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Volatility of Money Market Interest Rates Under the Inflation Targeting

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This study presents an analysis of the sources of variability of interest rates in the money market in the context of inflation targeting by Czech National Bank (CNB). The factors in question are changes in the structural characteristics of economies in transition, changing perception of inflation risks, the inconsistency of central bank's monetary decisions and central bank's weakened credibility and uncertainty about the efficient transmission of monetary measures. The empirical analysis documents non-stationary variability of ultra short-term PRIBOR interest rates and stability of longer maturity PRIBOR interest rates. These results reflect the role of CNB in bank system liquidity management, the uncertainty about the timing of CNB's monetary policy at the changing speed of the appreciation of the crown, tendencies of overestimation of expected inflation and changing structural characteristics.

Field of Research: monetary policy, interest rates dynamics

1. Introduction

In the context of inflation targeting there exists some inconsistency between the dynamics of inflation sources and the intensity of reactions of the main monetary interest rate. Making up the inflation forecast central banks have to cope with the high variability and instable structure of inflation shocks generated by the business cycle, wage development in the labour market, exchange rate variations, commodity prices or tax changes. Compared to these circumstances the approach of central bankers to monetary measures is markedly conservative. Central banks usually distribute adjustments in the main interest rate to a number of smaller changes.
Such behaviour of central bank makes it possible to stabilise the variability of interest rates at the short end of the money market yield curve. The variability of interest rates of longer maturity also reflects changing expectations about the dynamics of inflation and economic growth, expresses the credibility and consistency of central bank's monetary decisions, uncertainty about the effects of monetary policy, etc. This is the reason why interest rates at the long end of the yield curve usually show higher variability while instability of this variability is higher than in very short interest rates.

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The paper analyzes main theoretical and empirical aspects of variability of the Czech money market interest rates in the context of inflation targeting of Czech National Bank between 1998 and 2007.

2. Literature Review

Model decision of central bank on setting the main interest rate can be seen as a problem of optimal management of an economic system (Cecchetti, 2000). Formally the optimal level of the main interest rate is defined by the reaction function of central bank (Taylor, 1993). As stated by Svensson (1996) and Favero and Rovelli (2000), central bank's monetary policy decisions are influenced by the convolution of parameters describing central bank's preferences to the inflation and business cycle and structural characteristics of economy. A number of authors (Sack, 1998; Rudebusch, 2000) reported that in the practical execution of monetary policy there exists a disproportion between the model optimal level of the main interest rate and the actual setting of the announced main interest rate. Usually, the announced level of the main interest rate is less volatile and it is in a strong positive correlation with its lagged values (Clarida, Gali and Gertler, 1997). It is supposed that the high inertia of the announced main interest rate may be backed by the central bank's immediate interest to avoid impairment of its credibility that could be connected with high variability of the main interest rate (Goodhart, 1998). Besides, the dynamics of announced main interest rate may show high stability due to a systematic influence of other serially correlated factors shocks (Rudebusch, 2002). Long-term deviations of the main interest rate from its optimal level may therefore be a result of systematic under- or overestimation of the potential output dynamics (Orphanides, 1998). These errors follow from the need of data revision and from intensive changes in trend labour productivity, natural unemployment rate or dynamics of technological progress (Orhpanides, Porter, Reifschneider, Tetlow and Finan, 1999). According to Sack (2000) and Wieland (1996) gradualistic policy allows the central bank to gradually acquire new information about the actual pattern of structural relations in economy and about the character of exogenous shocks.

3. Methodology and Research Design

In this study the motivation of central bank is described in terms of the objective function which assumes that the objective of monetary policy is stabilisation of inflation on the level of the inflation target and GDP growth on its potential output. In such a case the objective function (L) of central bank is usually the sum of the present values of quadratic deviations of expected inflation (π^{e}_{t+i}) and/or expected economic growth (y^{e}_{t+i}) from inflation target (π^{TARGET}_{t+i}) and/or potential output (y^{*}_{t+i}):

$$L_t = \sum_{i=0}^{\infty} \delta^i \left[(1-\alpha)(\pi^{e}_{t+i} - \pi^{TARGET}_{t+i})^2 + \alpha (y^{e}_{t+i} - y^{*}_{t+i})^2 \right] \quad (1)$$

where δ ($0 \leq \delta \leq 1$) is the discount factor, α and/or ($1-\alpha$) are the relative weights of quadratic deviations of inflation and economic growth from targeted values and i is a shift in time looking forward to the future.

It is assumed that the present economic structure implies restrictions in the form of existing relations within the dynamics of particular variables. The economic structure is described by the VAR model, in which variables from the vector of endogenous variables Y_t are the function of actual and lagged values of endogenous variables from the matrix Y_{t-n}, actual and lagged values of exogenous variables from the matrix Z_{t-n} and actual and lagged values of the main interest rate from the vector $IR_{CB,t-n}$:

$$Y_t = \sum_{n=0}^{q} A_n Y_{t-n} + \sum_{n=0}^{q} B_n Z_{t-n} + \sum_{n=0}^{q} C_n IR_{CB,t-n} + v_t \qquad (2)$$

where A_n and B_n are the matrices of structural parameters, C_n is the vector of parameters expressing the relations of the particular variables to the main interest rate, q expresses the duration of the lag of variables in the VAR model and v_t is the vector of random shocks.

With regard to the central bank's objective function and model of economic structure such a level of the main interest rate is optimal for the actual moment that minimises the value of central bank's objective function for the actual inflation forecast applied to the model of economic structure in the horizon of efficient transmission (k periods). Formally the optimal level of the main interest rate ($IR_{CB,t}^{OPTIM}$) is defined by the reaction function of central bank:

$$IR_{CB,t}^{OPTIM} = IR_{CB}^{EQ} + \beta_t(\pi_{t+k}^{e} - \pi_{t+k}^{TARGET}) + \gamma_t(y_{t+k}^{e} - y_{t+k}^{*}) \qquad (3)$$

where IR_{CB}^{EQ} is the main interest rate corresponding to long-term economic equilibrium, parameters β_t and/or γ_t express the intensity of monetary restriction (expansion) by which the central bank reacts to the overshooting (undershooting) of inflation target and/or positive (negative) output gap.

Besides macroeconomic stabilisation the central bank's decisions may reflect a concern in maintaining the stability of financial (banking) system in the context of financial crisis, price bubbles in stock or real estate markets or bank credit crunch, they are based on the rigidity of the fixed exchange rate regime, on inflexibility in the labour market or they reflect the potential existence of systematic errors in estimates of economic growth:

$$IR_{CB,t}^{TARGET} = (1-\rho)IR_{CB,t}^{OPTIM} + \rho IR_{CB,t-1}^{TARGET} + w_t \qquad (4)$$

$$w_t = \sum_{n=0}^{q} D_1 U_{1,t-n} + \sum_{n=0}^{r} D_2 U_{2,t-n} + ... + \sum_{n=0}^{z} D_m U_{m,t-n} \qquad (5)$$

where ρ is the weight of the lagged announced main interest rate, being the measure of central bank's aggressiveness in the stabilisation of inflation and/or output around its targeted values, D_1, D_2, …, D_m are the vectors of parameters, $U_{1,t-n}$, $U_{2,t-n}$, …, $U_{m,t-n}$ are the vectors of the actual and lagged values of variables considered by the central bank for setting the main interest rate.

The analysis of variability of the main interest rate is derived from equation (4), which can be written as the sum of variabilities and covariances of the particular variables:

$$\begin{aligned}\operatorname{var} IR_{CB,t}^{TARGET} &= (1-\rho)^2 \operatorname{var} IR_{CB,t}^{OPTIM} + \rho^2 \operatorname{var} IR_{CB,t-1}^{TARGET} + \operatorname{var} w_t + 2(1-\rho)\rho \operatorname{cov}(IR_{CB,t}^{OPTIM}, IR_{CB,t-1}^{TARGET}) + \\ &+ 2(1-\rho)\operatorname{cov}(IR_{CB,t}^{OPTIM}, w_t) + 2\rho \operatorname{cov}(IR_{CB,t-1}^{TARGET}, w_t)\end{aligned} \quad (6)$$

The definition of key sources of the optimal main interest rate variability $IR_{CB,t}^{OPTIM}$ is based on the central bank's reaction function (3), which using Goodman's product of random variables (see Goodman, 1960):

$$\begin{aligned}\operatorname{var} IR_{CB,t}^{OPTIM} &= \bar{\beta}^2 \operatorname{var}(\pi_{t+k}^e - \pi_{t+k}^{TARGET}) + \overline{(\pi_{t+k}^e - \pi_{t+k}^{TARGET})}^2 \operatorname{var}\beta + 2\bar{\beta}\,\overline{(\pi_{t+k}^e - \pi_{t+k}^{TARGET})}\,\operatorname{cov}_{11}^{\beta\pi} + 2\bar{\beta}\operatorname{cov}_{12}^{\beta\pi} + \\ &+ 2\,\overline{(\pi_{t+k}^e - \pi_{t+k}^{TARGET})}\operatorname{cov}_{21}^{\beta\pi} + \operatorname{var}\left[\Delta\beta\Delta(\pi_{t+k}^e - \pi_{t+k}^{TARGET})\right] + \bar{\gamma}^2 \operatorname{var}(y_{t+k}^e - y_{t+k}^*) + \\ &+ \overline{(y_{t+k}^e - y_{t+k}^*)}^2 \operatorname{var}\gamma + 2\bar{\gamma}\,\overline{(y_{t+k}^e - y_{t+k}^*)}\operatorname{cov}_{11}^{\gamma\gamma} + 2\bar{\gamma}\operatorname{cov}_{12}^{\gamma\gamma} + 2\,\overline{(y_{t+k}^e - y_{t+k}^*)}\operatorname{cov}_{21}^{\gamma\gamma} + \\ &+ \operatorname{var}\left[\Delta\gamma\Delta(y_{t+k}^e - y_{t+k}^*)\right] + 2\operatorname{cov}\left\{\left[\beta(\pi_{t+k}^e - \pi_{t+k}^{TARGET})\right],\left[\gamma(y_{t+k}^e - y_{t+k}^*)\right]\right\}\end{aligned} \quad (7)$$

where $\bar{\beta}$ and/or $\bar{\gamma}$ is the mean value of parameter β and/or γ, the term $\overline{(\pi_{t+k}^e - \pi_{t+k}^{TARGET})}$ and/or $\overline{(y_{t+k}^e - y_{t+k}^*)}$ is the mean value of the deviation of expected inflation from the inflation target and/or expected output gap, $\operatorname{cov}_{ij}^{\beta\pi}$ is $\operatorname{cov}\left[(\Delta\beta)^i, (\Delta(\pi_{t+k}^e - \pi_{t+k}^{TARGET}))^j\right]$, $\operatorname{cov}_{ij}^{\gamma\gamma}$ is $\operatorname{cov}\left[(\Delta\gamma)^i, (\Delta(y_{t+k}^e - y_{t+k}^*))^j\right]$, the symbol Δ expresses the deviation of the respective variable from its mean value (i.e. e.g. $\Delta\beta = \beta - \bar{\beta}$).

From the aspect of dynamics of money market interest rates it is crucial that in the framework of daily management of bank system liquidity the announced level of the main interest rate plays the role of the average or limit price of supplied (withdrawn) liquidity. To fulfil the monetary objectives of central bank the effective interest rate from operations in the open market ($IR_{CB,t}^{EFEKT}$) should approximate on average the announced value of the main interest rate. It is to assume that the effective price of supplied (withdrawn) liquidity is a key factor of the actual level of overnight interest rates ($IR_t^{O/N}$).

In this case the actual level of *n*-day money market interest rate (IR_t^n) can be taken as the sum of the expected average level of O/N rates in the period *t* to *t+j* ($IR_t^{O/N,e}, IR_{t+1}^{O/N,e}, ..., IR_{t+j}^{O/N,e}$) and the actual term premium (ρ_t^n). The expected trajectory of overnight interest rates gains an explicit relation with the expected monetary decisions of central bank:

$$IR_t^n = \frac{1}{n}\sum_{j=0}^{n-1} IR_{t+j}^{O/N,e} + \rho_t^n = \frac{1}{n}\sum_{j=0}^{n-1} IR_{CB,t+j}^{TARGET,e} + \bar{q} + \rho_t^n . \quad (8)$$

where $\bar{q}$ is non-zero mean value of random shocks. Variability of interest rates in the money market is expressed as follows:

$$\operatorname{var} IR_t^n = \frac{1}{n^2}\operatorname{var}\sum_{j=0}^{n-1} IR_{CB,t+j}^{TARGET,e} + \operatorname{var}\rho_t^n + \frac{2}{n}\operatorname{cov}\left(\sum_{j=0}^{n-1} IR_{CB,t+j}^{TARGET,e}, \rho_t^n\right). \quad (9)$$

when besides the variability of expected dynamics of the targeted main interest rate the main factor of their instability is variability of term premium and anticipated positive covariance between the average level of the targeted main interest rate and the term premium.
With regard to the above defined mechanism of the monetary policy the variability of interest rates can be approached as a largely complex problem:

$$\operatorname{var} IR_t^n = \frac{1}{n^2}\left[\begin{array}{l}(1-\rho)^2 \operatorname{var}\sum_{j=0}^{n=l} IR_{CB,t+j}^{OPTIM,e} + \rho^2 \operatorname{var}\sum_{j=0}^{n=l} IR_{CB,t+j-l}^{TARGET,e} + \operatorname{var}\sum_{j=0}^{n=l} w_{t+j}^{e} + \\ + 2(1-\rho)\rho \operatorname{cov}(\sum_{j=0}^{n=l} IR_{CB,t+j}^{OPTIM,e}, \sum_{j=0}^{n=l} IR_{CB,t+j-l}^{TARGET,e}) + 2(1-\rho)\operatorname{cov}(\sum_{j=0}^{n=l} IR_{CB,t+j}^{OPTIM,e}, \sum_{j=0}^{n=l} w_{t+j}^{e}) + \\ + 2\rho \operatorname{cov}(\sum_{j=0}^{n=l} IR_{CB,t+j-l}^{TARGET,e}, \sum_{j=0}^{n=l} w_{t+j}^{e})\end{array}\right] + \\ + \operatorname{var}\rho_t^n + \frac{2}{n}\operatorname{cov}\left\{\left[(1-\rho)\sum_{j=0}^{n=l} IR_{CB,t+j}^{OPTIM,e} + \rho\sum_{j=0}^{n=l} IR_{CB,t+j-l}^{TARGET,e} + \sum_{j=0}^{n=l} w_{t+j}^{e}\right], \rho_t^n\right\} \quad (10)$$

For the analysis of interest rate variability the GARCH (p,q) model was used which considers the actual variability of n-day relative changes in interest rates as variability conditioned by past random shocks ε_{t-i} and by lagged variability of these shocks:

$$\psi_s(B)\ln\frac{IR_t^n}{IR_{t-1}^n} = \varepsilon_t^n \quad (11)$$

where $\psi_s(B) = (1 - \psi B - ... - \psi_s B^s)$, ψ_s are the parameters of autoregressive process of the s-th degree, B^s is the backward shift operator, s (s = 1, ..., S) expresses the range of backward shift, ε_t^n represents random shocks having normal probability distribution with the zero mean value and variance h_t^n. Variability of random shocks is expressed in the framework of GARCH (p,q) model:

$$h_t^n = \alpha_0 + \sum_{i=1}^{q}\alpha_i^n(\varepsilon_{t-i}^n)^2 + \sum_{i=1}^{p}\beta_i^n h_{t-i}^n + \zeta_t^n \quad (12)$$

where α_0 expresses the mean value of random component variability, α_i^n are the parameters of sensitivity of interest rate variability to random shocks, β_i^n are the parameters expressing the intensity of autocorrelation of random shock variability, ζ_t^n is the random error of estimate with standard characteristics.
The analysis of interest rate variability is done on reference interest rates of the Czech interbank market (PRIBOR) with maturity 14D, 1M, 3M, 6M, 9M and 12M. The variability of PRIBOR interest rates is tested on day data for the period 1998-2007 (2 521 observations). ADF tests of the time series of PRIBOR interest show that PRIBOR interest rates are integrated by degree one and they can be successfully stationarised by means of natural logarithms of relative changes in interest rates (hereinafter the relative changes in interest rates) (see equation 11).

4. Discussion of Findings

It was shown that variability of the announced main interest rate is based on the unstable level of optimal monetary-policy interest rate, the strong relation with preceding monetary decisions and the variability of factors being outside the defined objective function. The magnitude of optimal main policy interest rate variability is influenced by anticipated dynamics of the deviation of expected inflation from the inflation target and by development of the expected output gap. Taking into account the intensity of transmission of external equilibrium into internal equilibrium in case of small open economies we can expect stability of the main interest rate as a result of anticipated effects of the negative correlation of the real monetary restriction and dynamics of exchange rate on the length of efficient transmission of monetary measures. The variability of the optimal main interest rate can also change due to the influence of the asynchronous inflation and business cycle between domestic and foreign economies on the interest elasticity of inflation and economic growth through changing pressures on the appreciation of domestic currency. The presence of the variability of parameters from the reaction function in equation (7) indicates that dynamics of the optimal main interest rate is influenced by the instability level of the economy structure and to what extent the central bank's policy is consistent.

The instability of the optimal main interest rate also results from the fact to what extent the inflation cycle, business cycle and rate of monetary restriction are synchronised. In transition economies the long-term appreciation of domestic currency appears to potentially weaken the inflationary phenomena of high economic growth connected with intensive dynamics of private consumption and net export and to efficiently diminish the need of changes in the main interest rate.

In this context the money market interest rates are based on subjective expectations of agents in the financial market about the anticipated future monetary measures of central bank. Variability of interest rates is a result of a conflict between the central bank's official inflation forecast and forecast of the financial market; it is also influenced by the opinion of the financial market about the predictability of central bank's behaviour. Through the variability of term premium the financial market simultaneously shows the uncertainty about equilibrium establishment in economy and about necessary aggressiveness of central bank's future monetary measures.

In the period of observation there was a gradual drop in PRIBOR interest rates of all maturities due to disinflation monetary policy. During 2007 interest rates increased in connection with the gradual growth of price dynamics in domestic economy (see Figure 1 and 2).

The results of the estimate of model (11) (see Table 1) document the non-stationarity of variability of the residuals of relative changes in 14D and 1M PRIBOR interest rates and the stationarity of variability of relative changes in PRIBOR interest rates of longer maturity. The non-stationarity of variability of relative changes in PRIBOR interest rates of ultra-short maturity is apparently a result of jump fluctuations in their variability caused by the fact that the CNB uses the targeting of 14D repo rate for monetary policy management whereas the frequency of changes in the CNB's main interest rate is relatively low. Along with its high variability the extreme instability of variability of relative changes in 14D PRIBOR interest rate is a result of the contrast between the efficient stabilisation of 14D PRIBOR interest rate as close as possible to the repo rate in the situation of the expected repo rate stability and the jump

adaptation of 14D and of 1M PRIBOR interest rate to a lesser extent under the influence of factors leading to a change in the targeted level of repo rate.

Figure 1
Relative changes in PRIBOR (selected maturities)

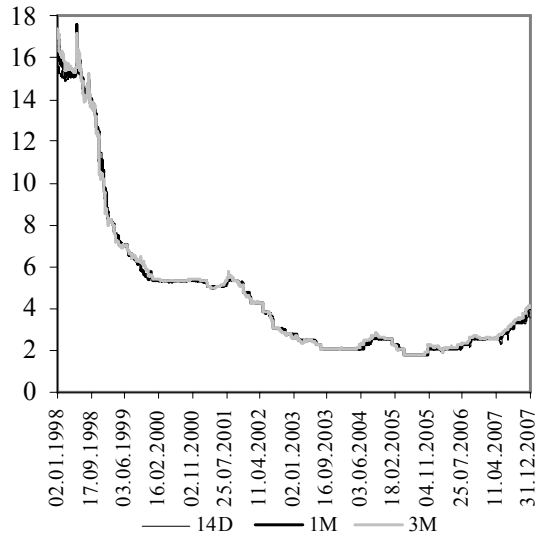

Figure 2
Relative changes in PRIBOR (selected maturities)

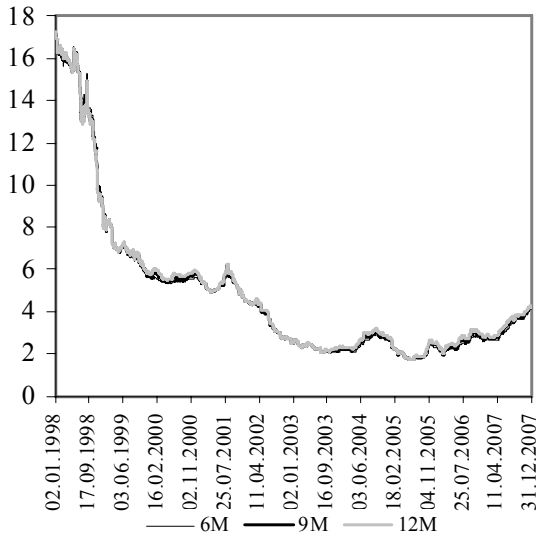

Table 1
Results of the estimate of GARCH (1,1) model from equation (16)

Maturity	Basic Model	α_0 (std. dev.)	α_1 (std. dev.)	β_1 (std. dev.)
14D	AR1	0,0000266** (0,0000120)	6,311* (1,342)	$2{,}392.10^{-10}$ (1,342)
1M	AR1	0,0000418* (0,0000135)	1,165* (0,451)	0,107 (0,076)
3M	AR3	0,0000434* (0,0000152)	0,367** (0,171)	0,181 (0,159)
6M	AR2	0,0000279* (0,0000114)	0,212* (0,081)	0,485* (0,102)
9M	AR3	0,0000279** (0,0000142)	0,175* (0,068)	0,498* (0,114)
12M	AR3	0,0000260** (0,0000130)	0,102*** (0,054)	0,591* (0,144)

*, **, *** statistically significant parameters at a 1%, 5% and 10% significance level

Compared to ultra-short PRIBOR interest rates the variability of 3M, 6M, 9M and 12M PRIBOR interest rates is not only absolutely lower but also more stable. The time series of relative changes in these interest rates becomes smoother as the value of parameter β_1 increases and at the same time the value of parameter α_1 decreases with their longer maturity. The variability of relative changes in PRIBOR interest rates increases with longer maturity but their kurtosis diminishes and so their

extreme fluctuations are reduced as a result of the only limited connection of these interest rates with daily management of the banking system liquidity.
With increasing maturity of PRIBOR interest rates the weight of those factors becomes higher that are connected with uncertainty about future determinants of ultra-shot interest rates. These were mainly speculations about the speed of disinflation process, uncertainty about the speed of moderation of CNB's monetary restriction and about the impacts of restrictive policy on economic growth dynamics. In subsequent years the financial market had a tendency of overestimating the expected inflation. It causes a fundamental deviation between the expected level of repo rate on the part of the financial market and the real decision of CNB on setting the targeted repo rate. The financial market faces the still more intensive uncertainty about future real effects of CNB's monetary policy at the changing speed of the crown appreciation. There also arise doubts about the structural characteristics of economy showing the high price stability (year-on-year inflation rate up to 2%) at a jump increase in the economic growth rate (from the growth of about 3% to the growth rate exceeding 6%), especially about the interest rate elasticity of the potential output, relations between the crown appreciation and labour productivity dynamics, impact of direct foreign investments and changes in the export performance of economy, and about the influence of global price stability on dynamics of the domestic price level.

5. Conclusion

This study presents an analysis of the sources of variability of interest rates in the money market in the context of inflation targeting by CNB. In the theoretical part, an emphasis is laid on the instability of variability of the optimal and targeted main policy interest rate. The factors in question are changes in the structural characteristics of economies, different perception of inflation risks and the inconsistency of central bank's monetary decisions. The effect of central bank's weakened credibility and uncertainty about the efficient transmission of monetary measures is also expected to be reflected through the term premium variability.
The empirical analysis documents the high and non-stationary variability of 14D and 1M PRIBOR interest rates that is based on a conflict between the role of CNB in the management of the banking system liquidity and the jump adaptation of 14D and 1M PRIBOR interest rates in reaction to a change in the repo rate. With the longer maturity of PRIBOR interest rates their increasing, but more stable variability is confirmed. This is due to speculations about the speed of disinflation process, uncertainty about the timing of CNB's monetary policy moderation in connection with a steep fall in economic growth, tendencies of overestimation of expected inflation, uncertainty about the future dynamics of repo rate at the changing speed of the appreciation of the crown. The variability also reflects the uncertainty about the changing structural parameters of domestic economy. These are the interest rate elasticity of the potential product growth, relations between the rate of the crown appreciation and labour productivity dynamics, export performance of domestic economy or the problem of the independence of price dynamics in relation to the global sources of inflation.

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