# Interest Reaction Function of the Central Bank: The Case of Czech Republic

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## Abstract

*Central banks will either increase or decrease interest rates, or resort to leave them fixed while making adjustments on interest rates. For this reason, in general, central banks examine different strategies of monetary politics and employ distinct interest reaction functions. The aim of this study is to examine different reaction functions explicating the movement of interest rates for Czech Republic. For this aim, the impacts of inflation gap and production gap on possibilities for materialization of the abovementioned movements of interest rates analyzed by multinomial probit models. According to the attained findings, while the lag of interest rates and inflation gap play an efficient role both on increasing and decreasing interest rates, production gap plays an efficient role only on increasing interest rates. Besides, it is possible to say that the lag of interest rate and inflation gap have further effect than of production gap. As a result, it can be said that reaction functions, which deal with inflation gap, production gap and the lag of interest rates for monetary politicians of Czech Republic, will be a good and simple guide.*

**Key words:** reaction function; inflation gap; production gap; multinomial probit; interest rate; probit.

## 1. Introduction

Central banks generate mechanisms, which can be used in determining an objective intended for any macroeconomic magnitude and enable performing of strategies constructed for reaching the specified target, by developing monetary policies. Commonly covered strategies for monetary policy are inflation targeting, monetary targeting and exchange rate targeting. In recent years, inflation targeting being particularly successful compared to the other two amongst those strategies draws attention. When commencing to practice the strategy of inflation targeting, central banks have liberty to exercise different monetary policy instruments in reaching the targeted interest rate unlike other strategies. Thus, inflation targeting has possibility to be able to focus on the specific circumstance and conditions for the central bank in question. As a result, monetary policy can be determined taking into account all kind of factors that can influence inflation.

Using interest rates as an instrument for inflation targeting is a frequently encountered situation. In recent years, policy rules, which attract attention in the field of economics and projects using interest rates as an instrument of monetary policy, have been employed widespread as well. The reaction of monetary policy is systematized vis-à-vis undesired tendencies that can come into being in economic conjuncture and thereby, enabling to foresee monetary authorities' attitude by these rules, which can be referred to as the central bank reaction function, exercising short-term interest rate as an instrument of monetary policy in general[1].

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[1] The Taylor rule is one of central bank interest reaction functions. The rule exists in the literature as simple monetary policy proposed by John Taylor (1993) for the US economy. The Taylor rule is based on the relationship between short-run nominal interest rate and inflation and production gap. Based on the rule and its components proposed and presented in a simple form

As is known, inflation-targeting central banks generally take into consideration inflation rates, employment and production when determining interest rates and facilitate the adjustment of interest rate according to changes in those variables. Ultimately, central banks will either increase or decrease interest rates, or resort to leave them fixed while making adjustments on interest rates.

Interest reaction functions (especially, the Taylor rule) have been gaining significance recently. There are many studies concentrating on the effect of production gap and inflation gap on interest rates. For instance, Clarida et al. (1998) analyzed prospective movements in interest reaction functions, which they constructed with the expected inflation rather than the current inflation for the specified countries in their study, and inferred that countries are successful regarding interest rate movements. Addressing interest reaction function by non-linear methods for Turkey, Omay and Mubariz (2006) inferred that the central bank pursue an expansionary monetary policy. In the studies they have conducted for England, Gascoigne and Turner (2003) have found out that the Central Bank of England responds to growth of production rather than inflation. Taking criticisms present in the literature into consideration in their studies, Caglayan and Astar (2010a), Caglayan and Astar (2010b) scrutinized the Taylor rule and Taylor-type rules, one of central bank reaction functions for the developing countries, and studied the necessity whether exchange rate gap should be added to function. They have acquired findings concerning that exchange rate gap situating inside of the Taylor rule model for many countries does not constitute an important change. Berument and Tasci (2004) examined interest reaction function for Turkey in their study and concluded that the central bank does not target inflation rate, rather it targets fixed market. Carvalha and Mauro (2008) have evaluated the applicability of the Taylor rule for seven Latin American economies by using monthly data and have found out that the rule produces positive results for the examined countries.

As we know, there are a few studies, in which interest reaction functions were investigated, related to Czech Republic[2], albeit initiating inflation targeting in 1998. Thus, this study contributes to the sparse literature. Caglayan and Astar (2010a), Caglayan and Astar (2010b) examined whether the Taylor rule will be a good guide for inflation-targeting central banks by using logit models. They found out that production gap and inflation gap have a significant impact on both reducing and increasing interest rates for Czech Republic. Besides, they attained significant outcomes for Czech Republic being in a status of developing country in 2009 with the addition of exchange rate gap into the model as well[3].

The study objective is to examine the effect of production gap and inflation gap on movements of interest rates by using the data from Czech Republic, using different reaction functions. To this end, the impacts of inflation gap and production gap on the possibilities for realization of those movements of interest rates will be estimated by multinomial probit models. Hence, whether production and inflation gap have effects on the adjustments of interest rates of the central bank (increases, decreases in interest rates and leaving them fixed) will be researched. Thus, an estimation of how interest rates, which are instrument for monetary policy, are used will be conducted as a reaction to deviation from the potential value of production and to inflation gap for Czech Republic. Reaction function of the central bank is explained in the second section following the introduction in this study and in the third section, estimation method is revealed.

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by Taylor, many researchers have formed different rules by modifying the original Taylor Rule in order to explain other components of monetary policy or to use different data such as past, current or estimated data instead of those that are used in the original rule. Following Taylor's study, these rules in which short term interest rates are used as main policy instruments are referred as "Taylor Type Rules".

[2] The central bank of Czech Republic adopted inflation targeting as an instrument to reduce inflation in the wake of the exchange rate crisis it experienced in 1997 and officially launched inflation targeting in 1998. At the beginning of targeting, the central bank of Czech Republic designated short-run objectives referred as net inflation to seize the intended inflation and acted in line with these objectives. In 2001, Consumer Price Index started to be used with the aim of moving to full-fledged inflation targeting and becoming more apprehensible by public opinion. The central bank of Czech Republic, which still carries on with the strategy of inflation targeting currently, uses short-term interest rate as an instrument for monetary policy as well Source: Czech national bank, http://www.cnb.cz/en).

[3] One of the most common criticisms directed at the Taylor Rule, states that the rule can be inadequate for developing countries and that the rate of exchange has to be added to the model. As it is also briefly explained earlier in the paper, in the rule he has proposed for USA, Taylor has argued that it was not necessary to add exchange rate to the model for his country. However, he has also stated that in studies to be made on developing countries, the exchange rate can be added to the models, considering the monetary policies and the economic statuses of the countries in question.

The data and estimation results lie respectively in the fourth and fifth sections. Outcomes are presented in the sixth section.

## 2. Reaction Function of the Central Bank

Reaction functions are functions that contain reaction parameters, which will ensure to be able to give effective and valid reactions to those deviations when a deviation occurs in growth and the intended interest rate for central banks. In other words, reaction functions are functions, which propose monetary policy instruments to fluctuations taking place in inflation and production gap. With the beginning of employing short-term nominal interest rates for reaction functions as an instrument of monetary policy, interest reaction functions have taken place among the subjects drawing quite interest in the literature in recent periods.

Central bank interest reaction function can be dealt with in different ways. It is possible to group these functions as forward-looking and backward-looking. In the backward-looking function form, the central bank systematically adjusts short-term nominal interest rate according to changes in inflation and production gap. It uses interest rate as an instrument with respect to increase and decreases in inflation and production gap and ensures that it reacts according to those changes. In these forms, the the lag of value of interest rate also appears in the function. This form, which is also going to be analyzed in our study, is as follows:

$$i_t = i_t^* + \pi_t + \alpha(\pi_t - \pi_t^*) + \beta(y_t - y_t^*)$$

In this equation, which also appears in the literature as the central bank interest reaction; $i_t$ refers to nominal interest rate (Nominal Federal Funds Rate), $i_t^*$ refers to real interest rate, $\pi_t$ refers to the current inflation rate and $\pi_t^*$ refers to the targeted inflation rate, $y_t$ refers to the current national income level (real GDP) and $y_t^*$ refers to the potential national income level (potential GDP) realized with the full employment of resources. The one identified as $(y_t - y_t^*)$ in the equation is the current production gap displaying the difference between the production, which can actualized in t time, and the production realized in t time[4]. In the forward-looking forms, as given place in the study of Clarida et al. (1998), it is anticipated that they react to the gap between the inflation projection and the targeted inflation rather than to the gap between the current inflation and the targeted inflation.

## 3. Multinomial Probit Model

The multinomial probit model covered as the generalization of binary probit models is obtained via utility-maximization (u). Utility in the multinomial probit model with m-outcomes dependent variable for j. options is attained as,

$$u_j = v_j + \varepsilon_j \qquad j = 1,2,\dots,m$$

The surplus vector has $(m \times 1)$ dimensions. Surpluses are compound normal distributed. $\varepsilon \sim N[0, \Sigma]$ and $\varepsilon = (\varepsilon_1, \dots, \varepsilon_m)$. Here, it will be

$$v_j = x_j{}'\beta$$

or

$$v_j = x'\beta_j.$$

$\Sigma$ is the covariance matrix (Cameron and Trivedi, 2006).

The most significant advantage of multinomial probit models is that they allow a relationship being possible among options, that is to say, provide elasticity in IIA assumption (Maddala, 1983). The similarity method is employed the most in estimation of the multinomial probit models. Due to the fact that the three-choice multinomial probit model is going to be used in our study, estimation of the model will be covered here. It will be

$$P[y = 1] = \int_{-\infty}^{-V_{31}} \int_{-\infty}^{-V_{21}} f(\varepsilon_{21}, \varepsilon_{31})\, d_{\varepsilon_{21}} d_{\varepsilon_{31}}$$

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[4] Fixing some values and also, concentrating on coefficients in the reaction function formula he proposed, Taylor stated he explicated the US monetary policy between 1987-1992 very well with this fixed-coefficient formula. The equilibrium real interest rate was fixed as 2.0 and the intended inflation rate not explained by FED was fixed as 2% in this fixed coefficient formula; inflation reaction coefficient and growth reaction coefficients were weighted as 0.5. The coefficient 0.5 was omitted from the simulation models by Taylor. But, the subsequent studies indicated that greater coefficients make the rule more stability-providing.

Here, $V_{31}$ and $V_{21}$ are covariance parameters and $f(\varepsilon_{21}, \varepsilon_{31})$ has normal distribution with two variables. The above integrals are analyzed one by one for the possibility of preferring each option. $\beta$ and $\Sigma$ should be estimated to calculate probabilities. For this reason, the maximum simulated likelihood estimator is obtained

$$\ln LN (\beta_1 \Sigma) = \sum_{i=1}^{N} \sum_{j=1}^{m} y_{ij} \ln \hat{p}_{ij}$$

Maximization of the function is carried out. Here, $p_{ij}$ is attained by using the GHK and other simulators (Geweke, 1992; Hajivassiliou and McFadden, 1994; Keane, 1994). $\beta$ and $\Sigma$ would be obtained via iterative process. Coefficients cannot be directly interpreted in multinomial probit models. Marginal effects are calculated for interpreting coefficients.

## 4. Data

Central banks will either increase or decrease interest rates, or resort to leave them fixed while making adjustments on interest rates. The monthly data pertaining to January 1999 – June 2011 period were also covered in the study in which we studied the impact of inflation gap and production gaps on the realization possibility of movements of interest rates for Czech Republic. Czech Republic initiated its official inflation targeting in 1998. But, the year 1999 was picked as the initial date of analysis for the preliminary process in the beginning of targeting not negatively affect the analysis. The covered data were acquired from databases on the official website of OECD[•].

The dependent variable to be used in models was generated according to movements of interest rates. Addressing the difference of interest rates compared to the previous period, the dependent variable gets three values due to the reason of encountering the situation of increase, remaining fixed and decrease of interest rates in comparison with the previous period. The dependent variable of the Three-Choice Multinomial Probit Model that we are going to use in our estimations will get 0 if the change in interest rates is decrease oriented, 1 if the change in interest rates remains fixed and 2 if the change in interest rates is increase oriented. They will be referred to as outcomes.

The dependent variable for the multinomial probit model was obtained as,
*If $\Delta i_t < 0$    $Y_t = 0$*
*If $\Delta i_t = 0$    $Y_t = 1$*
*If $\Delta i_t > 0$    $Y_t = 2$*

Here, when $i_t$ is defined as interest rate, $\Delta i_t$ defined as the change in interest rates and $Y_t$ is defined as the dependent variable, the change in interest rates was generated in the form of $\Delta i_t = i_t - i_{t-1}$.
Explanatory variables, which will appear in models to be estimated, are inflation gap, production gap and interest rate in the previous period. Inflation gap is calculated by extracting the difference between the expected and intended inflation. By using Consumer Price Index (CPI) for the current inflation and the average value of inflation for the intended inflation in calculating inflation gap in the study, differences between them were extracted. The potential production values were attained employing the Hodrick-Prescott Filter[5] (HP, 1997) method for production index series and values for production gap were arrived at by getting the difference of these values obtained from the current production values.

## 5. Findings

In our study, six different interest reaction functions, in which inflation gap, production gap and interest rate in the previous period take place, are covered. These functions are as follows:
Model I: Outcomes=f(interest rate$_{-1}$)
Model 2: Outcomes=f(interest rate$_{-1}$,inflation gap)
Model 3: Outcomes=f(interest rate$_{-1}$, inflation gap, production gap)
Model 4: Outcomes=f(interest rate$_{-1}$,production gap)

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[•] The official database of OECD http://stats.oecd.org/Index.aspx (date of access: 05.07.2011)
[5] The Hodrick-Prescott Filter Method used in our study is employed to examine the trend effect preferred by numerous central banks and many official institutions such as OECD and ECB. The TRAMO/SEATS filter is also used in this study for seasonality effect experienced in series.

Model 5: Outcomes=f(inflation gap)
Model 6: Outcomes=f(production gap)
The multinomial probit models were estimated with the maximum likelihood method by using the data of period for when Czech Republic made inflation targeting for it with the aim of examining the impacts of variables appearing in those 6 models on the realization possibility of interest rate movements[6]. Outcomes of the estimated models are summarized in Table 1.

**Table 1.Results of  Multinomial Probit Model**

(i)

| Models | Variables \ Outcome | Constant | Interest rate$_{t-1}$ | Inflation gap | Production gap |
|---|---|---|---|---|---|
| **Model 1** | $Y_t = 1$ | -0.7918 (0.4982) | -0.2643*** (0.1551) | | |
| | $Y_t = 2$ | 0.2191 (0.3314) | -0.1833** (0.0916) | | |
| **Model 2** | $Y_t = 1$ | -0.6720 (0.5190) | -0.3062*** (0.1671) | 0.7547*** (0.4034) | |
| | $Y_t = 2$ | 0.3334 (0.3497) | -0.2261** (0.0995) | 0.9204* (0.2473) | |
| **Model 3** | $Y_t = 1$ | -0.5464 (0.5282) | -0.3383** (0.1702) | 0.8788** (0.4194) | 0.0820 (0.0553) |
| | $Y_t = 2$ | 0.4878 (0.3666) | -0.2817* (0.1056) | 1.0894* (0.2679) | 0.1437* (0.0553) |
| **Model 4** | $Y_t = 1$ | -0.7150 (0.5027) | -0.2843*** (0.1565) | | 0.0649 (0.0532) |
| | $Y_t = 2$ | 0.3209 (0.3402) | -0.2221** (0.0946) | | 0.1186* (0.0362) |
| **Model 5** | $Y_t = 1$ | -1.6125* (0.2235) | | 0.6300*** (0.3678) | |
| | $Y_t = 2$ | -0.3997* (0.1522) | | 0.8569* (0.2392) | |
| **Model 6** | $Y_t = 1$ | -1.6107* (0.2198) | | | 0.0534 (0.0529) |
| | $Y_t = 2$ | -0.4098* (0.1514) | | | 0.1086* (0.0358) |

Comparison group is: Y=0

 (ii) *,**,*** indicate significance at the level 1%, 5% and 10%, respectively.
 (iii) $Y_t = 1$ and  $Y_t = 2$ indicate that no change and increasing the interest rates, respectively.
 (iv) Numbers in parentheses are standard errors.

It is observed that the lag of interest rate is significant in both $Y_t = 1$ and $Y_t = 2$ sets in Model 1 where the effect of the lag of interest rate on the materialization possibility of interest rate movements is studied. The obtained estimations in Model 2 where inflation gap is added to the lag of interest rate were also attained significant in both sets. In Model 3 attained with the addition of production gap into Model 2, while inflation gap and the lag of interest rate are significant in both $Y_t = 1$ and $Y_t = 2$ sets, production gap was acquired significant only in $Y_t = 2$ set. The lag of interest rate and production gap were subjected to reaction in Model 4 and it was seen that production gap is only significant in $Y_t = 2$ set. Inflation gap was single-handedly examined in Model 5 and it was observed that it yielded significant results in both $Y_t = 1$ and $Y_t = 2$ sets. Production gap was studied alone in the last model and it was obtained significant only in $Y_t = 2$ set. These outcomes attained demonstrate in which cases the lag of interest rate and inflation and production gaps play a role in interest rate movements.

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[6] Variables located in the models are stationary in the level. degree-stable. The ADF test statistics pertaining to interest, inflation gap and production gap series are respectively -4.09, -12.31, and -3.72. The critical values are -2.88 for all series.

Accordingly, while the lag of interest rate and inflation gap play an efficient role both in increasing and reducing interest rates, production gap is only effective in increasing interest rates. Marginal effects were calculated for coefficient interpretations in models in which the influences of variables appearing in reaction functions on interest rate movements are investigated and the results are presented in Table 2.

According to marginal effects belonging to the model, while variables are fixed; whereas, an increase of 1% in the lag of interest rate increase the possibility of reducing interest rates 0.05%, it decreases the possibility of increasing interest rates and keeping them fixed 0.01% and 0.04% respectively. While other variables are fixed for model 2; whereas, an increase of 1% in the lag of interest rate increase the possibility of reducing interest rates 0.06%, it decreases the possibility of increasing interest rates and keeping them fixed 0.01% and 0.05% respectively. While an increase of 1% in inflation gap decreases the possibility of reducing interest rates 0.25%, increases the possibility to increase interest rates and keeping them fixed 0.03% and 0.22% respectively. While an increase of 1% in the lag of interest rate in Model 3 increase the possibility to reduce interest rates 0.08%, decreases the possibility to increase interest rates and keep them fixed 0.01% and 0.06% respectively.

### Table 2. Marginal Effects

| Models | Variables ⟍ Outcome | Interest rate$_{t-1}$ | Inflation gap | Production gap |
|---|---|---|---|---|
| **Model 1** | $P(Y_t = 0)$ | 0.0573** (0.0250) | | |
| | $P(Y_t = 1)$ | -0.0162 (0.0122) | | |
| | $P(Y_t = 2)$ | -0.0410*** (0.0244) | | |
| **Model 2** | $P(Y_t = 0)$ | 0.0694** (0.0270) | -0.2580* (0.0684) | |
| | $P(Y_t = 1)$ | -0.0182 (0.0126) | 0.0317 (0.0316) | |
| | $P(Y_t = 2)$ | -0.0512** (0.0261) | 0.2263* (0.0643) | |
| **Model 3** | $P(Y_t = 0)$ | 0.0843* (0.0284) | -0.3035* (0.0741) | -0.0382* (0.0105) |
| | $P(Y_t = 1)$ | -0.0198 (0.0133) | 0.0383 (0.0339) | 0.0020 (0.0046) |
| | $P(Y_t = 2)$ | -0.0644** (0.0272) | 0.2652* (0.0687) | 0.0362* (0.0101) |
| **Model 4** | $P(Y_t = 0)$ | 0.0676* (0.0257) | | -0.0316* (0.0098) |
| | $P(Y_t = 1)$ | -0.0171 (0.0127) | | 0.0013 (0.0045) |
| | $P(Y_t = 2)$ | -0.0505** (0.025) | | 0.0302* (0.0095) |
| **Model 5** | $P(Y_t = 0)$ | | -0.2377* (0.0663) | |
| | $P(Y_t = 1)$ | | 0.0252 (0.0324) | |
| | $P(Y_t = 2)$ | | 0.2125* (0.0628) | |
| **Model 6** | $P(Y_t = 0)$ | | | -0.0286* (0.0097) |
| | $P(Y_t = 1)$ | | | 0.0007 (0.0048) |
| | $P(Y_t = 2)$ | | | 0.0279* (0.0094) |

(i) Comparison group is: Y=0

  (ii) *,**,*** indicate significance at the level 1%, 5% and 10%, respectively.

  (iii) $P(Y_t = 0)$, $P(Y_t = 1)$ and $P(Y_t = 2)$ indicate the probability of decreasing, no change and increasing the interest

    rates, respectively.

  (iv) Numbers in parentheses are standard errors.

An increase of 1% in inflation and production gap decreases the possibility to reduce interest rates 0.30% and 0.03% respectively, it increases the possibility to keep interest rates fixed 0.03% and 0.002% respectively and increases the possibility to increase interest rates 0.25% and 0.03% respectively. While a 1% increase in production gap in Model 4 decreases the possibility to reduce interest rates 0.03%, increases the possibility to increase and keep interest rates fixed 0.001% and 0.03% respectively. According to Model 5, while an increase of 1% in inflation gap decreases the possibility of reducing interest rates 0.23%, increases the possibility of increasing and keeping holding interest rates fixed 0.02% and 0.21% respectively. While other variables are fixed in Model 6, whereas an increase of 1% in production gap decreases the possibility to reduce interest rates 0.02%, it increases the possibility to increase and keep interest rates fixed 0.0007% and 0.027% respectively.

According to these results acquired, while inflation gap raises the possibility to increase interest rates, decreases the possibility to reduce interest rates. While the lag of interest rate increases the possibility to reduce interest rates, decreases the possibilities to increase interest rates. Whereas production gap decreases the possibility of reducing interest rates, raises the possibility of increasing interest rates. But, when all these results covered together, it is possible to say that the lag of interest rate, to wit interest rate in the previous period, and inflation gap have more effect on interest rate movements than production gap.

## 6. Conclusion

The impacts of production gap and inflation gap on the materialization possibilities of movements of interest rates were researched via different reaction functions in our study we have used the data pertaining to 1999-2011 period containing the period when inflation targeting for Czech Republic was carried out.

The results obtained gravitate towards that the central bank of Czech Republic decided according to the intended inflation rate and deviation from this objective and interest rate in the previous period, while it was employing short-term nominal interest rates as a monetary policy instrument. Results indicate that whereas inflation gap and the lag of interest rate play an effective role on both increasing and reducing interest rates, production gap is only effective on increasing interest rates. This situation can be interpreted in a way to behave according to the intended inflation rate rather than production, while interest rates are determined. Another outcome is that when the marginal effects of the model acquired by the addition of inflation gap into the model estimated via the lag of interest rate, it is observed that marginal effects belonging to inflation gap variable in both models yielded quite close results to each other. This situation indicates that interest rate of a previous period is a fundamental value, is an essential factor in allaying inflation gap for a central bank performing inflation targeting strategy.

As is known, interest reaction functions were rather suggested for the purpose of monetary authorities to control nominal interest rates in respond to gaps in production and inflation. Central bank would resort to raise interest rates when inflation and production gap are expected to be higher than their own levels of intention or, decrease if production is below their objectives. Evaluating all results attained from our study, it can be said that reaction functions, which deal with inflation gap, production gap and the lag of interest rates, would be a good and simple guide for monetary politicians of Czech Republic. It will be important to further take inflation and production gap into account when a decision to increase in interest rates are taken in particular; as for reducing interest rates, to further take interest rate of the previous period into account.

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