The Effects of Domestic and External Shocks on a Small Open Country: the Evidence from the Czech Economy

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***Abstract*—**This paper describes the impact of selected domestic and external shocks on selected macroeconomic variables in the Czech economy. For these purposes is modified and estimated a long-run macroeconomic model of a small open economy developed by Garratt, Lee, Pesaran and Shin (2006). A macroeconomic core model includes five long-run relationships (the relative purchasing power parity, the real money market equilibrium condition, the output gap, the interest rate parity and the interest rate relationship – Fisher inflation parity). It is estimated through a structural cointegrating vector error correction model using data over the period 1996q1 – 2010q4. We identify the long-run structure of the Czech economy and study the effects of domestic supply, demand and also monetary shocks. There are also studied the external exchange rate shocks. The effects of these shocks were investigated for selected macroeconomic variables (the domestic interest rate, the domestic output, the domestic monetary demand and the exchange rate). The results of general impulse response functions (GIRF) analysis showed familiar patterns. We can observe the occurrence of price puzzle as an short-run phenomena and we reject the evidence of the exchange rate puzzle.

***Keywords*—**domestic shocks, cointegrating VAR model, Czech economy, exchange rate shocks, external shocks, general impulse response functions, monetary shocks, long-run relationships.

I. Introduction

At present, there are two elementary methodological approaches to the modern macroeconometric modeling of economies – *Dynamic Stochastic General Equilibrium models (DSGE)* and *Cointegrated Vector Autoregression models (CVAR)*..

Models *CVAR* follow up modeling of a complex dynamic system the features of which respect real data.

DSGE models follow and develop two significant waves of thinking - models of Real Business Cycle (RBC) and new Keynesian models. *DSGE* models continue in quantitative economics with a strong theoretical background despite the effort to enrich them by standard statistical testing processes. These models are used by creators of macroeconomic policy mainly as a supportive tool for the analysis of the economic policy impacts on the economy in question. For example Tvrdon paid attention to relationship between the economic cycle and unemployment in the Visegrad group countries in [20].

In the structural models of *Cowles commission* the economic theory was used to identify the systems of equations and for the regression estimation the theoretical (a priori) limitations were applied. This is why the estimations could not serve for the showing of the principally new facts. Jakon Marschak made widening on so called *probability approach* which evaluates the known data based on pre-defined stochastic model. In the first half of sixties in 20th century in opposition to this probability approach of the Cowles commission the methodology of London School of Economics (LSE) so called *British approach* was defined. This approach defined itself on contrary to the economics as logically-deductive science and demanded empirical testing of the economic theories with regard to the principal disagreement between equilibrium theory and mostly non-equilibrium data of a real word.

The other option of macroeconometric modeling is a use of vector autoregression (*VAR*) and mainly structural *VAR*. CVAR models follow up modeling of a complex dynamic system the features of which respect real data. Cointegrating ideas as introduced by Granger are commonly embodied in empirical macroeconomic modeling through the vector error correction model (VECM). The VECM representation of a dynamic system is obtained as a simple rearrangement of the vector autoregressive (VAR) model advocated by Sims [18], once the variables in the VAR are cointegrated. In a similar way the identification of multiple cointegrating relationships by restrictions drawn from economic theory, leaving the short-run dynamics and stochastic specification unrestricted, is called “long-run structural modeling” by Pesaran and Shin [15].

CVAR models began to appear at the end of eighties and at the beginning of nineties of the last century and were orientated on the U. S. economy mainly. In the article [12] King, Plosser, Stock and Watson dealt with the cointegrating

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relations between consumption, investment, output and nominal interest rates and real monetary balance. Restrictions were the implications of RBC, Fisher equation theory and monetary demand equation.

CVAR approach is applied in the construction of a small quarterly model of the UK economy by Garratt, Lee, Pesaran and Shin in their book called *Global and National Macroeconometric Modelling* [5]. The model includes five long-run equilibrium relations derived from the economic theory and thus having a structural feature. When deriving these relations the authors took into account neoclassical production function, arbitrage conditions, solvency conditions and conditions of portfolio equilibrium. In the model following long-term relations occur: purchasing power parity in a relative version (*PPP*), parity of domestic and foreign interest rates representing Fischer´s effect (*IRP*), a gap of domestic and foreign product (*OG*). A long-term requirement on solvency and equilibrium of portfolio of actives is reflected in monetary demand (*MD*) and Fischer´s inflation parity represents Fischer´s domestic effect (*FIP*).

The basic argument for setting of just these relations is a fact that in a small open economy domestic quantities are closely related to the foreign quantities mainly through exchange rate. Shocks influencing domestic price level are linked to the monetary rule e.g. of Taylor type with regard to the monetary policy and are reflected in the changes of domestic interest rate, real monetary balances and aggregate product. Monetary demand describes a link among these quantities. Fischer´s inflation parity describes a relation between domestic interest rate and inflation. The nominal exchange rate is linked to the foreign price level due to the purchasing power parity in a long-run, international output gap and interest rate parity differential represent links between domestic and foreign economic development in a long-run.

The paper deals with an estimation of the cointegrated macroeconomic model of the Czech economy which is further used for investigation of domestic supply, demand and monetary shocks and also external exchange rate shocks.

The outline of the paper is as follows. An introduction presents main developments in the area of macroeconomic development modeling of small open economies. Section 2 introduces the basic long-run macroeconomic model of a small open economy. Section 3 sets the approach and methods for estimation of long-run structural relations. The fourth section estimates of this core model for the Czech economy over the period 1996q1 – 2010q4. Section 5 deals with the estimation and analysis of the effects of domestic supply, demand, monetary and also the exchange rate shocks on selected macroeconomic variables. Conclusion ends with some concluding remarks.

II. Econometric Formulation of the Core Model

We follow the long-run structural modeling strategy that was suggested by Garratt, Lee, Pesaran and Shin [5] who applied it to the UK. Other modifications were made for Germany [17] by Schneider, Chen and Frohn and also, for Switzerland [2] by Assenmacher-Wesche and Pesaran. The first study for the Czech economy was reported in [7] and [8].

This paper presents the estimation of this model for the Czech economy using quarterly data from the first quarter 1996 to the fourth quarter of 2010. We improve previous studies [6] - [9] by:

- Extending the investigated period since 1996.
- Introducing the linear trend function into cointegration relations.
- Analyzing the consequences of imposing the long-run restrictions for the impulse response functions. The responses of the macroeconomic variables have been investigated both for the domestic and external shocks.

The basic macroeconomic framework is a core small open economy model consisting of five long-run relationships. This five long-run equilibrium relations are derived from the economic theory and thus having a structural feature. When deriving these relations the authors took into account neoclassical production function, arbitrage conditions, solvency conditions and conditions of portfolio equilibrium. Domestic variables comprise: P_t - the domestic producer prices (manufacturing), PR_t - harmonised consumer prices, E_t - bilateral exchange rate CZK/EUR, Y_t - real per capita GDP (EUR), R_t - nominal interest rate as interbank 1Y middle rate, M_t - real per capita domestic monetary aggregate M2 . Foreign variables for EU25 involve: YS_t - real per capita GDP, RS_t - 1Y interest rate as Euribor 1Y- offered rate, PS_t - producer prices.

Economic theory yields have five long-run conditions of equilibrium equation: (1) represents the log-linear version of relative purchasing power parity (PPP), the money market equilibrium condition (MD) is presented in equation (2), the output relations (OR) is represented by equation (3), and followed by uncovered interest rate parity (IRP) in equation (4) and finally Fisher inflation parity (FIP) is described in equation (5).

$$PPP: \quad p_t - ps_t - e_t = b_{10} + b_{11}t + \xi_{1,t+1} \tag{1}$$

$$MD: \quad m_t = b_{20} + b_{21}\cdot t + \beta_{22}\cdot r_t + \beta_{24}\cdot y_t + \xi_{2,t+1} \tag{2}$$

$$OR: \quad y_t = b_{30} + b_{31}\cdot t + \beta_{39}\cdot ys_t + \xi_{3,t+1} \tag{3}$$

$$IRP: \quad r_t - rs_t = b_{40} + b_{41}\cdot t + \xi_{4,t+1} \tag{4}$$

$$FIP: \quad r_t = b_{50} + b_{51}\cdot t + \beta_{53}\cdot dpr_t + \xi_{5,t+1} \tag{5}$$

where

$$p_t = \ln(P_t), ps_t = \ln(PS_t), pr_t = \ln(PR_t), dpr = \Delta pr_t,$$
$$e_t = \ln(E_t), y_t = \ln(Y_t), ys_t = \ln(YS_t), m_t = \ln(M_t),$$
$$r_t = \ln(1+(R_t/100)), rs_t = \ln(1+(RS_t/100)).$$

The PPP, IRP and FIP relations are commonly from the arbitrage conditions. Since 1989 the Czech economy has undergone the transition from the communist regime, economic reforms and has been opening and integrating to the European economy. There are articles documenting changes in the development of this economy – [16] and [19].

As Garratt, Lee, Pesaran and Shin [5] claim, the primary explanation of long-run deviations from relative PPP is the Harrod-Balassa-Samuelson (HBS) effect in which the price of basket of traded and non-traded goods rises more rapidly in countries with relatively rapid productivity growth in the traded goods sector. Since we assume that Czech productivity has been generally increasing we capture the HBS effect by assuming a trend in the PPP relation (1).

We also expect a trend in the money demand relation (11) to capture the possible effect of the changing nature of financial intermediation, and the increasing use of credit cards in settlement of transactions.

The transformation of the Czech economy should have an impact on productivity and steady state output. Using the economic growth theory (Barro and Sala-i-Martin [4]) we assume that Czech economy has been in a transition state and is converging to the EU economy and therefore we assume a trend in the output relation (3) with accordance to the results in paper Nevima and Melecky [14].

Finally, successful reforms could decrease the risk premium, and therefore we assume a trend in the IRP relation (4) and also FIP relation (5).

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III. The conditional Vector error correction model

If In this part of the paper we summarize current methodological approaches to the econometric modeling which will be used for the macroeconomic modeling of the Czech economy.

The estimation of the core long-run model involves an unrestricted VAR(p) model with following specification:

$$\boldsymbol{A}\cdot\boldsymbol{z}_t=\boldsymbol{A}_1\cdot\boldsymbol{z}_{t-1}+\cdots+\boldsymbol{A}_p\cdot\boldsymbol{z}_{t-p}+\boldsymbol{D}\cdot\boldsymbol{d}_t+\boldsymbol{\varepsilon}_t, \tag{6}$$

where vector $\boldsymbol{z}_t$ is an k x 1 vector of endogenous variables, $t=1, 2, ..., T$ and $\boldsymbol{d}_t$ is a vector of deterministic variables (e.g. intercept, trend), $\boldsymbol{\varepsilon}_t$ is vector serially uncorrelated errors distributed independently of $\boldsymbol{z}_t$ with a zero mean and a constant positive definite variance-covariance matrix. For given values of $\boldsymbol{d}_t$ the above dynamic system is stable if all the roots of the determinantal equations

$$\left|\boldsymbol{A}-\boldsymbol{A}_1\cdot\boldsymbol{\lambda}-\boldsymbol{A}_2\cdot\boldsymbol{\lambda}^2-\cdots-\boldsymbol{A}_p\cdot\boldsymbol{\lambda}^p\right|=0 \tag{7}$$

lie strictly outside the unit circle. This stability condition ensures the existence of long-run relationships between $\boldsymbol{z}_t$ which will be cointegrating when one or more elements of $\boldsymbol{z}_t$ are integrated, namely contain unit roots. We assume that the VARr(p) model only contains endogenous $I(1)$ variables. The VAR(p) model can be re-parametrerised as a Vector Error Correction Model (VECM(p-1)):

$$\triangle\boldsymbol{z}_t=-\boldsymbol{\Pi}\cdot\boldsymbol{z}_{t-1}+\sum_{i=1}^{p-1}\boldsymbol{\Gamma}_i\cdot\triangle\boldsymbol{z}_{t-i}+\boldsymbol{d}_0+\boldsymbol{u}_t, \tag{8}$$

If the elements of $\boldsymbol{z}_t$ are $I(1)$ and not cointegrated then it must be that $\boldsymbol{\Pi}=0$ and a VAR model in first differences will be appropriate. If the elements of $\boldsymbol{z}_t$ are $I(1)$ and cointegrated with rank($\boldsymbol{\Pi}$)=r, then $\boldsymbol{\Pi}=\boldsymbol{\alpha}\cdot\boldsymbol{\beta}'$, where $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are k x r full column rank matrices, and there will be $r < k$ linear combinations of $\boldsymbol{z}_t$, the cointegrating relations $\xi_t=\boldsymbol{\beta}'\cdot z_t$, which are $I(0)$. The variables ξ_t are often interpreted as the *deviations from equilibrium*. Under cointegration relationship (8) can be written as

$$\triangle\boldsymbol{z}_t=-\boldsymbol{\alpha}\cdot\boldsymbol{\beta}'\cdot z_{t-1}+\sum_{i=1}^{p-1}\boldsymbol{\Gamma}_i\cdot\triangle\boldsymbol{z}_{t-i}+\boldsymbol{d}_0+\boldsymbol{u}_t, \tag{9}$$

where $\boldsymbol{\alpha}$ is the matrix of *adjustment or feedback coefficients*, which measure how strongly the deviations from equilibrium, the r stationary variables $\boldsymbol{\beta}'\cdot z_{t-1}$, feedback onto the system. If there are $0<r<\mathrm{k}$ cointegrating vectors, then some of the elements of $\boldsymbol{\alpha}$ must be non-zero, i.e. there must be some Granger causality involving the levels of the variables in the system to keep the elements of $\boldsymbol{z}_t$ from diverging.

The unrestricted estimate of $\boldsymbol{\Pi}$ can be obtained using (8). In the restricted model (9), which accommodates $r < k$ cointegrating vectors, we need to estimate the two k x r coefficient matrices, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$. This rank reduction therefore imposes k^2-2kr restrictions to be imposed on $\boldsymbol{\Pi}$. We also require r independent restrictions (r of which are provided by normalization conditions). Thus in the restricted model, we impose $\left(k^2-2kr\right)+r^2=\left(k-r\right)^2$, namely $\left(k^2-2kr\right)$ restrictions imposed by the rank restrictions on $\boldsymbol{\Pi}$, and r^2 exact identifying restrictions. Under the restriction on the linear deterministic trend in the cointegration relations if $\boldsymbol{z}_t$ is trended, an associated vector error correction formulation is given by:

$$\triangle\boldsymbol{z}_t=-\boldsymbol{\alpha}\cdot\boldsymbol{\beta}'\cdot\left(z_{t-1}-\boldsymbol{\gamma}\cdot(\boldsymbol{t}-1)\right)+\sum_{i=1}^{p-1}\boldsymbol{\Gamma}_i\cdot\triangle\boldsymbol{z}_{t-i}+\boldsymbol{c}_0+\boldsymbol{u}_t. \tag{10}$$

The final matrix $\boldsymbol{\beta}'$ in (9) imposes 40 restrictions in our VECM. Estimation of the parameters of the model (10) was carried out using the long-run structural modelling approach and it is based on a modified version of Johansen's estimation of our VECM.

$$\boldsymbol{\beta}'_{long}=\begin{pmatrix} \overset{e}{1} & \overset{r}{0} & \overset{dpr}{0} & \overset{y}{0} & \overset{p}{-1} & \overset{ps}{1} & \overset{m}{0} & \overset{rs}{0} & \overset{ys}{0} \\ 0 & \beta_{22} & 0 & \beta_{24} & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & \beta_{39} \\ 0 & -1 & 0 & 0 & 0 & 0 & 0 & \beta_{48} & 0 \\ 0 & -1 & \beta_{53} & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}\begin{matrix} PPP \\ MD \\ OR \\ IRP \\ FIP \end{matrix} \tag{11}$$

Estimation of the parameters of the model (10) was carried out using the Johansen's method (see Juselius [11], Lütkepohl, [13]). When we estimate the CVAR model it is as follows:

- setting the number and list of endogenous variables and deterministic variables,
- testing the endogenous variables $\boldsymbol{z}_t$ for unit roots,
- selection the order p of the VAR(p) model,
- testing of number of cointegration relations,

- estimation of long-run relationships using our VECM(*p-1*) model and making the diagnostic tests.

For this treatment it is necessary to combine properly an economic theory with results of statistical verification.

IV. Estimation and Verification of the VECM for the Czech Economy

We use the quarterly data in the applied study that are seasonally adjusted series covering the period 1996q1-2010q4 for the Czech economy. We can specify our vector of endogenous variables as

$$z_t = (e_t, r_t, dpr_t, y_t, p_t, ps_t, m_t, rs_t, ys_t)' \qquad (12).$$

Databases of Eurostat, Czech National Bank have been used as a data source. Software EViews version 7.1. has been used for following data analysis and modeling.

Figures 1-4 plot the development of the macroeconomic variables for the Czech economy. We can identify long-term equilibrium relationships between some variables.

Fig. 1 The domestic and foreign producer prices (*p*, *ps*) and the exchange rate (*e*)

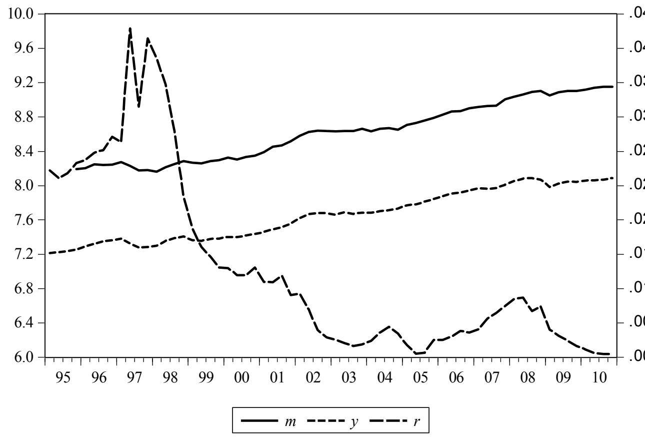

Fig. 2 The money aggregate (*m*), the domestic output (*y*) and the domestic interest rate (*r*)

In the first part of the data analysis we pre-test the variables for unit roots using the ADF test. We can conclude that mainly all the endogenous variables are *I(1)* at the 5% level of significance. The next step for the *VECM* estimation is to select the order of the underlying unrestricted *VAR* in nine endogenous variables. We selected *VAR(3)* with regard on Wald test. Next, having established the appropriate order of the VAR model, Johansen's cointegration tests are carried out using the trace and the maximum eigenvalue statistics. According to unit root tests we assume an intercept with trend in the cointegrating relationship and a linear data trend. In this case we can indicate five cointegrating equations at the 5% level of significance, especially by the trace statistics.

Fig. 3 The domestic output (*y*) and the foreign (EU25) output (*ys*)

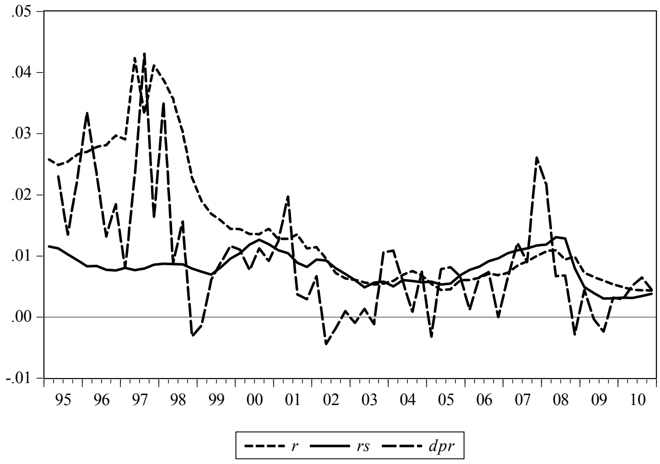

Fig. 4 The domestic interest rate (*r*) and the domestic inflation (*dpr*), the foreign interest rate (*rs*)

The estimated long-run relationships for the Czech economy, incorporating 40 restrictions suggested by the theory and with *t-statistics* in [], are:

$$PPP: p_t - ps_t - e_t = -4.88 + \underset{[17.09]}{0.0063}\, t + \xi_{1,t+1} \qquad (13)$$

$$MD: m_t = 0.49 + \underset{[2.05]}{0.0025}\, t + \underset{[7.07]}{3.74} \cdot r_t + \underset{[16.49]}{1.04} \cdot y_t + \xi_{2,t+1} \qquad (14)$$

$$OR: y_t = 11.06 + \underset{[21.21]}{0.0017} \cdot t - \underset{[-8.18]}{0.458} \cdot ys_t + \xi_{3,t+1} \qquad (15)$$

$$IRP: r_t - rs_t = 0.008747 - \underset{[-0.643]}{0.000095} \cdot t + \xi_{4,t+1} \qquad (16)$$

$$FIP: r_t = 0.008605 - \underset{[-2.14]}{0.000102} \cdot t + \xi_{5,t+1} \qquad (17)$$

Equation (13) describes *PPP* relations and does not reject the context for the core model. We use the trivariate model (p_t, ps_t, e_t) as separate variables with respect to data analysis. We can also identify the positive trend (0.0063 % per quarter) and we have the evidence that Czech productivity has been generally increasing in accordance to the Harrod-Balassa-Samuelson (HBS) effect.

Money market equilibrium is presented by equation (14). It turns out that the income elasticity of money demand is positive and close to unity (1.04%). We could reject the hypothesis of the negative elasticity of real money balances with respect to domestic interest rate. We estimate that the long-run elasticity of the influence of the domestic output on the money demand about 3.74% and it is not with accordance to the quantitative theory of the money. We can identify the positive trend 0.0025 % per quarter to capture the possible effect of the changing nature of financial intermediation, and the increasing use of credit cards in settlement of transactions.

The third long-run output relationship, given by (15), describes the average long-run growth rate in the Czech economy in comparison with the EU25 economy. We provide the evidence that the long-run elasticity of the domestic output on the foreign output is statistically significant (0.46%). We estimate increasing trend function of the domestic output at about 0.0017% per quarter which is in accordance to the economic growth theory and we can document that Czech economy has been in a transition state and is converging to the EU25 economy.

Next, equation (16) includes the interest rate parity condition. This includes the intercept, which can be interpreted as the deterministic component of the risk premium associated with bond and foreign exchange uncertainties. Its value is estimated at 0.0089 implying a risk premium of approximately 0.89% per year. Finally, the fifth equation (17) defines the FIP relationship, where the constant implies the average long-run Czech real rate return about 0.86% per year. We can confirm very low decreasing trend for the risk premium in the IRP relation (about 0.0095 % per quarter) and also FIP relation approximately 0.0102 % per quarter.

Fig. 5 documents the development of all five cointegrating relations of the Czech economy. We can see problematic development of domestic interest rates (*r*) before the year 2000.

The results also confirm satisfactory diagnostic statistics of the estimated VECM(2). The assumption of normally distributed errors is tested by the chi-square distributed Jarque-Bera statistics. This assumption is rejected only in the equation of the domestic and EU25 interest rates with respect to kurtosis.

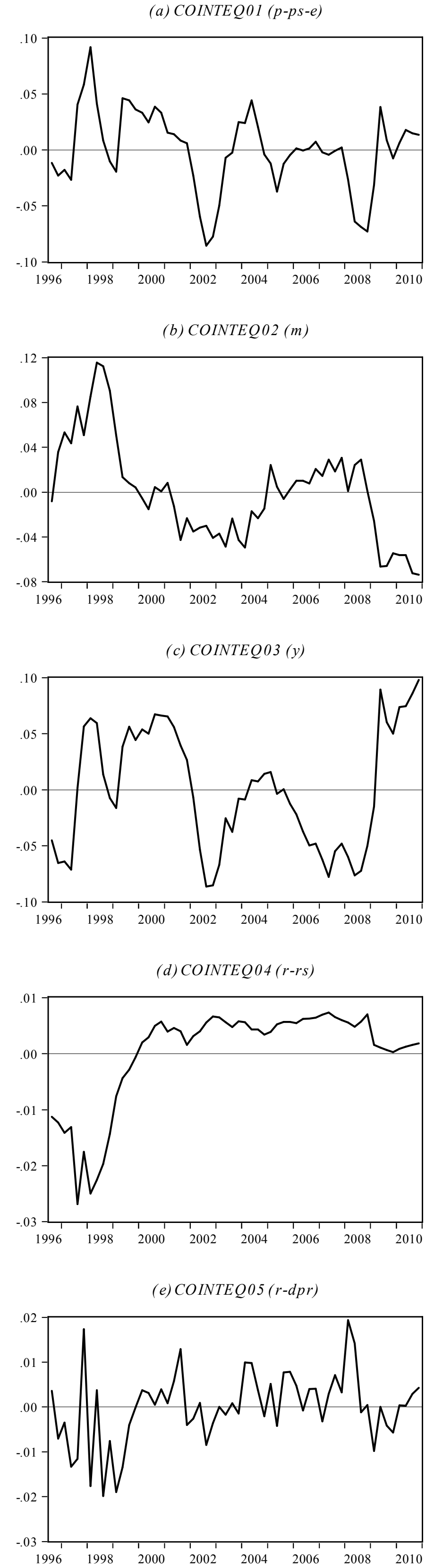

Fig. 5 Development of cointegration relationships

The LM tests are employed as a check of the residual serial correlation. We cannot reject the hypothesis of no serial autocorrelation of the first order in all equations at the 5% level of significance. The presence of autoregressive conditional heteroscedasticity is rejected in all equations. We can also detect a relatively high level of explanatory power for each evaluation using R^2_{ADJ} (0.288 – 0.700).

The over-identifying restrictions are tested by the log-likelihood ratio statistic which takes the value 97.6. The test statistic is asymptotically distributed as a χ^2 variate with 17 degrees of freedom. We don't make the conclusion directly, because the works by Haug [10] and Abadir, Hadri and Tzavalis [1] shown that the asymptotic critical values may not be valid for vector autoregressive models with a relatively large number of variables, unless samples are sufficiently large, which is just our case. That's why we decided to implement the significance test of the log-likelihood ratio statistics using critical values (mean=126.1) which are computed by non-parametric bootstrap techniques with 10000 replications. This shows that we cannot therefore reject the over-identifying restrictions implied by the theory.

V. Impulse Response Analysis

Another interesting discovery applying to the short-term dynamic reactions of quantity to shock effects are provided by the analysis of the estimated model on innovations. These impulses of variables affect other endogenous variables indirectly via dynamic structure of time delay in the VAR model. For this analysis we will apply general impulse response function (GIRF). We provide here the time profiles of the effects of shocks to a unit (one standard error) unexpected increase on the various endogenous variables.

The Fig. 6 shows the influence of *domestic supply shock effects* (*dpr)* on the domestic interest rate (a), the exchange rate (b) and the domestic output (c). Most of these plots exhibit familiar patterns. If the economy is hit by the supply shocks it leads to the increase of the domestic interest rate (about 0.0016 % in the third quarter – Fig. 6(a)) and the value of the Czech crown to euro decreases down in the fourth quarter around -0.12 % (Fig. 6(b)). The increase of the real interest rate and appreciating of the exchange rate leads to a steep decrease in the domestic output in the thirteenth quarter at the level
-0.003 % (Fig. 6(c)). With a further decreasing of the domestic interest rates the domestic inflation and the currency rate are coming back to its equilibrium. Returning of the domestic interest rates to baseline level is gradual during twenty-one quarters.

Fig. 7 shows the impact of *domestic demand shock effects (y)* on the domestic inflation (a), the domestic interest rate (b) and the exchange rate. If the domestic demand shocks are reached then it increases the output of the domestic economy that is followed by steep increase in inflation up to the level 0.002 % in the seventh quarter (see Fig. 7(a)) and the Czech National Bank reacts by increasing domestic interest rates up to 0.0007 % around ninth quarter according to Fig. 7(b). The real interest differential is positive. The increase in interest rates and strengthening of domestic currency on Fig. 7(c) decreases the demand pressures and the domestic output of economy and inflation are back to its baseline values in the fifth year.

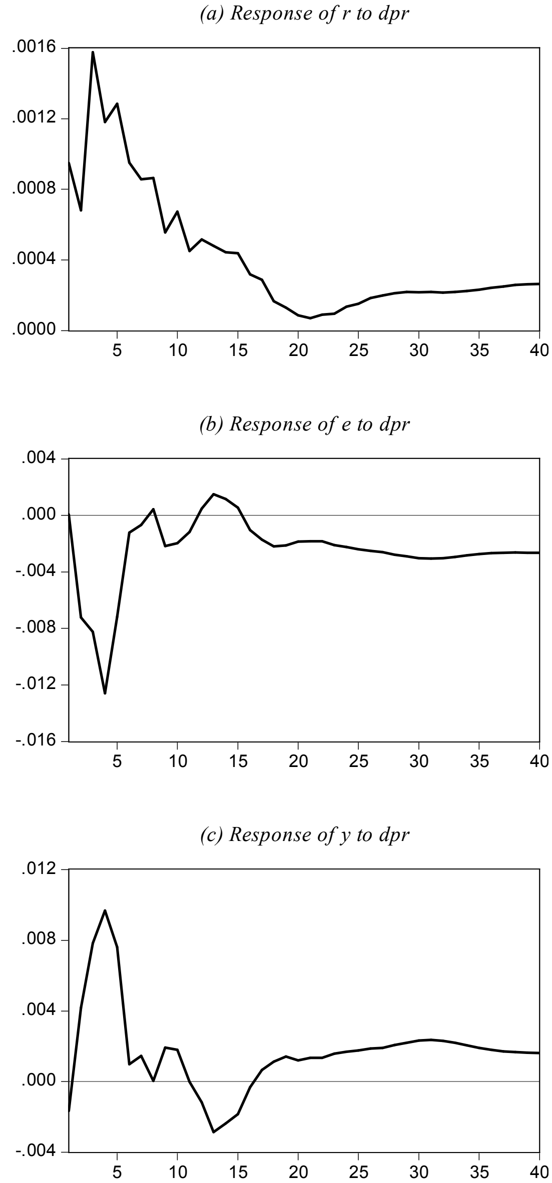

Fig. 6 Generalized impulse responses of *r, e, y* to domestic inflation shocks

Fig. 8 plots the persistence profiles of the effects of a unit shock of the domestic interest rate (*monetary shocks)* to the domestic inflation (a), the exchange rate (b), the domestic output (c) and the domestic money demand (d). Increase in the domestic interest rate points to the reduction of inflation observed in the sevenths quarter is associated in Fig. 8(a). It leads to positive differential of the domestic and the foreign interest rates and follows with the increase of the real exchange rate during the fifth - thirteenth quarters up to the level 0.012 % as it is shown on Fig. 8(b). That leads to decrease in the output of domestic economy on Fig. 8(c) to around -0.01% after 13 quarters and due to the effect of the decrease of domestic and international demand in Czech products there is a reduction in competitiveness in the Czech economy. After the initial impact and in tandem with the fall in the domestic interest rate, the excess of supply of money declines to approximately -0.012 % in thirteen quarters (Fig. 8(d)) and then reaches its equilibrium after approximately 8 years. These results clearly show the presence of a sizeable liquidity effect in our model following the unexpected tightening of the monetary policy.

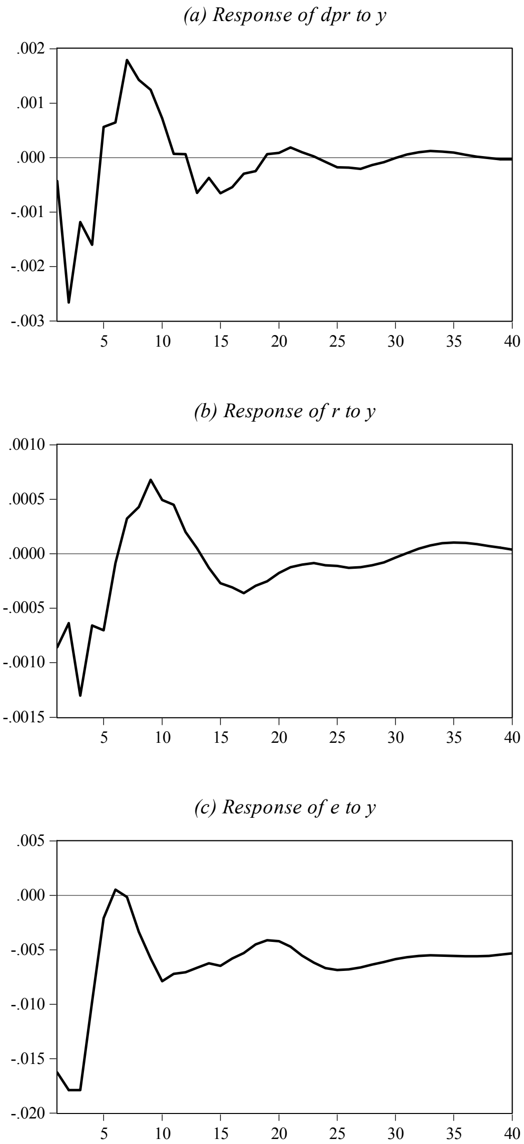

Fig. 7 Generalized impulse responses of *dpr*, *r, e* to domestic output shocks

Our analysis of impulse responses functions on Fig. 8(b) *does not support the evidence of the so called exchange rate puzzle.* It means that restrictive monetary policy is leading to the increase of nominal interest rate that causes increase in the devaluation of the Czech crown. The Garratt, Lee, Pesaran and Shin [5] discovered that this aforementioned violation of UIP happens only on short-term basis and after seven quarters the trend returns to its trend level.

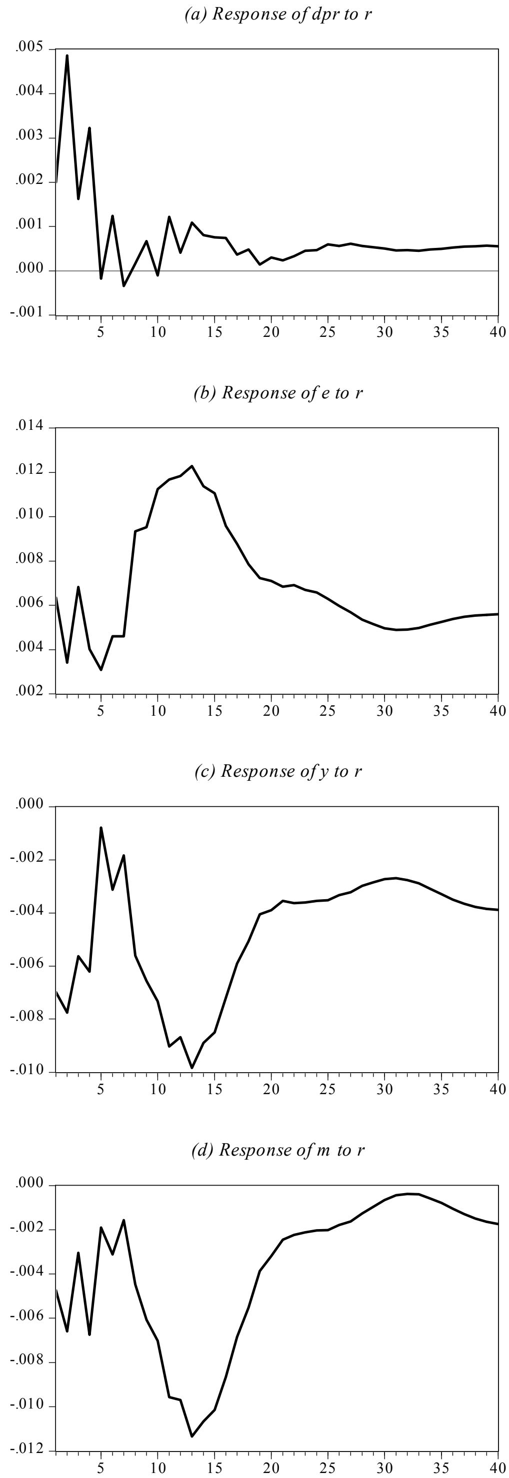

Fig. 8 Generalized impulse responses of *dpr, e, y, m* to domestic interest rate shocks

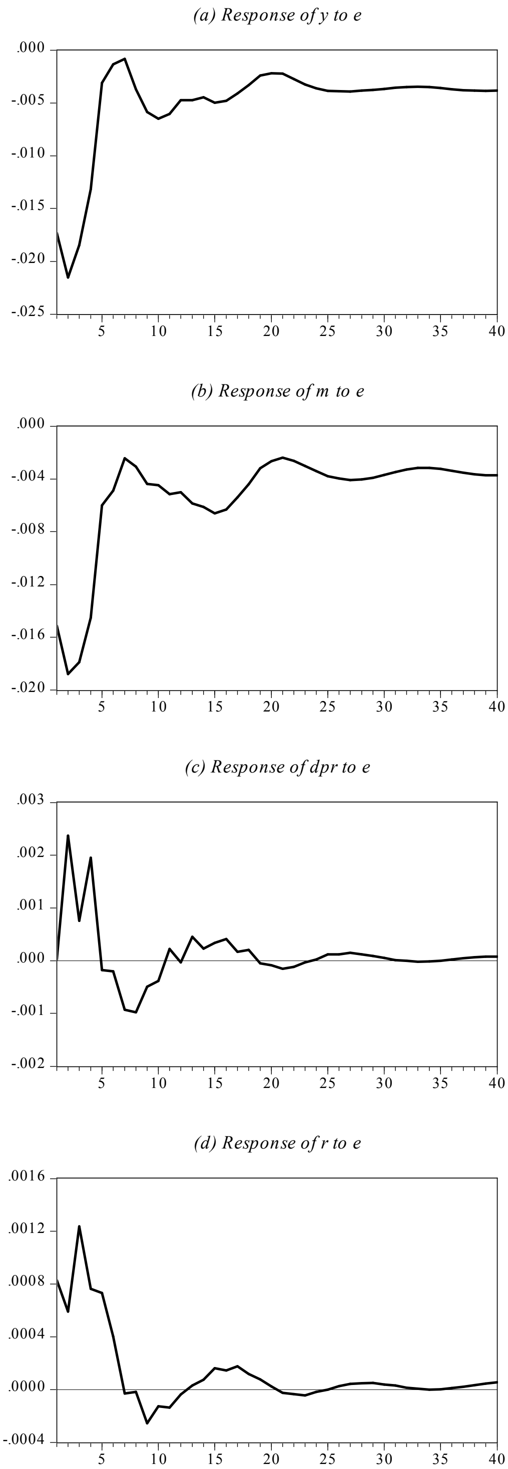

Fig. 9 Generalized impulse responses of *y, m, dpr* and *r* to exchange rate shocks

We also study the impact of *exchange rate shocks* (*e*) on the domestic output *y* (a), on the monetary aggregate *m* (b), on the domestic inflation *dpr* and to the domestic interest rates *r* (d). Positive exchange rate shocks will cause a sharp decrease of the domestic output during two quarters at the level around -0.02 % (Fig. 9(a)) and domestic inflation in the eighth quarter (-0.002 %) on Fig. 4(c). In regard to short-term appreciation of the Czech crown it will expected quickly readjustment of the output of Czech economy during the third – seventh quarters and also the positive values of the output gap due to the euro area which causes short-term increase of inflation during eighth - fifteenth quarters. Czech National Bank will react by increasing the domestic interest rate as it is given on Fig. 4(d). After three quarters, the CNB will reduce its rate to smooth exchange rate which returns to the original value.

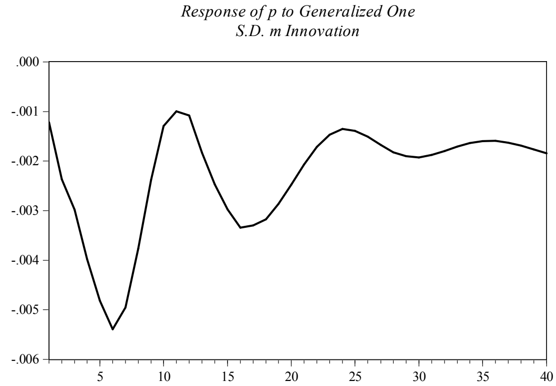

Fig. 10 Generalized impulse responses of the domestic prices *(p)* to money demand shocks

It is worth noting the occurrence of so-called *price puzzle* which is described in the literature as empirically documented opposite reaction in the price level (*p*) to the quantity of money (*m*). Although standard economic theory predicts that monetary growth leads to rising prices in the economy, in this case, money demand growth causes the prices drop on the contrary according to Garratt, Lee, Pesaran and Shin [5]. The tested model of the Czech economy identifies *the price puzzle* on Fig. 10. We can quantitatively observe that the decline in the price level of domestic industrial producers (*p*) is associated with money growth shocks (*m*) and reaches the bottom after six quarters at -0.006 %. The opposite movement can be observed as the impact of the monetary shocks to domestic inflation. The existence of the price puzzle is implicitly supported by time temporary negative decline of the price level and inflation in response to rise in domestic product or short-term positive response of inflation to increase in domestic interest rate. There is a lot of literature devoted to clarification of this phenomenon. Balke and Emery [3] explain of the price puzzle as an insufficient increase in central bank interest rates in response to rising inflationary pressures and expectations related to such negative shock in economy. We can discuss the effect of expectations of agents in the modeled economy and their influence on the results of the analysis based on VAR models.

VI. Conclusions

The final summary is divided into two parts. The first part is devoted to the results of estimating long-run equilibrium relations for the Czech economy during the period 1996q1 –

2010q4. The second part deals with the results of the analysis of the effects of domestic and external shocks to selected endogenous variables using general impulse response function.

The results of the estimated long-run core model illustrate that:

- It is possible to except the hypothesis on applicability of the PPP relative trivariety version and it has been shown the evidence that Czech productivity has been generally increasing in accordance to the Harrod-Balassa-Samuelson (HBS) effect.
- The monetary balance demand is positively dependent on the domestic output close to unity. We can also identify the positive trend to capture the possible effect of the changing nature of financial intermediation, and the increasing use of credit cards in settlement of transactions.
- We estimate increasing trend function of the domestic output that is in accordance to the economic growth theory and we can document that Czech economy is converging to the EU25 economy.
- The risk premium for the interest rate parity was estimated at 0.89 % annually and annual real rate return presenting internal Fisher effect was estimated at 0.86 %. It is in compliance with the values in developed countries with a long tradition of established market economy. We can confirm very low decreasing trend for the risk premium and the real rate return for the Czech economy.

The paper also reports impulse response functions for domestic supply, demand, monetary shocks and also for external the exchange rate shocks on levels of the model's endogenous variables.

- Domestic supply shocks affect the domestic interest rate and output positively during 1 to 4 years and negatively on the exchange rate during 2 years.
- Domestic demand shocks affect the domestic interest rate negatively during the same period and the responses of the exchange rate is also the same comparing with the supply shocks.
- Monetary shocks effect positively on the domestic inflation, the exchange rate and show a negative effect on the domestic output during 3-5 years. These results clearly show the presence of a sizeable liquidity effect in our model following the unexpected tightening of the monetary policy.
- The model illustrates a number of the dynamic features identified elsewhere in the literature, including strong liquidity effect. We can quantitatively observe the occurrence of price puzzle (opposite reaction in the producer price level to the quantity of money) but cointegrating properties of our model ensure that the effects of monetary shocks on the long-run relations will not be permanent. This means that the price puzzle is a short-run phenomenon only. The results do not support the evidence of the exchange rate puzzle.

In summary it is necessary to mention that the estimated model seems to have reasonable long-run properties. It is obvious that obtained empirical evidence is influenced by the monetary crisis in the Czech economy in the period of investigation for which non-typical behavior of interest rates, monetary indicators, interest rate indicators and other indicators is distinctive.

The current model could be extended into three directions. First, we can consider expand the time span of the analysis by using VECM with structural breaks. The second issue is the identification of a short-run structure for the model and to produce conditional forecasts. Thirdly, we can to extend this model into a global model combining individual country vector error-correction models.

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