

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Causes of Deviations of Inflation from CNB Targets

It is important to understand why the announced CNB inflation targets were often missed in the past, typically to the downside. This article presents an empirical analysis of the underlying reasons. While in the short term, shocks to agricultural producer prices and oil prices are the most important factor, exchange rate shocks are clearly the most important medium-term factor.

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

As monetary policy is forward-looking, decision making is largely based on forecasts. This article assesses the accuracy of the CNB's forecasts for the main macroeconomic variables in relation to the missing of inflation targets. The precision of the inflation forecasts is found to improve over time. The inflation target undershooting in 1998–2007 was, at least in some periods, associated with external and supply-side factors.

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The History of Inflation Targeting in the Czech Republic Through the Lens of a Dynamic General Equilibrium Model

If monetary policy is not set in accordance with the observed state of the economy and the inflation target, monetary policy shocks emerge, affecting the real interest rate and inflation. This study focuses on estimating such structural shocks. The results of a dynamic general equilibrium model suggest that monetary policy shocks did indeed exist between 1998 and 2005.

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Causes of Deviations of Inflation from CNB Targets – An Empirical Analysis

Tomáš Holub¹

During the first ten years of inflation targeting the Czech National Bank (CNB) successfully completed the disinflation process and anchored inflation expectations to the inflation targets (see Holub and Hurník, 2008). Nevertheless, this period also brought challenges as regards fulfilment of the announced inflation targets, which were often missed, typically to the downside. Therefore, it is important to analyse empirically which factors contributed to the frequent non-fulfilment of the CNB's inflation targets.

The fulfilment of the CNB's targets was significantly affected by two episodes characterised by a noticeable undershooting of the targets, namely in the years 1998–1999 and 2002–2003. The existing literature concurs on the list of relevant causes of such distinct target undershooting (see, for example, Kotlán and Navrátil, 2003; Geršl and Holub, 2006). The list comprises declining food prices (in both periods), low oil prices (in both periods), a pause in deregulation (in 2002–2003), fiscal and monetary restrictions (in 1998–1999), a growth slowdown in the EU (in 2002–2003) and a strengthening of the exchange rate of the Czech koruna (in both periods). A similar list of factors is mentioned in past CNB Inflation Reports. Holub and Hurník (2008) express the opinion that the exchange rate was a common key feature of both target undershooting episodes.

Based on this literature, we focus on the following variables: the real exchange rate, agricultural producer prices, crude oil prices in USD, foreign and domestic economic activity, and domestic real interest rates. All variables are used on a quarterly basis in the form of deviations from their estimated equilibrium levels², covering the period from the first quarter of 1998 until the fourth quarter of 2007.

We found that all the analysed explanatory variables have a statistically significant and, in the majority of cases, economically intuitive correlation with

the deviations of inflation from the target, with a time lag ranging from zero (for agricultural producer prices) up to ten quarters (for the foreign output gap). In the case of the real exchange rate, the time lag amounts to three quarters; in the case of the real interest rate gap it is 0–2 quarters. At the same time, all of the explanatory variables, with the exception of agricultural producer prices and the real interest rate gap, Granger-cause the deviations of inflation from the target at least at the 10% significance level, usually with a time lag of 1–2 quarters (only with the foreign output gap does the time lag extend to 10 quarters).

To allow for endogenous links between the individual variables we used a VAR model, which also allows us to identify both the statistical and economic significance of the individual factors. More specifically, the model can be expressed in general as follows:

TABLE 1

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

$$Y_t = [ea_gap_t, poil_gap_t, er_gap_t, czv_gap_t, gdp_gap_t, pi_gap_t, ir_gap_t] \quad (2)$$

where *ea_gap* denotes the foreign output gap, *poil_gap* denotes the USD crude oil price, *er_gap* denotes the real exchange rate gap, *czv_gap* denotes agricultural producer prices, *gdp_gap* denotes the domestic output gap, *pi_gap* denotes the deviation of inflation from the target, *ir_gap* denotes the real three-month interest rate gap, v_t is the vector of residuals and L stands for the lag operator. Shocks to the individual variables were identified in a standard manner on the basis of the Cholesky decomposition, with the variables ordered as in equation (2), which corresponds to the view of the transmission of shocks in a small open economy applying inflation targeting.³

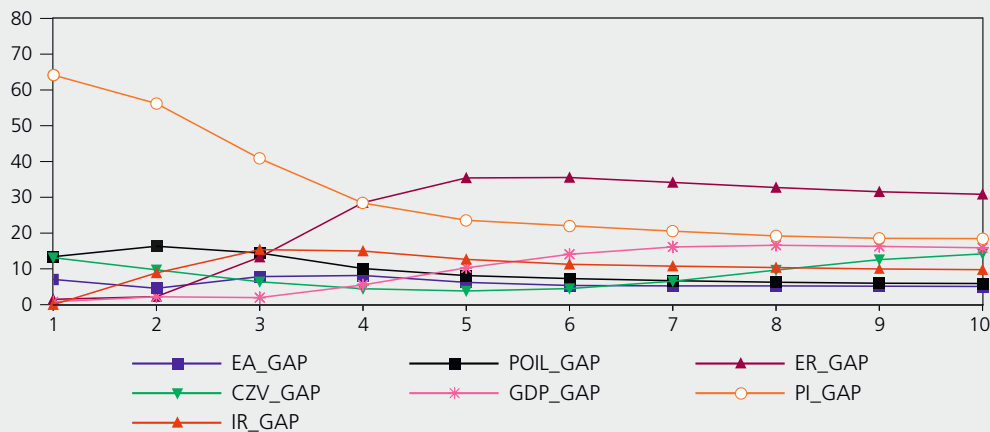
¹ This article is based on Holub (2008a,b).

² As far as prices of crude oil and agricultural producer prices are concerned, they always represent deviations from the trend as estimated using the Hodrick-Prescott (HP) filter. As regards the other variables, we work with two alternative estimates. The first one is based on the structural Kalman Filter (see Beneš and N'Diaye, 2003) and the other one on the HP Filter. For the sake of brevity, however, we report in detail here only the results based on the HP-filtered variables.

³ This ordering means an implicit presumption that shocks to foreign variables may have an immediate impact on the exchange rate of the Czech koruna, rather than the other way round. The exchange rate, together with agricultural producer prices and the domestic output gap, may then directly affect the deviations of inflation from the target, which, however, does not immediately influence the said variables. Monetary policy then responds to all the available information.

FIGURE 1

Variance decomposition of the deviations of inflation from the target



Note: The vertical axis denotes the percentage of the variance of the deviations of inflation from the target explained by the indicated shocks. Time periods are shown on the horizontal axis.

The variance decomposition of the deviations of inflation from the target is presented in Figure 1. As can be seen, in the short term the most important factors of the deviations of inflation from the target (apart from the shocks to inflation itself) are agricultural producer prices and crude oil prices. Their influence, however, would get weaker in the long run. Shocks to real interest rates, i.e. monetary policy shocks, hold roughly a 15% share in the analysed variance at the horizon of approximately 2–4 quarters, and this share is at the edge of statistical significance. However, at the horizon of one year or longer, the most distinct factor is the real exchange rate, which explains a substantially larger portion of the variance (in excess of 35%) than the other macroeconomic variables, and its influence is statistically significant. The domestic demand shocks, i.e. shocks to the domestic output gap, are also at the edge of statistical significance at a horizon exceeding six quarters.

The impulse responses of the deviations of inflation from the target to shocks affecting the individual variables are depicted in Figure 2. It shows that shocks to agricultural producer prices are statistically significant for short time lags; however, their impact would gradually decline and would quickly become statistically insignificant. The same is true for shocks hitting global crude oil prices.⁴ The real exchange rate shocks are most effective with a lag of 4–5 quarters and strongly statistically significant. The maximum real exchange rate pass-through to inflation is roughly 28–38%, which broadly matches the conclusions from the previous empirical studies focusing on the Czech Republic (see Babetskaia, 2007). There is also a statistically significant response in the medium term to domestic demand shocks, and in the short term to interest rate shocks, but in a counter-intuitive direction.⁵ On the other hand, international demand shocks do not appear to have any statistically significant impact on the deviations of inflation from the target.

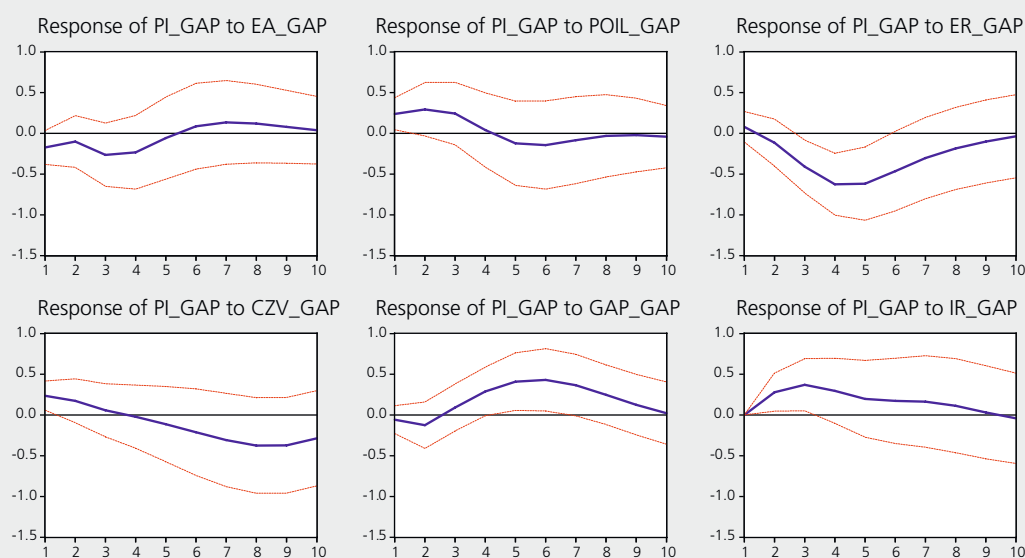
⁴ This conclusion, however, was not confirmed when we used Kalman-filtered variables instead of the HP-filtered ones in the VAR model, and thus cannot be considered sufficiently robust.

⁵ These two findings, however, do not hold if one uses the Kalman-filtered variables in the estimate.

FIGURE 2

Impulse responses to deviations of inflation from the target to shocks

Response to Cholesky One S.D. Innovations – 2 S.E.



Note: The impulse responses to Cholesky one-standard-deviation innovations are plotted along with two standard error bands.

It can thus be concluded that the most important short-term factor of deviations of inflation from the target is shocks hitting agricultural producer prices and international oil prices. In the medium term, however, the real exchange rate gap takes over as the most important factor. The main common macroeconomic feature of the two periods of the most significant inflation target undershooting was indeed a noticeable and unexpected appreciation of the Czech

koruna. The difficulties caused by the exchange rate shocks were further accentuated by their concurrence with other factors, but these were less significant and – as such – would have resulted only in a less distinct and merely short-lived undershooting of the inflation targets. Finally, it is not possible to prove that monetary policy in itself created any significant shocks contributing to the non-fulfilment of inflation targets.

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

Juraj Antal, Michal Hlaváček and Roman Horváth¹

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 forecasts of the evolution of inflation and other macroeconomic variables. Good forecasts can thus contribute to the implementation of monetary policy objectives. The quality of forecasts and forecasting tools can be assessed using various methods. The focus can, for example, cover general methodology aspects, verification of the model calibration, the optimal combination of forecasts drawn from various models or statistical evaluation of the forecast performance of the models.

Our contribution is primarily concerned with assessing the bias of the CNB's forecasts 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. Our analysis approaches the CNB's model toolkit as a "black box", i.e. it deals primarily with the resultant numerical forecasts for the main macroeconomic variables, and does not attempt to provide a more detailed review of the method according to which the forecasts were developed (for a description of forecast development, see Coats et al., 2003, and for forecasting quality and the success rate through the lens of the CNB's forecasting 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 forecast errors (such as inaccurate calibration within the model or failure to include relevant variables in the model).

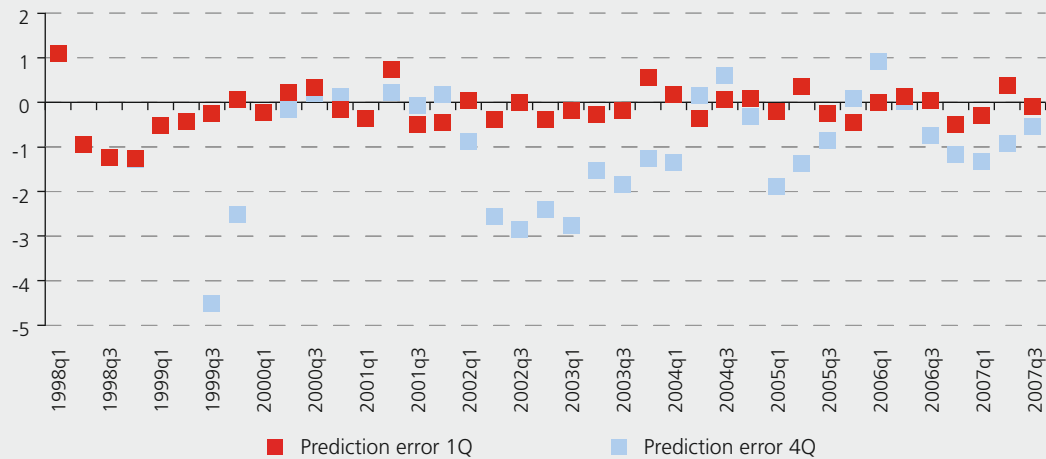
In the present study we first deal with a statistical examination of the unbiasedness of the CNB's forecasts for the following macroeconomic variables: inflation (headline, net and core), GDP, the exchange rate, the short-term interest rate, oil prices, euro area GDP, euro area inflation and euro area short-term interest rates. As regards domestic inflation, we also investigate the forecast errors for various price segments, such as food and energy prices. Next, we discuss the development of the forecast errors (of the aforementioned macroeconomic variables) over time in relation to the missing of inflation targets. Finally, we provide a regression analysis of whether the forecast errors of exogenous variables contributed to the undershooting of the inflation target.

The key conclusions of our study are as follows. As Figure 1 shows, the inflation forecast error has decreased over time. While the (absolute) error of the one-year-ahead forecast recorded 1.2 pp for the entire period 1998–2007, it dropped slightly to 1 pp following the introduction of the Quarterly Projection Model (QPM) in 2002. The trend is even more obvious in the forecasts for the next quarter (0.4 pp in 1998–2007 and 0.2 pp following the introduction of the QPM).

¹ This article is based on Antal, Hlaváček and Horváth (2008a,b). This article is based on Antal, Hlaváček and Horváth (2008a,b).

FIGURE 1

Forecast errors of headline inflation (actual – predicted), 1Q and 4Q horizons, 1998–2007



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

The one-quarter-ahead forecasts from the QPM were found to be statistically unbiased for all our variables except oil prices. For the one-year horizon, we find that the forecasts of inflation, GDP growth, short-term interest rates and oil prices are systematically biased (while the forecasts for the remaining variables are unbiased).

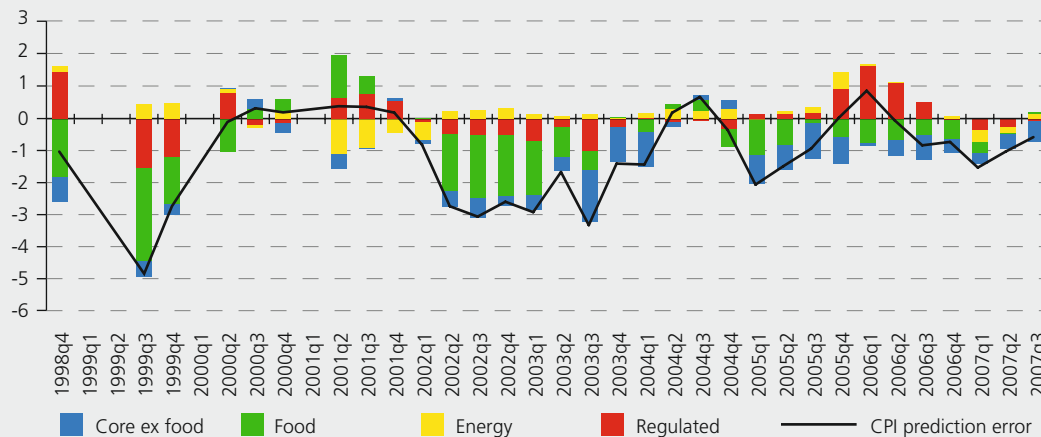
GDP growth was above the forecast and interest rates were below the forecast most of the time, even in a situation of systematic undershooting of the target. The undershooting thus cannot be explained with the help of standard demand mechanisms. Positive supply impulses were likely to be underestimated in the past. The model tools typically 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 have led to target undershooting.

As follows from the distribution of the inflation forecast errors across separate price segments, the overpredictions of inflation during most of the period under review were due to mistakes in the forecasts for food prices and core CPI ex food, while the forecast errors in energy prices mostly fostered convergence to the target (see Figure 2). The forecast 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 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.

FIGURE 2

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



Note: The figure presents the contributions of the separate inflation elements to the deviation of actual inflation from the forecast. The contributions of the separate inflation elements in pp are rendered in colours in the figure. Had the forecast fully matched the outturn, the total of the separate contributions above and under the axis would have been zero. The missing forecast errors for 1999 Q1 and Q2, 2000 Q1 and 2001 Q1 are due to the fact that during these periods inflation forecasting and its elements were prepared for a horizon shorter than 4 quarters. In 1998–2002 Q1 conditional forecasts were in use; the structural model – the QPM – was adopted as of 2002 Q2.

According to our regression analysis, about half of the apparent target undershooting in 2003 was due to errors in forecasts of exogenous factors (euro area interest rates, euro area GDP and euro area inflation), in line with the conclusions arrived at by Antal, Hlaváček and Holub (2008). In other years, errors in exogenous variable forecasts added more or less insignificantly to the target undershooting (up to approximately 10% of the total undershooting). Errors in the forecasts for short-term euro area interest rates, when compared to errors in the exchange rate forecasts, 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 assessment of the impact that errors in endogenous variable forecasts had on the inflation undershooting, while the analysis results need to be taken with caution even for the exogenous variables.

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Evaluation of the CNB's Forecasts

Zuzana Antoniřová, Karel Musil, Luboš Růžiřka and Jan Vlřek¹

This paper contributes to the discussion about the fulfilment of past inflation targets by evaluating the quality and effectiveness of forecasts as a basis for monetary policy decisions. It covers a comprehensive assessment of the full set of forecasts over the period from the beginning of 2004 until mid-2006, focusing on the medium-range horizon of 4–6 quarters. The paper only deals with forecasts produced by the CNB and does not compare them with forecasts issued by other institutions.

The CNB's Monetary and Statistics Department regularly analyses six-quarter-old forecasts, trying to identify the main factors which caused the observed deviations from reality. The results are summarised in an internal document entitled *Evaluation of Inflation Target Fulfilment* and the conclusions are regularly published in the *Inflation Report*.

Between 2004 and 2008, the main forecasting instrument was a medium-term quarterly cyclical model applicable to small open economies: the Quarterly Projection Model (QPM).² The QPM describes the medium-term relations of key macroeconomic variables, focusing primarily on the process of transmission within the inflation targeting environment. In July 2008, the model was replaced by a dynamic general equilibrium model called g3. Similarly to the existing practice, an evaluation of the inflation forecast is regularly provided with the g3 model.³

EVALUATIONS OF HISTORICAL FORECASTS

An evaluation of the success rate of historical forecasts can be performed by analysing the deviations of the forecast from reality. Simple comparisons of historical forecasts with the observed realisation of the selected variables do not help to identify factors leading to the non-fulfilment of forecasts. However, information about these factors is relevant for the further development, review and modification of forecasting tools.

The factors that can bias forecasts are either exogenous or endogenous to the forecasting process. Utterly exogenous factors enter the forecasts in the form of assumptions and are adopted in a relative mechanical manner. They include the development of key foreign indicators, such as inflation, interest rates and real economic activity, but also local factors such as domestic regulated prices and indirect taxes. Endogenous factors incorporate the determination of initial conditions for related forecasts as well as equilibrium trajectories within the forecast horizon.

The partial effects on the forecasted variables can be evaluated simply by gradual replacement of the originally assumed exogenous and endogenous factors with their actual realisation and running adjusted simulations. By comparing the adjusted and historical forecasts one can answer how much each factor contributed to the (non-)fulfilment of a historical forecast had one known its realisation at the time it was prepared. Although this comparison provides a fair basis for assessment, it can lead to wrong conclusions regarding monetary policy. This is mainly due to the unconditional nature of forecasts⁴ and the assumption of perfect knowledge of all exogenous values along the forecast horizon. Thus, the analysis must be complemented with a detailed knowledge of the story behind the forecasts.

FORECASTS PUBLISHED IN 2004

The inflation forecasts made in that period presumed growth of inflation pressures and actually exceeded the observed values. According to the forecasts, as a result of changes to indirect taxes and regulated prices, inflation was supposed to grow, reflecting an increase in inflation expectations. The inflation pressures were accompanied by a significantly positive output gap, leading to a U-turn in real economic activity in the direction of expansion. Thus, they implied a need for higher ex-post interest rate trajectories than the one consistent with fulfilment of the target.

1 See, for example, Beneř, Hlédik, Vávra and Vlřek (2003).

2 For more details about the g3 model see Anderle, Hlédik, Kameník and Vlřek (2009).

3 The unconditional nature of the forecast means that the forecast incorporates the reaction of interest rates. In other words, the forecast does not impose an assumption about an exogenous path of interest rates, but produces a trajectory that is consistent with expected inflation approaching the inflation target.

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In reality, the impact of the changes to indirect taxes was lower than expected. Moreover, the growth of the supply side of the economy and the appreciation of the real exchange rate were faster. As a result of the lower impact of changes to indirect taxes, inflation in 2005 dropped under the inflation target and thus ended up significantly below the forecast. However, the forecasts in that period presumed considerable penetration of the effects of the changes to indirect taxes and regulated prices into inflation via inflation expectations. Based on analyses performed in the period under review, this penetration was reduced in several steps. This had a significant disinflationary impact on the inflation forecasts. Another important factor causing errors in the inflation forecasts at that time was an ex-post incorrect assumption about faster growth of food prices.

Incorrect projections of the phase of the economic cycle contributed significantly to the overvaluation of the forecasts as well. The forecasts made at that time correctly expected a higher growth rate of real economic activity, but rather through growth in demand (via the output gap). In reality, inflation was not increased at the forecast horizon, despite relatively high observed real GDP growth. Recently, the output gap is believed to have had an anti-inflationary effect along the forecast horizon. The high real growth was pulled rather by the supply side of the economy, i.e. a faster growth of equilibrium output occurred. Moreover, faster equilibrium real exchange rate appreciation was identified.

FORECASTS PUBLISHED IN 2005

The forecasts for inflation and interest rates made in 2005 were fulfilled in general. The only exception was the October 2005 forecast, which was substantially higher than the reality. The reason was that the forecast disaggregated the impact of the equilibrium real exchange rate appreciation on the components of inflation for the first time and it also took into consideration the tradable and non-tradable character of those components, which was

later found to have been wrongly preset. The average bias of the other three forecasts was close to zero.

The forecasts were consistent with the observed inflation, which fluctuated close to the point target in 2006. Similarly, real economic activity was in line with the contemporary view. However, the forecasts for real GDP continued to lag behind the reality. The growth of equilibrium output was higher than expected since, similarly to 2004, difficulties regarding the correct assessment and setting of the long-term equilibrium trends remained.

The assumption about the development of economic activity also implied the setting of equilibrium real exchange rate growth. Although the forecasts from this period may seem fully in order, they contained partial errors in the prediction of the exchange rate. They did not expect such a significant appreciation of the exchange rate. In the overall picture, and in view of the recommendations, the forecasts ended up well, because unexpected growth in regulated prices offset the negative contribution to inflation stemming from import prices and low food price inflation..

FORECASTS PUBLISHED IN 2006

The first two forecasts from 2006 expected that inflation would keep close to the point target. In reality, however, inflation dropped significantly in the fourth quarter of 2006. In particular, adjusted inflation excluding food prices stayed at lower values in 2007, along with faster-than-expected appreciation of the nominal exchange rate. The nominal exchange rate thus again became the main factor of non-fulfilment of the forecasts. It was accompanied by a significant revision of the impact of the changes to indirect taxes on tobacco products, which were substantially lower in 2007 than initially assumed.

The historical inflation forecasts, however, are not fully comparable with the observed values. The reason is that the weights of the consumption basket, as published by the Czech Statistical Office, changed in the course of 2007.

In 2006, a historical comparison led to more significant changes being made to the model apparatus, reflecting the conclusions of the available analyses of the fulfilment of the inflation target. In particular, this included a reassessment of the equilibrium values in order to remove effects leading to overvaluation of the inflation forecasts.

CONCLUSIONS

The forecasts produced during the period under review were biased on average towards higher inflation, lower real growth and a more depreciated nominal exchange rate. Consistent with that, the implied interest rate trajectory was also, on average, higher than the observed one. The deviations of the basic macroeconomic variables increased with an extending forecast horizon. However, the deviations gradually declined over time and are lower in the case of the reviewed forecasts dating back to 2006.

Based on an evaluation of the forecasts produced between 2004 and mid-2006, three basic groups of factors explaining the forecast deviations have been identified. The first group comprises influences

resulting from the settings of the equilibrium trajectories. This is the group of factors which contributed to the largest extent to the deviations of the forecasts from reality in the past. In the ex-post evaluation, incorrect estimation of non-inflationary output growth, the rate of equilibrium appreciation of the exchange rate (undervaluation in both cases) and the high level of equilibrium interest rates in the past ended up in the forecasts being biased.

The second group incorporates non-fulfilment of some exogenous assumptions and the impact of unexpected shocks. In first place is overvaluation of the first-round effects of indirect tax changes on inflation. The lower observed inflation also reflected a different food price inflation path.

The last group of factors is represented by incorrect calibration of some behavioural relationships within the model, which constitutes the core instrument of the forecasts. Based on analyses performed during the period under review, modifications of the model equations mainly resulted in a reduction of the influence of energy prices and regulated prices on inflation expectations, which reduced the inflation forecast errors.

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The History of Inflation Targeting in the Czech Republic Through the Lens of a Dynamic General Equilibrium Model

Jaromír Hurník, Ondřej Kameník and Jan Vlček¹

The Czech economy experienced sharp disinflation following the introduction of inflation targeting. It was certainly not the only transition economy that experienced such disinflation, but it stands out in terms of inflation being below the declared inflation targets most of the time (Holub and Hurník, 2008). While it could be argued that this target undershooting was due to many reasons, we focus in more detail on one of the possibilities, namely on the role that may have been played by monetary policy itself (Hurník, Kameník and Vlček, 2008).

We analyse past monetary policy in the Czech Republic with respect to its publicly declared inflation target using a dynamic general equilibrium model. The underlying rationale of our approach is that monetary policy should be analysed with the help of an economic model in which monetary policy is present, but is such that its parameterisation is policy independent (Lucas, 1976).² The heart of the method used consists in explaining, with the help of the economic model and a set of observed economic variables, the observed dynamics of the economic variables with economic shocks which include changes in technology, changes in consumer preferences, exchange rate shocks and monetary policy shocks.

The monetary policy shocks identified and their impact on nominal interest rates and inflation are of primary interest in our analysis. If any part of the observed realisation of nominal interest rates or inflation can be attributed to a monetary policy shock, we conclude that the central bank set interest rates either above or below the level consistent with the observed state of the economy and the published inflation target. That does not mean, of course, that whenever, for example, a positive monetary policy shock occurs, observed inflation will necessarily, with some lag, appear below the inflation target. In practice, inflation may well

hit the target precisely or even exceed it, as a result of other shocks that hit the economy at the same time. A simple comparison of the observed inflation and the inflation target thus may lead to a wrong evaluation of the policy stance, while the method applied is such that even in the case of a precise hit of the target, we are able to estimate the impacts of monetary policy shocks and document whether or not monetary policy was set consistently with the declared inflation target. Another advantage of the method consists in the fact that, in order to identify monetary policy shocks, it makes no difference what analyses the central bank actually based its decisions on. The resulting identification of monetary policy shocks, while being subject to the specification of the economic model used, is in fact independent of the analytical framework used within the central bank.

Unfortunately, the identification of monetary policy shocks in itself only provides information on when the central bank set nominal interest rates below or above the level consistent with the observed state of the economy and the inflation target, without actually revealing why the central bank did so. However, an analysis of other shocks identified at the same time as the monetary policy shock, or before or after such time, may lead us to some conclusions in the end.

The model used for the analysis should include endogenous monetary policy, reflect its transmission mechanism well and have a sufficiently rich supply (production) structure to enable it to be calibrated on the observed data and the information contained within the GDP components. The model that meets all these conditions is a dynamic general equilibrium model developed at the Czech National Bank for forecasting purposes. An earlier version of it was described in Beneš, Hlédík, Kumhof and Vávra (2005), while the version we use is discussed in

¹ This article is based on Hurník, Kameník and Vlček (2008a,b).

² This condition gains even more on importance when the hypothesis cannot be excluded that monetary policy actually did something else than that which it publicly committed itself to doing.

detail by Andrlé, Hlédik, Kameník and Vlček (2008). The model includes the sectors of households, intermediaries in the financial market, domestic producers of intermediate goods, importers of intermediate goods, producers of final consumption goods, exporters and producers of capital goods, as well as the government and the central bank, which is expected to carry out credible monetary policy under the inflation targeting regime. It is important for our method to avoid any ad hoc detrending of the observed time series. Therefore, the model structure is extended for both nominal and technology trends so as to enable direct use of the observed nonstationary time series.

A reduced form of the model serves as a starting point for the estimation of structural shocks based on the method of Kalman filtration. The Kalman filter applies a reduced form of the model extended for measurement equations that map the observed variables to the unobserved and identifies all unobserved variables that are part of the model, including structural shocks.³

The data set covers the period from 1998 Q1 to 2007 Q4 and the variables used as observed are the domestic CPI index, the regulated price index, the consumption deflator, the investment deflator, the export deflator, the import deflator, the government consumption deflator, real consumption, real investment, real exports, real imports, real government consumption, the nominal wage (the average wage in the business sector), the nominal exchange rate (CZK/EUR), the 3M nominal interest rate (PRIBOR) and foreign prices (the PPI index for the euro area), the 3M nominal interest rate (EURIBOR) and demand (real imports of the euro area). All the variables are used in levels.

Similarly to Smets and Wouters (2007), the estimated structural shocks are used in the next stage for historical simulations of the model, where we simulate the impact of each particular estimated realization of shocks (such as an exchange rate shock, a shock to regulated prices, etc.) on the deviation of nominal interest rates and inflation

from their long-term values. Such a long-term level is represented by the inflation target in the case of inflation and by the sum of the equilibrium real interest rate and inflation expectations (or the inflation target in the long run) in the case of nominal interest rates.

Our results suggest that exchange rate shocks were the key determinant of the nominal interest rate (its deviation from the long-term level). The other determinants were shocks to foreign interest rates and monetary policy shocks, the latter being crucial for the purposes of our analysis. It holds that whenever such shock is positive (negative), nominal interest rates were set higher (lower) than ideally consistent with the observed state of the economy and the inflation target.

The first period following the introduction of inflation targeting for which we identify a sequence of positive monetary policy shocks starts in 1998 Q2 and ends in 1999 Q3. The largest contribution of the monetary policy shock is estimated for 1998 Q3–Q4. As a result, we may note that especially during the second half of 1998, monetary policy was more restrictive than corresponded to the observed state of the economy and the inflation target. At the same time, the behaviour of the other shocks suggests that the monetary policy shock occurs due to an insufficiently quick response by the central bank to the fading inflationary effect of the previous depreciation exchange rate shock that took place in 1997.

One explanation of the slow response may be policymakers' aversion to sharp moves shortly after the launch of inflation targeting regime. At that time, monetary policymakers faced numerous uncertainties regarding the estimation of equilibrium trends and the transmission mechanism, as well as an inefficient banking sector and underdeveloped financial market. They were probably also aware that had the declared disinflation been unsuccessful, any subsequent attempt would have been much more expensive in terms of lost credibility. Therefore, the decision to decrease the interest rate more

³ Identification of structural shocks is conditional on expectations of future events. Within the identification process a reduced form of the model is used and therefore expectations are fully model consistent. An alternative for future prospective research is to expand this procedure to enable us to include the expected development of exogenous (foreign) variables.

slowly than would otherwise have been optimal might have been motivated by risk aversion that led monetary policymakers to transfer into the present time a portion of the expected costs of future disinflation attempts.

During the second half of 1999 and until the second half of 2001, we identify no marked monetary policy shocks being a determinant of nominal interest rates. We therefore conclude that, during that period, nominal interest rates were set consistently with the inflation targets and the observed economic developments.

The situation began to change in the second half of 2001, when an exchange rate appreciation shock hit the economy, followed by another shock stemming from falling foreign interest rates. A positive monetary policy shock arose concurrently with a negative exchange rate shock. This may indicate that the reason behind the monetary policy shock might have been an insufficiently quick response by the central bank in lowering the interest rate. The size of the monetary policy shock rose gradually during the first half of 2002 and the central bank succeeded in breaking this tendency as late as 2002 Q3, when the absolute size of the monetary policy shock decreased, despite the culminating exchange rate shock.⁴

The period from 2003 Q3 to 2004 Q2 was a time of negative monetary policy shocks. Nominal interest rates were kept lower during this period than was consistent with the observed state of the economy and the inflation target. We identify the most marked negative shock in 2004 Q1, during the concurrent effects of an exchange rate depreciation shock.⁵

In 2004 Q3, a positive monetary policy shock appears once again and persists, albeit very modestly, until 2006 Q1. Identically to the previous example, the positive monetary policy shock is accompanied by a negative exchange rate shock. As opposed to the previous period, however, the exchange rate shocks tend to follow the initial monetary policy shock. Indeed, while a positive monetary policy

shock occurs in 2004 Q3, a negative exchange rate shock follows only in the fourth and subsequent quarters. The central bank may have contributed to the exchange rate appreciation shock, as the low level of the foreign interest rate at that time caused strong pressure for exchange rate appreciation.⁶ It could be that the observed state of the economy was not entirely accurately assessed in those analyses.

The decomposition of inflation consequently shows monetary policy shocks as a significant and comparatively long-term factor of negative deviations of inflation from the inflation target. The monetary policy shocks identified for the period from 1998 Q2 to 1999 Q3 push inflation below the inflation target during the period from 1998 Q2 to 2000 Q2, i.e. over the first two years of the new monetary policy regime. Similarly, the monetary policy shocks identified for the period from the second half of 2001 onwards ebb away in the second half of 2003, although their impact on inflation is present until the end of that year.

Interestingly, the impact of monetary policy shocks on inflation is more persistent than the monetary shocks themselves. Out of the 39 observed periods (counted from 1998 Q1 until 2007 Q4), monetary policy was more anti-inflationary than was consistent with the observed state of the economy and the inflation target during 30 periods.

Summing up, the history of persistent undershooting of inflation targets by the Czech National Bank evokes the question of the reasons for this undershooting, including an obvious emphasis on the role of monetary policy itself. We provide an answer to this question from the perspective of a dynamic general equilibrium model designed and calibrated to fit the Czech economic data.

The strong conclusion of our analysis, derived from the estimation of structural economic shocks, is that in three periods Czech monetary policy was significantly more restrictive than was consistent with the observed state of the economy and the declared inflation target. Those periods

4 Interest rates were lowered by 0.75 pp in July 2002. During the first half of 2002, the CNB was additionally making efforts to stop the exchange rate appreciation by intervening in the foreign exchange market.

5 In 2004 Q1, the temporary depreciation of the koruna peaked. The koruna recorded an average of 32.90 CZK/EUR in that quarter.

6 In August 2004, the interest rate was increased by 0.25 pp. The decision to increase it followed the July forecast, which was consistent with a rising trajectory of interest rates (see the July 2004 Inflation Report).

were as follows: 1998 Q2–1999 Q1, 2001 Q3–2003 Q2, and 2004 Q3–2005 Q4. For one period, specifically from 2003 Q3 to 2004 Q2, we identify a relatively loose monetary policy.

The weak conclusion is our view that the most probable reasons were, in the first period, a slow response to an already fading previous pro-inflationary shock, in the second period, a slow response to an exchange rate appreciation shock in progress, and, in the third period, erroneous directing of interest rates in a situation that no longer justified such a step.

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The CNB Economic Research and Financial Stability Department announced the regular Call for Research Projects 2010, direct link:

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The fifth CNB Research Open Day will be held in the Czech National Bank's Commodity Exchange (Plodinová Burza) building on **Tuesday, 26 May 2009**. This half-day conference will provide an opportunity to see some of the best of the CNB's current economic research work, to learn about the CNB Call for Research Projects 2010 and to meet CNB researchers informally.

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Programme

Tuesday, 26 May 2009

The Czech National Bank's Commodity Exchange (Plodinová Burza) building,
Senovážné nám. 30, Praha 1

8.30	Registration & Morning Coffee Chair: Kateřina Šmídková, CNB	10.15	Coffee Chair: Michal Hlaváček, CNB
9.00	ERD Award 2009 and Call for Projects 2010, Kateřina Šmídková (Executive Director, Economic Research and Financial Stability Department, CNB)	10.40	Central Bank Losses and Economic Convergence, Martin Cincibuch, Tomáš Holub and Jaromír Hurník, CNB
9.20	Survey on Wage and Price Formation of Czech Firms, Jan Babecký, Kamil Dybczak and Kamil Galuščák, CNB	11.05	Discussion: Marie Hoerová, ECB
9.45	Discussion: Ana Lamo, ECB	11.30	Q&A
10.10	Q&A	11.35	The Origins of Global Imbalances, Jan Brůha and Jiří Podpiera, CNB
		12.00	Discussion: Roland Straub, ECB
		12.25	Q&A
		12.30	Lunch