Interest rates and prices causality in the Czech Republic - Granger approach

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1 July 2009

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POMĚNKOVÁ, J., KAPOUNEK, S. (2009), Interest Rates and Prices Causality in the Czech Republic - Granger Approach. Agricultural economics : Zemědělská ekonomika. Vol. 55, No. 7, pp. 347-356. ISSN 0139-570X.

Monetary policy analysis concerns itself with both the assumptions of the transmission mechanism and the direction of causality between the nominal (i.e. the money) and real economy. The traditional channel of monetary policy implementation works via interest rate changes and their impact on the investment activity and the aggregate demand. Altering the relationship between the aggregate demand and supply then impacts the general price level and hence inflation. Alternatively, Post-Keynesians postulate money as a residual, In their approach, banks extend credit in response to movements in investment activities and demand for money. In this paper authors use the VAR (i.e. the vector autoregressive) approach applied to the "Taylor rule" concept to identify the mechanism and impact of the monetary policy in the small open post-transformation economy of the Czech Republic. The causality (in Granger sense) between the interest rate and prices in the Czech Republic is then identified. The two alternative modelling approaches are tested. First is the standard VAR analysis with lagged values of interest rate, inflation and economic growth as explanatory variables. This model shows the one way causality (in a Granger sense) between inflation rate and interest rate (i.e. the inflation rate is (Granger) caused by lagged interest rate). In second, the lead (instead of lagged) values of interest rate, inflation rate and real exchange rate are used. This estimate shows one way causality between inflation rate and interest rate in the sense that interest rate is caused by the lead (i.e. the expected future) inflation rate. The assumptions based on the money as a residual of the economic process were rejected in both models.

Keywords:
exogenous and endogenous money, transmission mechanism, Taylor rule

The Constitution of the Czech republic states that: “the primary target of the Czech national bank is to maintain price stability“ (the Constitution of the Czech republic, head 6, article 98). The basic law establishing the Czech National Bank (CNB) (law Nr..6/1993, §2) then defines its basic function as: “the primary target of the Czech national bank is to maintain price stability. Without the prejudice to this primary target, Czech national bank sustains economic policy of the government which leads to the sustainable economic growth“.

In fulfillment of its mandate, CNB adopted so called IT (inflation targeting) monetary policy strategy in December 1997. The key element in this strategy is setting the medium term target for the inflation rate. This is then compared to the medium term forecast of the same rate The CNB then determines the changes in monetary policy character according to the deviations of forecasted inflation rate from its target.

The main operational tools for the CNB are the central bank´s referencing rates. An increase in those rates is assumed to lead to a decrease of aggregate demand dynamics and hence to a weakening of inflationary pressures (and, indeed, vice versa). The basic idea behind this policy is the concept of a monetary transmission mechanism where changes in monetary policy reference rates directly determine the short interest rate on the interbank market. This in turn causes commercial banks to raise/lower both their deposit and credit rates. The result is a contraction/expansion of investment activity and aggregate demand and ultimately a weakening/strengthening of inflationary pressures.

Common approach for the analysis of the nature and functioning of the monetary transmission mechanism is the VAR analysis. The general assumptions about the transmission mechanism are based on the unidirectional causality between the monetary variables and aggregate demand. The behaviour of commercial banks, non-bank public and the basic parameters of the demand for money are determined by monetary authorities. As a result, these authorities control the short-term interest rates on the interbank market. Underlying these assumptions are historically the monetarists´ ideas which focus on the authorities behaviour and the stability of the money multiplier. In contrast, post-Keynesians argue that the stability of monetarist empirical relationships comes about because money is a residual in the economy without any causal significance. The authorities, from this point of view, have passively supplied money in response to contemporaneous and prior movements in income and thus the demand for money.

To determine the nature of monetary transmission mechanism and hence the role of money in the Czech economy, we use the VAR approach. This approach enables us to ascertain the direction of causality between monetary and real variables and hence to answer the question about the role of money in the Czech economy implicitly posted in the previous paragraph.

Indeed, one of the major issues in VAR modelling is the nature of lags and leads in the model. It stems from two areas. Some authors argue that the major disadvantage of the VAR model is an inadequate description of the central bank reaction function. And, indeed, the length of lags (and leads) in any monetary analysis remains always a major issue. In the view of the existence of lags and leads in the practice of monetary policy it is always necessary to work with current as well as past and future values.

This is even more important under the inflation targeting regime where monetary policy decisions generally arise from expected future value of inflation rate. Inflation targeting generally (and in this paper as well) means setting of monetary policy according to discrepancy between the expected and desired inflation rate.

Because the monetary policy implementation is based on this fact, the monetary policy operational target represented by short-term interest rate on the inter-banking market is affected not only by actual trends in the economy but also by predictions of the main macroeconomic variables included in the inflation specification models.

The discussion in this paper is based on the analysis of the relationship between the short-term interest rate, inflation and economic growth as represented by the Taylor rule. For small open economies this was expanded by including the exchange rate movements (Romer, 2001). Under these assumptions the variable vector considered includes the inflation rate, the short term interest rate, an economic growth and the real exchange rate.

The aim of this paper is to identify causality in the monetary policy reaction function, modelled by Taylor rule. In the first step, the VAR approach is applied empoying alternatively both lags and leads. Secondly, Granger causality is applied to identify type of causality (bilateral or unilateral) between the variables.

The results reported in this paper are outcomes of the research grant n. MSM 6215648904 with the title "The Czech Economy in the Process of Integration and Globalisation, and the Development of Agricultural Sector and the Sector of Services under the New Conditions of the Integrated European Market", thematic area "Macroeconomic and microeconomic performance of the Czech economy, and the Czech government's econo-political measures in the context of the integrated European market." The holder of the research grant is Mendel University of Agriculture and Forestry Brno, Faculty of Business and Economics.

VAR MODELLING AND GRANGER CAUSALITY

The price stability, an increase in economic growth, the full employment and a quality of life are often mentioned as general goals of central banks. In this context, the impact of the monetary policy on the price stability and exchange rate movement in the open economy is generally agreed upon. But there is no theoretical or empirical consensus whether the central banks are able to exert an influence over the economic growth.

According to classical economics (and its supply oriented models) the real output is in the long run determined by a production capacity of the economy, which can not be directly influenced by central banks monetary policy. However, the monetary policy can be used to affect accumulation of capital, i.e. value of investments, and consequently the level of technological advance. On the other hand Keynesian economics admits that the real output could be influenced by the monetary policy to the extent to which it is able to influence the aggregate demand. Especially, interest rates directly affect the investment decision-making process in the most companies. Živělová (2004) describes the long-term financial planning which is based on the expected cash flows and calculated interest rates. *"The basic function of calculated interest rate is to express the expected profitability of an investment. The calculated interest rate also enables to express the level of expected risk. Regarding the fact that the future revenues will be attained not only by means of owned capital but also by foreign funds..."* (Živělová, 2004). If the calculated return on the investments is less than the interest rate on the outside funds (credit), the company management rejects the investment project financed by borrowed funds.

From this argument it could be assumed that in the demand-side economics the monetary policy is an effective tool to influence the economic growth. According to supply-side economics, however, a monetary expansion exerts influence over the real output only in the short-run, in the long-run the rise in the real output is offset by price increase.

In the supply-side economic theory the monetary policy is an effective tool for influencing the real output under the conditions that it is also able to maintain price stability effectively. Price stability increases transparency of the price mechanism and so helps to improve the allocation of resources. Moreover, it reduces inflation risks and inflation premia in interest rates. Lower real interest rates have positive impact on investments, which then lead to innovations and technological advance, which determines the log-run real output of the economy. Furthermore, price stability reduces distortions caused by inflation or deflation and creates conditions essential for the formation of a stable rational expectation. Many economists (e.g. Angeloni, 2002) therefore assume that the price stability is the important tool to maintain the economic growth. The impact of central bank's monetary policy on the real output is therefore indirect, but significant.

On the assumption that there is a dichotomy between the real and monetary sectors, the real activity is determined only by real factors such as the capacity of capital, marginal labour and capital productivities, natural resources, a technology development and other real factors which determine the aggregate supply and demand of labour. On the other hand, nominal wages and prices are determined by monetary factors only. Therefore, an increase in the money supply leads only to increases in nominal wages and prices, leaving the real variables unchanged. (This is the phenomenon called the neutrality of money.).

Although the central banks accept the neutrality of money assumption and their monetary policy objectives therefore have monetarist character, the transmission mechanism includes many alternate elements. On the one side, the Czech national bank´s monetary policy assumes that money supply in the middle and long-run periods affects the aggregate demand and prices. On the other side, the relationship between the interest rates and saving and investment decisions is typical for the Keynesian transmission mechanism. The Keynesians assume that lower interest rates stimulate investments demand and autonomous consumption along with the aggregate demand and output. Of course, in the extreme textbook case of liquidity trap, monetary expansion has no impact on the aggregate demand and output even in the Keynesian thinking. It happens in the situation of high sensitivity money demand to interest rates which causes a high speculation demand for money as well the changes in the interest rates. The change in the money supply is then absorbed by change in the velocity of money. (Mach, 2002)

In this analysis the authors accept the Keynesians assumptions that the lower interest rates stimulate investments demand and autonomous consumption along with the aggregate demand and output. This process will be understood as a Keynesian transmission mechanism. The complexity of the transmission mechanism and the existence of lags between the external shocks, main referencing interest rates of the central bank, financial market´s reactions and final effects on the macroeconomic indicators, especially on the inflation and economic growth complicate monetary policy implementation in the real economy. Max. 16 months lags will be applied in the analysis.

Secondly, with the exogenous money assumption, the interest rate changes allowed to proceed with different behaviour. Although central banks may have certain control of the money supply, they cannot fix the stock of money in a country. The money supply is not an exogenously set policy variable but is the result of the portfolio decisions of the bank and non-bank private sector. *"Thus, even if a central bank can directly set the value of its own liabilities, the money supply is endogenously determined as a residual of the economic process."* (Fontana, Palacio-Vera, 2003) If the money is a residual of the economic process, the rate of change in monetary aggregates is in fact a function of the aggregate demand and economy fluctuations. The implied direction of causation would then be from changes in nominal income to changes in the stock of the money which, in turn impact the short interest rates on the interbank market.

For the empirical part of this article we start with the simple specification based on the quantity theory of the money:

$$M \times V = P \times Y \,, \qquad (1)$$

where M represents money stock, V velocity of the money in the economy, P aggregate price level and Y is real output of the economy. Assume that money stock is fixed or grows in the predetermined constant rate If the velocity of the money is dependent on the interest rate r and real output of the economy, from the formula (1) it follows:

$$IR = f(P,Y), \quad (2)$$

This is the formula used by Taylor (2001) and defines linear causality between the interest rates, price level and real output:

$$IR = P + gy + h(P - P^*) + IR^f, \quad (3)$$

where IR represents short-term interest rates, P inflation and y real output of the economy (percentage change). The variable IR^f represents long-term safe interest rate and variable P* is inflation target.

Romer (2006) reformulated the Taylor rule in the following form:

$$IR_t - P_t = \overline{IR} + b(P_t - P^*) + c(\ln Y_t - \ln \overline{Y}_t), \quad (4)$$

where variable $\overline{Y}_t$ represents potential economy growth and IR_t nominal short-term interest rate, $\overline{IR}$ long-term safe interest rate. For the case of the Czech Republic, small open economy is the formula (4) expanded on the exchange rate movements e_t:

$$IR_t - P_t = \overline{IR} + b(P_t - P^*) + c(\ln Y_t - \ln \overline{Y}_t) + dER_t. \quad (5)$$

The authors assume that central banks have direct impact on the short-term interest rates which represented the operational target of the monetary policy and that money has an exogenous character in the empirical analysis.

The money endogeneity assumption could be accepted only if the causality between the interest rate movements and other variables is rejected. Concurrently, the interest rates are determined on the interbank money market which is caused by the money demand and supply. Thus, endogenous money is directly followed by the supply and demand movements on the interbank market and, in turn, by short term-interest rate. The key decision to be made by the central bank relates to the discount rate, with the general structure of the short-term interest rates resting on the stock of money endogenously determined outside the control of the monetary authority. The central bank´s reaction function, in this paper represented by Taylor rule, is not significant in the context of endogenous money.

Vector autoregressive model of the order k, or *VAR(k)*, can be written as follows:

$$\boldsymbol{Y_t} = \boldsymbol{\delta} + \boldsymbol{A_1 Y_1} + \ldots + \boldsymbol{A_k Y_k} + \boldsymbol{v_t} = \boldsymbol{\delta} + \sum_{j=1}^{k} \boldsymbol{A_j Y_{t-j}} + \boldsymbol{v_t}, \quad (6)$$

where

$$\boldsymbol{Y_t} = \begin{bmatrix} Y_{1t} \\ Y_{2t} \\ \vdots \\ Y_{mt} \end{bmatrix}, \boldsymbol{\delta} = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \\ \vdots \\ \alpha_{m0} \end{bmatrix}, \boldsymbol{A_j} = \begin{bmatrix} \alpha_{11,j} & \alpha_{12,j} & \cdots & \alpha_{1m,j} \\ \alpha_{21,j} & \alpha_{21,j} & \cdots & \alpha_{2m,j} \\ \vdots & \vdots & \vdots & \vdots \\ \alpha_{m1,j} & \alpha_{m2,j} & \cdots & \alpha_{mm,j} \end{bmatrix}, \boldsymbol{v_t} = \begin{bmatrix} v_{1t} \\ v_{2t} \\ \vdots \\ v_{mt} \end{bmatrix}. \quad (7)$$

indicates that all variables in this model have the same lag length of order k. The assumptions that usually follow VAR model are the assumptions of a reduced form simultaneous equations model, i.e.

$v_{it} \sim N(0, w_{ii})$, for all t, and $i=1,\ldots,m$, where $w_{ii} = \text{var}(v_{it})$,

$E(v_{it} v_{is}) = 0$, for $t \neq s$, and $i=1,\ldots,m$,

$E(v_{it} v_{is}) = w_{ij}$, for all t, and $i=1,\ldots,m$, where $w_{ii} = \text{cov}(v_{it}, v_{jt})$.

Due to its structure, VAR obviates a decision as to what contemporaneous variables are exogenous. It has only lagged variables on the right-hand side, and all variables are endogenous. However, in most cases the VAR order is not known and therefore it has to be selected. For selecting the VAR order the likelihood ratio (LR) test, Akaike information criterion (AIC) and Schwartz criterion (SC) (Enders, 2004) are commonly used.

Once set up and identified, VAR model can be estimated and the results of estimation can be used to test various hypothesis inherent in the data. One of the testable hypothesis is the concept of Granger causality..

Causality in the sense by Granger (1969) and Sims (1972) is inferred when the lagged values of a variable, say X_t, have explanatory power in a regression of a variable Y_t on lagged values Y_t and X_t. Test of the restrictions can be based on simple F test in the single equations of the VAR model. That the unrestricted equations have identical regressors means that these tests can be based on the results of the OLS estimates. If lagged values of a variable X_t have no explanatory power of any of the variables in a system, that we would view X as weakly exogenous to the system. With respect to the direction of causality we can distinguish the following cases:

- unidirectional causality: the case when X_t caused Y_t but Y_t does not cause X_t
- bilateral causality: the case when variables X_t and Y_t are jointly determined

This causality can be identified using Granger test (1969) based on the premise that the future cannot cause the present or the past, utilising the concept of the VAR approach. Let us consider the two variable VAR(k) (X_t and Y_t) model

$$\begin{aligned} Y_t &= \alpha_{10} + \sum_{j=1}^{k} \alpha_{1j} X_{t-j} + \sum_{j=1}^{k} \beta_{1j} Y_{t-j} + \varepsilon_{1t} \\ X_t &= \alpha_{20} + \sum_{j=1}^{k} \alpha_{2j} X_{t-j} + \sum_{j=1}^{k} \beta_{2j} Y_{t-j} + \varepsilon_{2t} \end{aligned} \qquad (8)$$

With respect to this model following cases can be distinguished:

$\{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1k}\}$	$\{\beta_{21}, \beta_{22}, \ldots, \beta_{2k}\}$	the type of causality
$\neq 0$	$= 0$	Unidirectional causality, X $\rightarrow$Y
$= 0$	$\neq 0$	Unidirectional causality, Y $\rightarrow$ X
$\neq 0$	$\neq 0$	Bilateral causality, X $\leftrightarrow$ Y

For the testing causality hypotheses referring to the significance of the VAR model described above, the Wald FW-statistic can be used

$$FW = \frac{(RSS_r - RSS_u)/k}{RSS_u/(n-2k-1)} \sim F(k, n-2k-1), \quad (9)$$

where

RSS_u- sum of squared residuals from the unrestricted equation,

RSS_r- sum of squared residuals from the equation under the assumption that a set of variables is redundant (restricted).

Thus, hypotheses in this test can be formed as follows

H_0: X does not Granger cause Y, i.e. $\{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1k}\} = 0$, inconclusive, $FW < F$,

H_1: X does Granger cause Y, i.e. $\{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1k}\} \neq 0$, conclusive, $F \geq FW$,

and

H_0: Y does not Granger cause X, i.e. $\{\beta_{21}, \beta_{22}, \ldots, \beta_{2k}\} = 0$, inconclusive, $FW < F$,

H_1: Y does Granger cause X, i.e. $\{\beta_{21}, \beta_{22}, \ldots, \beta_{2k}\} \neq 0$, conclusive, $FW \geq F$,

EMPIRICAL RESULTS AND DISCUSSION

For the empirical analysis the Taylor rule the small open economy was reformulated as:

$$IR_t = a + dP_t + cY_t + dER_t.$$

where (P) stand for inflation (price index percentage change compared to corresponding period of previous year, based on 1995=100 and national currency), IR is the nominal interest rate, Y stands for economic growth (GDP in constant prices, percentage change compared to corresponding period of the previous year) and ER indicates the real effective exchange rate (industrial countries' real effective exchange rates excluding NMS). For empirical analysis quarterly data 1997:1 – 2007:1 used. All data were obtained from the Eurostat database.

The inflation targeting regime of the central banks requires the predictions of the various macro and microeconomic indicators. The authors of this article approximate these the predictions in the estimations by using the actual observed values (the approach justifiable by the rational expectations hypothesis) as leads in the actual VAR model construction. Jílek (2004) argues that it takes approximately one year for the monetary policy changes to impact the demand and inflation rate. Standard procedures of VAR analysis are then used for identification of statistically significant dependent variables and their lags (leads). Forward VARs is based on the central bank reaction function. The Granger causality for the identification of a type of relationship in both cases is subsequently identified.

Transmission mechanism of monetary policy is a chain of economic connections through which changes in short-term interest rate lead to changes in prices (inflation). The lag among monetary aggregates and inflation is commonly estimated between 6 and 12 month (Jílek, 2004). In our VAR analyses the AC, SC and LL identification criteria were applied to determine the lag length. For leads (where applicable) the optimum length p=4 was identified using LR criteria (Seddighi, 2000). (Other criteria values (AIC, SC; Seddidghi 2000) showed as optimum lag length p=19. VAR application for leads showed same problem, optimum length was identified as p=15.) Given the data set character and sample size large lags (leads) values can caused reduction of test power and model parsimony. Thus, using the economic theory combined with the "second best" results, the length p=3 was chosen.

In the case of the lagged variables results for the interest rate are given in Table I and for the inflation rate in the Table II below.

Tab. I: Results of lagged VAR(4), IR dependent variable in period 1997/Q1 – 2008/Q1

Variable	lag	Coefficient	t-statistic	t-probability	Significance
IR	1	1,2419	5,8814	0,0000	***
	2	-0,3361	-1,5680	0,1300	
	3	0,0655	1,7258	0,0972	*
	4	-0,0072	-0,2415	0,8113	
P	1	-0,0031	-0,0291	0,9771	
	2	-0,0966	-0,8876	0,3836	
	3	-0,0339	-0,3190	0,7525	
	4	0,0260	0,0340	0,7370	
Y	1	0,3648	1,1148	0,2760	
	2	-1,0894	-1,7577	0,0916	*
	3	0,3046	0,4870	0,6307	
	4	0,4090	1,0218	0,3171	
ER	1	-3,0618	-0,8330	0,4131	
	2	-3,3713	-0,8338	0,4126	
	3	2,8430	0,7373	0,4681	
	4	-3,1289	-1,1717	0,2528	
const		0,8137	1,4736	0,1536	
	n = 41	$R^2_{adj} = 0,9861$	*Q = 2,6153*		

Note: Statistical significance at the 1% (***),10% (*)
Source: Own calculation

From estimated model for interest rate (IR) in Table I can be seen that interest rate (IR) and economic growth (Y) are statistically significant. Real exchange rate (ER) as well as the inflation rate (P) are statistically insignificant, i.e. they don't have impact on interest rate in the analysed period.

Tab. II: Results of "lagged" VAR(4), P dependent variable in period 1997/Q1 – 2008/Q1

Variable	Lag	Coefficient	t-statistic	t-probability	Significance
IR	1	0,2369	0,6432	0,5262	
	2	-0,0403	-0,1079	0,9150	
	3	0,0392	0,5924	0,5591	
	4	0,0622	1,1893	0,2460	
P	1	0,4273	2,2904	0,0311	**
	2	0,0325	0,1712	0,8655	
	3	0,3733	2,0141	0,0553	*
	4	-0,6035	-4,5203	0,0001	***
Y	1	-1,3148	-2,3033	0,0302	**
	2	0,4001	0,3701	0,7146	
	3	0,6546	0,6001	0,5541	
	4	0,0536	0,0768	0,9394	
ER	1	-9,1509	-1,4272	0,1664	
	2	-6,8991	-0,9782	0,3377	
	3	8,4057	1,2497	0,2234	
	4	-2,2073	-0,4739	0,6399	
const		2,5560	2,6535	0,0139	**
	n = 41	*R_{adj}^2 = 0,9514*	*Q = 1,0017*		

Note: Statistical significance at the 1% (***), 5%(**), 10% (*)
Source: Own calculation

From estimated model for inflation rate (P) in the table II can be seen the statistical significance of inflation rate and economic growth. Effective real exchange rate (ER) as well as the interest rate (IR) appear to be statistically insignificant, i.e. they don't have impact on inflation rate in analysed period.

Tab. III: Granger causality results for lags VAR

Granger Causality Test		
Model with IR as dependent variable		
Variable	FW-statistic	Probability
IR	94,1896	0,0000
P	1,0885	0,3845
Model with P as dependent variable		
IR	4,0326	0,0122
P	9,4205	0,0001

Source: Own calculation

From the Granger causality test for the above specified and estimated models (Table III) we can conclude:
a) in case of model for interest rate (tab. I), Granger causality test for interest rate shows statistical insignificance for variable inflation rate (Probability = 0,3845)
b) in case of model for inflation rate (tab. II), Granger causality test for inflation rate shows statistical significance for variable interest rate (Probability = 0,0122)

If statistical Granger causality test with respect to estimated model for lagged VAR is used, we can see unilateral causality between inflation rate and interest rate in accordance with I $\rightarrow$ P, i.e. inflation rate is caused by the lagged interest rate. Comparison economic theory and Taylor rule (describing the relationship between the interest rate and inflation), the causality test confirm (in a Granger sense) our expectations about the transmission mechanism and money exogenity. Thus, these results can be thought of as confirming the idea of the transmission mechanism of monetary policy and the direction of causation from the changes of interest rate to changes in inflation rate. Indeed, this appears to validate the effectiveness of the Czech national bank´s monetary policy.

Under inflation targeting regime, the monetary policy generally focuses on the expected (predicted) value of inflation rate. Hence, in the context of this paper, the inflation targeting means setting of monetary policy according to expected inflation rate value, which in turn influences the values of the main operational tool of the monetary policy, the short-term interest rate. To model this phenomenon, the VAR approach was modified to incorporate the lead values of the relevant economic variables.

In the "lead" VAR analysis the classic VAR algorithm was used, albeit modified. During this modification process the data file was reordered and the same criteria used for lag identification were used to identify leads. Subsequently, three quarters of "leads" were chosen. Value of dependent variable was expressed in dependence on other lead values. The aim of this procedure was to estimate relationships for the interest rate and inflation rate. Granger causality test were applied to identify the interrelationships and then compare these with expectations. In the case of the „forward" lag results for interest rate is given in Table IV and for inflation rate in Table V.

Tab. IV: Results of "lead" VAR(3), IR dependent variable in time 1997/Q1 – 2008/Q1

Variable	Lead	Coefficient	t-statistic	t-probability	significance
IR	1	-0,3321	-1,6885	0,1020	
	2	-2,8140	-2,7450	0,0128	**
	3	4,7563	5,0133	0,0000	***
P	1	0,8971	1,8779	0,0705	*
	2	0,1727	0,2475	0,8063	
	3	-1,4424	-2,3590	0,0253	**
Y	1	3,7687	1,5953	0,1215	
	2	-2,4388	-0,6607	0,5140	
	3	-2,2321	-1,1943	0,2421	
ER	1	-9,7072	-0,5839	0,5638	
	2	53,6995	2,1830	0,0373	**
	3	-83,9501	-4,5501	0,0001	***
const		6,5320	2,1702	0,0383	**
	n = 42	*R_{adj}^2 = 0,8233*	*Q = 1,7154*		

Note: Statistical significance at the 1% (***), 5%(**), 10% (*)
Source: Own calculation

From estimated model for interest rate (IR) in Table IV can be seen statistical significance of interest rate (IR), inflation rate (P) and real exchange rate. In case of interest rate, as well as real exchange rate, lead 3 is significant on 1 % significance level, in case of inflation rate lead 3 significance is on 5 % significance level. Economic growth (Y) is statistically insignificant and does not have impact on interest rate in analysed period.

Tab. V: Results of forward VAR(3), P dependent variable in time 1997/Q1 – 2008/Q1

Variable	Lag	Coefficient	t-statistic	t-probability	significance
IR	1	-0,0549	-0,7145	0,4807	
	2	0,3856	0,9629	0,3435	
	3	-0,1045	-0,2820	0,7800	
P	1	1,0296	5,5118	0,0000	***
	2	-0,0583	-0,2140	0,8320	
	3	-0,4025	-1,6853	0,1027	
Y	1	0,2702	0,2928	0,7718	
	2	-0,3060	-0,2123	0,8334	
	3	-0,0777	-0,1065	0,9159	
ER	1	10,8147	1,6655	0,1066	
	2	-5,5988	-0,5827	0,5646	
	3	-6,2632	-0,8691	0,3919	
const		0,9832	0,8363	0,4098	
	n = 42	*R_{adj}^2 = 0,9070*	*Q = 3,3313*		

Note: Statistical significance at the 1% (***)
Source: Own calculation

From estimated model for inflation rate (P) in Table V can be seen statistical significance of lead inflation rate (P, lead 4) on 1% significance level. Any other independent lead variable is not significant. Therefore inflation rate depends on inflation rate in the future period (i.e. on the expected inflation).

Tab. VI: Granger causality results for leads VAR

Granger Causality Test		
Model with IR as dependent variable		
Variable	FW-statistic	Probability
IR	14,0498	0,0000
P	3,8831	0,0190
Model with P as dependent variable		
IR	1,0920	0,3682
P	20,2563	0,0000

Source: Own calculation

Comparing results of Granger causality test for models describing interest rate and inflation from forward point of view (Table VI), we can conclude:

- in case of the model for interest rate (tab. IV), Granger causality test for interest rate shows the statistical significance for variable inflation rate (Probability = 0,0189)
- in case of the model for inflation rate (tab. V), Granger causality test for interest rate shows statistical insignificance for variable interest rate (Probability = 0,3682)

If statistical Granger causality test with respect to estimated model for the "lead" VAR is used, we can see unilateral causality between inflation rate and interest rate in accordance with P $\rightarrow$ I, i.e. interest rate is caused by „lead", i.e. the expected, inflation rate. Indeed, it confirms that the current interest rate depends on a future (predicted) value of inflation.

Central bank which applies inflation targeting regime uses interest rate as the operational target aimed ultimately to achieve the desired inflation rate. The level of interest rate is defined on the basis of predicted (future) inflation values. In this sense, result of the Granger causality tests applied on "leads" VAR estimates can be taken as a confirmation of this targeting process.

Hence we conclude, that in the case of the lags empirical analysis confirms our expectations of central bank´s monetary policy transmission mechanism, especially, monetary policy effectiveness of its price level stabilization function. In the second part of the Granger causality analysis, the "leads" estimates confirm the Czech national bank´s monetary policy decision-making process. Moreover, the Granger causality results confirm the unilateral causalities of the both variables (interest rate and inflation) based on the exogenous money assumptions.

CONCLUSION

The aim of this paper is to identify causality between the interest rate and prices in a small open economy of the Czech Republic. Empirical analysis is based on the Taylor rule, defined as the relationship between the short term interest rate on the interbank market, price index, economic growth and exchange rate movements. Applied VAR methodology is used with the unilateral and bilateral causality identification in the Granger sense.

VAR modelling was used in the two steps. The first step is the classical VAR with lags, the second step then utilized leads. The empirical analysis results are argued in the context of the exogenous/endogenous money assumptions.

In the first step the standard VAR analysis was utilized to identify the relationship between the interest rate and inflation. It concluded that:

- interest rate depends on lagged values of interest rate and economic growth
- inflation rate depends on lagged variables of inflation rate and economic growth

The real exchange rate was not found statistically significant in either case. These models facilitated the evaluation of Granger causality between the involved variables. The unilateral causality between inflation rate and interest rate (i.e.) could not be rejected.

In the second step the "lead" VAR analysis was used and models for interest rate and inflation were specified, with the following results:

- interest rate depends on the “lead” values of the interest rate, inflation rate and real exchange rate
- inflation rate depends on the “lead” value of the inflation rate

In neither case the economic growth appeared significant. The Granger causality tests here indicate the unilateral causality between the future (i.e. the expected) inflation rate and interest rate (i.e. E(P) → I). I.e. the current. interest rate is caused by the expected inflation rate.

The assumptions based on the money as a residual of the economic process were rejected in the analysed period and Czech Republic interbank market.

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