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Causes of Deviations from the CNB's Inflation Targets: An Empirical Analysis*

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Abstract
This paper provides an empirical analysis of the factors that caused deviations from the CNB's inflation targets during the first ten years of inflation targeting in the Czech Republic. While in the short term, shocks to agricultural producer prices represent the most important factor, exchange rate shocks are clearly the most important medium-term factor. At the same time, it could not be proved that monetary policy created any major shocks contributing to the non-fulfillment of inflation targets, although some role thereof cannot be excluded either.

1. Introduction

This paper analyzes empirically the causes of deviations from the inflation targets of the Czech National Bank (CNB) during the first ten years of inflation targeting. Section 2 presents a review of such causes as contained in the existing literature dealing with inflation targeting in the Czech Republic, and applies simple cross-correlation analyses and Granger causality tests to identify which explanatory variables – and with what time lags – seem to have a statistically significant relationship to the deviations of inflation from the CNB's targets. Section 3 then offers estimates of two VAR models examining the impulse responses of the deviations of inflation from the target to the individual shocks, and providing a variance decomposition of these deviations. Section 4 concludes.

Based on those analyses, it can be concluded that the most important short-term factor of the deviations from the CNB's inflation targets are shocks to agricultural producer prices. In the medium term, however, real exchange rate shocks take over as by far the most important factor. Indeed, the main common macroeconomic feature of the two periods of the most significant inflation target undershooting was a noticeable and unexpected strengthening of the Czech koruna's (CZK) exchange rate. The difficulties caused by the exchange rate were further accentuated by their coincidence with other factors, although these were less important and – as such – they would have probably only resulted in less distinct and shorter-lived episodes of inflation target undershooting. The analysis, however, does not provide an answer to the question of why the target fulfillment was asymmetrically skewed in the undershooting direction and why the periods characterized by depreciation corrections of the exchange rate did not result in any overshooting of the CNB's targets.

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2. Literature Review and Basic Statistical Tests

The fulfillment of the CNB's targets during the first decade of inflation targeting was affected to a significant extent by two episodes characterized 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 CZK exchange rate (in both periods). To compare, in its Inflation Reports the CNB assigned the 1998–1999 target undershooting in first place to food prices, and then also to weak domestic demand, the strong exchange rate, and low oil prices in 1998. In 2002–2003, the CNB pointed in particular to the disinflationary effects of regulated prices, food prices, exchange rate appreciation, and international developments.

A disadvantage of the above-mentioned papers – with the exception of the CNB's Inflation Reports – lies in the fact that they do not quantify the relative importance of the individual factors. At the same time, they do not take into consideration possible endogenous links among those factors, such as the effect of the exchange rate, monetary and fiscal policies or international developments on local food prices and on regulated prices, as well as the feedback effects of price developments on monetary policy decisions. Without considering such links, any reliable quantification is difficult, something which also casts doubt on the analysis of the two challenging periods as presented in the Inflation Reports. The CNB's forecasts were compiled for both of those periods using short-term forecasting methods and their fulfillment was also assessed based on these tools afterwards. Those methods were not particularly suitable for capturing medium-term endogenous links in the economy (see (Coats et al., 2003)). The core QPM model was not used for forecasting until mid-2002, i.e., until the second exchange rate appreciation episode was already peaking. Therefore, it was possible to use it in the analysis of inflation target fulfillment (see (Filáček, 2007), (Antoničová et al., 2008)) only starting at the beginning of 2004, when inflation had already started returning to the target.

Holub and Hurník (2008) express the opinion that exchange rate appreciation shocks were the key common feature of both target undershooting episodes. For the sake of brevity, however, no sufficiently detailed evidence for such claims is presented in their paper, except for a brief footnote. The present paper removes the above-described shortcomings of all the earlier papers and presents a detailed empirical analysis of the causes of the deviations from the CNB's inflation targets.

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

All the variables are used at quarterly frequency in the form of deviations from their estimated equilibrium levels, because the variable in focus – i.e., deviations

of inflation from the target[1] – may also be considered to be deviations from the equilibrium. As far as prices of crude oil and agricultural producer prices are concerned, they always represent deviations from the trend as estimated using the Hodrick-Prescott (HP) filter.[2] As regards the real exchange rate gap, real interest rate gap, and domestic and foreign output gaps, we work with two alternative estimates. The first one is based on the structural Kalman Filter, which is applied by the CNB in its analyses and forecasts (see (Beneš and N'Diaye, 2003)); the other one is based on the HP Filter. The advantage of using the Kalman Filter is that the estimated "gaps" correspond to the view of the central bank concerning the development of the Czech economy. On the other hand, though, its application may cause some "bias" in the analyses in the form of an implicit a priori presumption about the course of monetary transmission as captured by the QPM model applied by the CNB. The application of an alternative estimate based on the HP Filter, which represents a non-parametric filter, may thus be understood as a robustness check of the results.[3]

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

Simple cross-correlation analyses and pair-wise Granger causality tests were used in the first step to test the statistical significance of the above-described variables. One of the variables was always represented by the deviations of inflation from the CNB's target, while the other side was always occupied by one of the above--described "explanatory" variables. The results are reported in *Table 1*. The results of both tests are always shown for the time lag which maximizes the correlation coefficient or minimizes the zero-hypothesis probability level in the Granger causality test.

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

At the same time, all of the explanatory variables, with the exception of agricultural producer prices[4] and the real interest rate gap estimated using the HP Filter, Granger-cause the deviations of inflation from the target at least at the 10 percent sig-

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

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

[3] As concerns the real interest rate gap, there is also a difference in that the nominal interest rate is deflated by partly forward-looking expectations in the Kalman filter estimate, while inflation expectations are deemed purely backward-looking when using the HP filter.

TABLE 1 Factors of Deviations from Inflation Targets – Cross-Correlation Analysis and Granger Causality Tests

Explanatory variables	Correlation coefficient [a, b]	Reverse correlation [a, b]	Granger causality test – probability [b]	Reverse causality [b]
Foreign output gap – KF	-0.40* (10)	-0.37* (4)	4.0% (10)	9.4% (8)
Foreign output gap –HP	-0.44* (10)	-0.33* (4)	5.1% (10)	2.4% (10)
Oil prices	0.51* (3)	-0.46* (3)	0.8% (1)	1.0% (1)
Real exchange rate gap - KF	-0.59* (3)	0.55* (2)	0.0% (1)	0.1% (1)
Real exchange rate gap - HP	-0.52* (3)	0.57* (2)	0.0% (1)	0.1% (1)
Agricultural producer prices	0.58* (0)	-0.71* (5)	14.1% (1)	1.5% (2)
Output gap – KF	0.55* (0)	0.55* (0)	0.5% (2)	0.7% (3)
Output gap – HP	0.47* (1)	0.44* (0)	5.4% (1)	2.5% (1)
Real interest rate gap – KF	-0.51* (2)	0.38* (3)	0.0% (1)	0.5% (4)
Real interest rate gap – HP	-0.75* (0)	0.57* (5)	14.1% (4)	1.7% (6)

Notes: HP denotes estimates produced using the HP Filter, and KF denotes estimates produced using the Kalman Filter.

[a] * denotes statistically significant results at the 5 percent probability level.

[b] The numbers in brackets show the time lag/lead between the explanatory variables and the deviations of inflation from the target maximizing the statistical significance of the identified relationship.

Source: Own calculations.

nificance level, usually with a time lag of 1–2 quarters (only with the foreign output gap does the time lag extend to 10 quarters, in line with the correlation analysis, making this relationship hard to interpret). These results, therefore, justify further research of the causal links between those variables and the deviations of inflation from the target.

We also examined the reverse correlation and causality directed from inflation deviations from the target to the analyzed variables (see *Table 1*). The reverse causality was statistically significant at least at the 10 percent probability level with all the variables. In the case of the foreign output gap and oil prices, which can be deemed purely exogenous factors for a small open economy, this conclusion is not intuitive. For oil prices, it can be presumed – in view of the small time lag – that the reverse causality rather represents a coincidence of both variables than any causal relationship. For the foreign output gap, the causality is most probably spurious. In the case of the domestic variables, however, the option of reverse causality is not surprising and only confirms the opinions expressed in the introduction to this section of the paper, namely, that a number of factors used in the literature so far to explain deviations of inflation from the CNB's targets are in reality of an endogenous nature, which needs to be considered in the analysis.

3. Estimates of VAR Models

The endogenous links among the individual variables can be properly taken into account by estimating the VAR models which are presented in this section. The VAR models at the same time allow us not only to identify the statistical sig-

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

nificance of the individual factors by examining the significance of the impulse responses to shocks, but also to analyze their economic significance via a variance decomposition of the deviations of inflation from the CNB's targets.

Two models have been estimated, which can be expressed in general as follows:

$$Y_t = aLY_t + \boldsymbol{v_t} \quad (1)$$

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

where *ea_gap* denotes the foreign output gap (approximated by the effective eurozone, i.e., with the individual countries weighted according to their shares in Czech foreign trade), *poil_gap* denotes the deviation of the USD crude oil price from its trend, *er_gap* denotes the real exchange rate gap, *czv_gap* denotes the deviation of agricultural producer prices from their trend, *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, $\boldsymbol{v_t}$ represents the vector of residuals, and L stands for the time-lag operator. The two models differed only in one sense: whether they included the foreign and domestic output gap, the real exchange rate gap, and the real interest rate gap as estimated by the Kalman Filter or by the HP Filter.

Shocks to the individual variables were identified based on the Cholesky decomposition, with the variables ordered as in Equation (2). This is a fairly standard ordering, reflecting the transmission of shocks in a small open economy applying inflation targeting. The ordering means an implicit presumption that shocks to exogenous variables (*ea_gap* and *poil_gap*) may have an immediate impact on the exchange rate, 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 under the inflation targeting regime via the setting of interest rates to all the available information. The lag length in the model was determined at two quarters, in view of the relatively short time series and making use of the standard tests.[5]

The variance decomposition of the deviations of inflation from the CNB's targets is presented in *Figure 1* for the VAR model using the estimates made using the Kalman Filter, and in *Figure 2* for the model with the variables estimated by the HP Filter.

It turns out that in the short term the most important factors of the deviations of inflation from the target (apart from the shocks to inflation itself) are agricultural producer prices and – in the case of the model with the HP Filter variables – also crude oil prices. Their influence, however, would get weaker in the longer run. Shocks to real interest rates, i.e., monetary policy shocks, hold roughly a 15 percent share in both models in the variance of the deviations of inflation from the target at the time horizon of approximately 2–4 quarters, and this share is at the edge of statistical sig-

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

FIGURE 1 Variance Decomposition of Deviations from Inflation Targets (Kalman Filter)

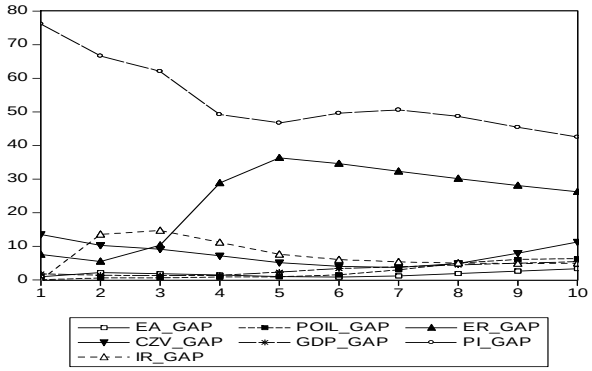
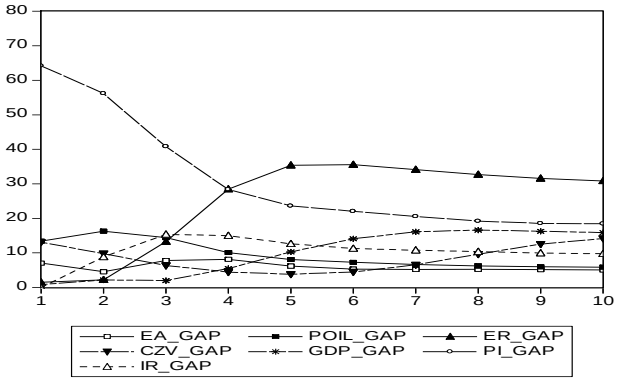


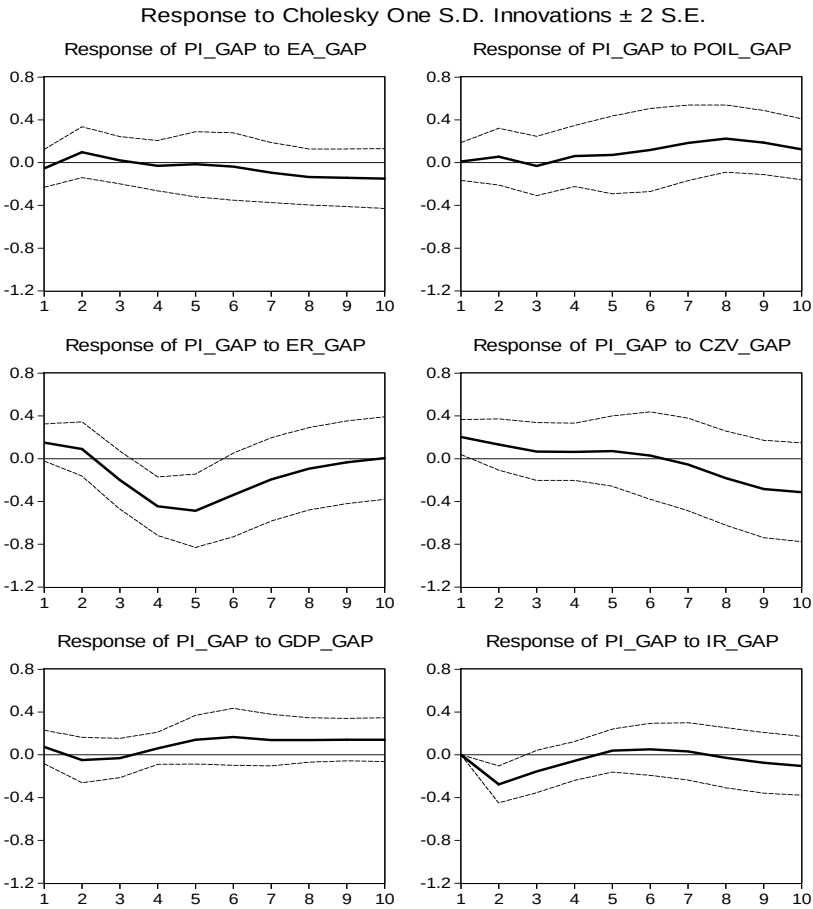
FIGURE 2 Variance Decomposition of Deviations from Inflation Targets (HP Filter)



nificance. However, at the horizon of one year or longer, by far the most important factor is the real exchange rate gap, which explains a substantially larger portion of the variance of the deviations of inflation from the CNB's targets (more than 35 %) than the other macroeconomic variables, and its influence is statistically significant. As far as the model with the HP Filter variables is concerned, the shocks to the domestic output gap are also at the edge of statistical significance at a horizon exceeding 6 quarters; the model using the time series derived from the Kalman Filter, however, would not support this conclusion.

The impulse responses of the deviations of inflation from the target to shocks affecting the individual variables are shown in *Figure 3* for the model using variables derived from the Kalman Filter and in *Figure 4* for the model using variables from the HP Filter. Some conclusions would be qualitatively identical for both models. Shocks hitting agricultural producer prices are statistically significant for short time lags; however, their impact would gradually decline and would quickly become statistically insignificant. The real exchange rate shocks are most effective with a lag of 4–5 quarters, and an overvaluation (undervaluation) of the real exchange rate results in a statistically significant decline (increase) of inflation below (above) the target. The maximum real exchange rate pass-through into inflation is roughly 28–38 %,

FIGURE 3 Impulse Responses of Deviations from Inflation Targets to Shocks (Kalman Filter)

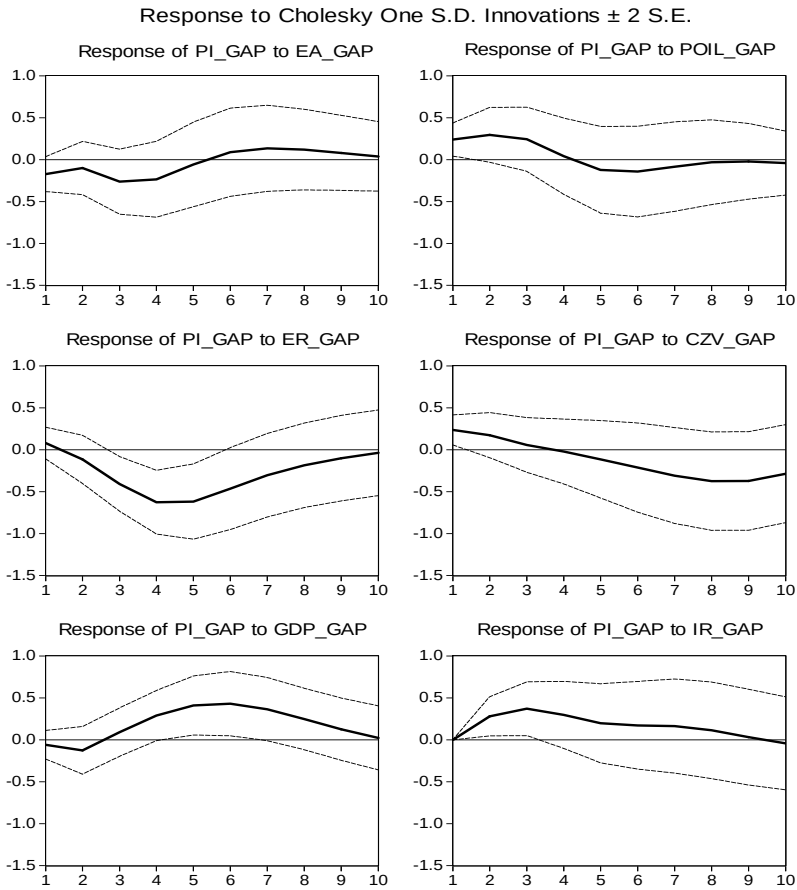


which broadly matches the conclusions from the previous studies focusing on the Czech Republic (see (Babetskaia, 2007)).[6] The two models also agree that international demand shocks would not have any statistically significant impact on the deviations of inflation from the target. These conclusions, therefore, may be considered reasonably robust.

However, some partial differences exist between the two estimates, which call for cautious interpretation of the results. The model based on inputs from the HP Filter identified shocks hitting global crude oil prices as statistically significant for short time lags, while the model with the Kalman Filter variables did not. The same applies in the medium term also for the impact of domestic output gap shocks. This finding

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

FIGURE 4 Impulse Responses to Deviations of from Inflation Targets to Shocks (HP Filter)



is surprising given that the output gap estimated using the Kalman Filter, contrary to the HP Filter, explicitly considers the relationship between this unobserved variable and inflation. The last noteworthy difference relates to the effect of real interest rates, which is statistically significant in both cases but – contrary to expectations – only at short-term horizons of 2–3 quarters and, moreover, with opposite signs in the two models (an intuitive one in the model with inputs from the Kalman Filter, and an counter--intuitive one in the model with inputs from the HP Filter). Such results can most probably be assigned to the well-known general difficulties concerning the identification of monetary transmission in VAR models (see, for example, the discussion and references in (Arnoštová and Hurník, 2005)) and to uncertainties in the measuring of real interest rates (forward-looking vs. backward-looking inflation expectations).

4. Conclusion

The results presented in this paper show that the exchange rate probably played the most important role in causing the deviations of inflation from the CNB's

targets. This is in line with the fact that the main common feature of the two most distinct periods of inflation target undershooting (1998–1999 and 2002–2003) was a significant and unexpected strengthening of the exchange rate of the Czech koruna (by roughly 8 % vis-à-vis the DEM and 15 % vis-à-vis the euro, respectively).

The difficulties caused by the exchange rate were further accentuated by their concurrence with other short-term factors, including in particular the development of agricultural producer prices and probably also the development of crude oil prices. Those factors, though, were of lesser importance and would probably in themselves have resulted only in less distinct and shorter-lived episodes of inflation target undershooting. [7]

Based on the econometric methods applied, it is not possible to prove or disprove that monetary policy itself created any significant shocks contributing to the non-fulfillment of inflation targets. Similarly, using the selected approach it is not possible to find out why the non-fulfillment of the target was on average significantly skewed towards undershooting and, for example, why no overshooting of the targets occurred during the periods of exchange rate depreciation.

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

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