The monetary transmission mechanism in the Czech Republic: evidence from the VAR analysis

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1. Introduction

One of general claims almost all economists would agree on is that there exists significant lag between the monetary policy action and the subsequent reaction of the economy. Next to it, they would probably also agree on the existence of enormous uncertainty surrounding this lag. Mentioned uncertainty arises not only from the time point of view but covers also the uncertainty connected with precise understanding of ways the monetary policy influences the economy. Unfortunately, for monetary policy purposes, exactly the knowledge of ways and lags, i.e. the transmission mechanism is of primary interest, as without the knowledge of transmission mechanism the monetary policy can not be fully successful.

Next to this general demand for the transmission mechanism studies, also the expected adoption of the euro brings several additional questions concerning the international comparison of the transmission mechanism among the home country and the present euro area member countries.

In order to face both mentioned topics this paper analyses the transmission mechanism using VAR models. The VAR methodology is the most widely used in empiric to analyse the transmission mechanism and, moreover, its results are also convenient for an international comparison. The use of VAR models began with the seminal work by Sims (1980). Recently Leeper, Sims and Zha (1998) and Christiano, Eichenbaum and Evans (1999) have reviewed the extensive literature on the monetary transmission mechanism in the United States. In Europe the constitution of EMU has led to a quite frequent use of the VAR methodology to evaluate the cross-country differences in the transmission mechanisms. The results are summarised in Angeloni, Kashyap and Mojon (2003).

Bearing in mind the characteristics of the VAR methodology also the focus of this paper can be divided into two parts. First, the focus is on what we can learn regarding the transmission mechanism in general. Second, the results are useful for comparison with the transmission mechanism for EMU member countries. The paper is organised in the following way. After a brief introduction we devote the second part to the description of identification procedure, the third part of the paper deals with estimation and discussion of results. Finally, the forth part concludes.

2. Identification

In this section we describe the benchmark that was used in our VAR model for analysing the effects of monetary policy. To enable the comparison with the EMU results we follow as much as possible the identification used by Peersman and Smets (2001) for the EMU as a whole and Mojon and Peersman (2001) for particular member countries. Mojon and Peersman (2001) distinguish basically three different types of countries depending on their economic position and exchange rate position against the former German currency (i.e. the DEM). They also distinguish three different types of VAR identification. Taking into account the position of the Czech economy among other European countries, we follow the identification type for the small open economy with relatively independent monetary policy. Then the estimated system has the following representation:

(1) $$Y_t = aY_{t-1} + bX_t + v_t$$

where Y_t is the vector of endogenous variables and X_t is the vector of exogenous foreign variables. The use of the vector of exogenous variables in general helps to solve the so-called price puzzle[1] that is often observable in VAR results. Lack of available data constraints the possibility to follow Mojon and Peersman (2001) identification completely. In comparison to their identification that assumes foreign country GDP and world commodity index being exogenous variables, we consider the vector of exogenous variables containing only one variable, the level of GDP in Germany (y^F):

(2) $$X_t = \left[y_t^F \right]$$

In comparison with Peersman and Smets (2001) or Mojon and Peersman (2001) we do not include the commodity price index into the vector of exogenous variables. Instead, we use the core inflation as an endogenous variable. The core inflation adjusts the development of regulated prices and energy prices. The exclu-

[1] The term price puzzle is connected with the empirical finding that an interest rate tightening is followed by price increase. The price puzzle results from the monetary policy reaction on external shocks.

sion of the commodity price index from our vector of exogenous variables is, at least partially, compensated via the usage of the core inflation, as the energy prices comprise substantial part of commodity price index.

One can wonder about the influence of foreign interest rate that is also often included in the vector of exogenous variables. On the other hand, the foreign interest rate can be also a direct part of the vector of endogenous variables. Including the foreign interest rate as an endogenous variable reflects the strong relationship among the home and a foreign country. The domestic interest rate then responds to the foreign one without any impact on the exchange rate. Mojon and Peersman (2001) claim that neglecting the foreign interest rate in the model results in a price and exchange rate puzzle. The reason is that if one does not control for increases in the domestic interest rate that are just a response to increase in the foreign rate, then the positive interest rate shock may be associated with exchange rate depreciation. Exchange rate depreciation then puts upward pressure on prices.

Following the Mojon and Peersman (2001) specification for small open economies with flexible exchange rate, the vector of endogenous variables contains real GDP (y_t), core price index (p^{core}), the foreign nominal short-term interest rate (s^F), the domestic nominal short-term interest rate (s_t) and the nominal bilateral Euro exchange rate (x_t):

(3) $$Y_t = \left[y_t, p_t^{core}, s_t^F, s_t, x_t \right]$$

The foreign interest rate is represented by the German nominal interest rate till the year 1999 and since 1999 by the EMU short-term nominal interest rate. The bilateral Euro exchange rate is used instead of the effective exchange rate given its prominence for the international trade.

The monetary policy shock is identified through a standard Choleski decomposition with variables ordered as in (2) and (3). The VAR model described by equation (1) represents already the reduced form system. However, with a high probability there is simultaneity among variables. The reduced form VAR is derived from the VAR model that allows for contemporaneous relationships among variables. The initial model has the following representation:

(4) $$KY_t = AY_{t-1} + BX_t + \varepsilon_t$$

where K matrix includes all the coefficients describing simultaneous relationships among variables. Multiplying the VAR system with the inverse matrix $K^{(-1)}$ we get

(5) $$Y_t = K^{(-1)} AY_{t-1} + K^{(-1)} BX_t + K^{(-1)} \varepsilon_t$$

which can be rewritten in a form as in the equation (1)

(1) $$Y_t = aY_{t-1} + bX_t + \nu_t$$

where

$$a = K^{(-1)}A$$
$$b = K^{(-1)}B$$
$$\nu = K^{(-1)}\varepsilon$$

The Choleski decomposition[2] is just an attempt to identify the original shocks ε_t using the vector of residuals ν_t. However, the Choleski decomposition is able to identify the original shocks ε_t only if we assume that there exist exactly $n^2 - \left[\left(n^2 - n\right)/2\right]$ simultaneous relationships among variables, where n is a number of endogenous variables. It means that the Choleski decomposition imposes $\left(n^2 - n\right)/2$ additional restriction on our model. It is done in a very simple way by imposing the matrix K as a lower triangular one (i.e. setting all the coefficients above the diagonal equal to zero). Bearing in mind that the matrix K is in the lower triangular form we can choose ordering of endogenous variables reflecting an assumed structure of the economy. By doing so, we assume that there exists simultaneity only among particular variables.

The ordering of the variables expressed by (3) imposes an implicit assumption that the monetary policy actions have no contemporaneous impact on output and prices but have an immediate impact on the exchange rate. Besides, the interest rates respond to the contemporaneous changes in output and prices. On the other hand the interest rates does not respond in the same period to changes in the nominal exchange rate. The latter assumption may be more convenient for a large, relatively closed economy than for a small and open economy. For example Clarida and Gertler (1997) have found a significant contemporaneous response of interest rates to changes in the exchange rate in the case of Germany. Smets and Wouters (1999) show that allowing for such a simultaneous response helps to avoid the price puzzle. They also propose a methodology to solve the simultaneity problem between interest and exchange rates behavior. The methodology proposed by Smets and Wouters (1999) is based on the application of a reaction coefficient on the exchange rate. The reaction coefficient is estimated by using the interest rates spread between the home country and another foreign country and exchange rate behavior for the foreign country and another foreign country. For example Mojon and Peersman (2001) used for the German case the spread between the German and the French long-term interest rates and US dollar/Yen exchange

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[2] For precise description of Choleski decomposition see Enders (2004) or original work by Sims (1980).

rate as instruments. The foreign economy that was, in this case, caught by the vector of exogenous variables was the US economy.

Alternative identification scheme that allows for contemporaneous interaction between the interest rate and the exchange rate is due to Sims and Zha (1998) and Kim and Roubini (2000). When using the Choleski decomposition it is assumed that the residuals vector v_t can be related to the original vector of shocks ε_t. Their relationship can be represented by the following matrix equation:

(6)
$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ k_{21} & 1 & 0 & 0 & 0 \\ k_{31} & k_{32} & 1 & 0 & 0 \\ k_{41} & k_{42} & k_{43} & 1 & 0 \\ k_{51} & k_{52} & k_{53} & k_{54} & 1 \end{bmatrix} \begin{bmatrix} v_t^y \\ v_t^{p\_core} \\ v_t^{s^F} \\ v_t^s \\ v_t^x \end{bmatrix} = \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^{p\_core} \\ \varepsilon_t^{s^F} \\ \varepsilon_t^s \\ \varepsilon_t^x \end{bmatrix}$$

Following Sims and Zha (1998) and Kim and Roubini (2000) alternative scheme we allow for contemporaneous interaction between the interest rate and the exchange rate that can be written as:

(7)
$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ k_{21} & 1 & 0 & 0 & 0 \\ k_{31} & k_{32} & 1 & k_{34} & 0 \\ 0 & 0 & k_{43} & 1 & k_{45} \\ k_{51} & k_{52} & k_{53} & k_{54} & 1 \end{bmatrix} \begin{bmatrix} v_t^y \\ v_t^{p\_core} \\ v_t^{s^F} \\ v_t^s \\ v_t^x \end{bmatrix} = \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^{p\_core} \\ \varepsilon_t^{s^F} \\ \varepsilon_t^s \\ \varepsilon_t^x \end{bmatrix}$$

The condition for $\left(n^2 - n\right)/2$ additional restriction on the model is still fulfilled. The only difference is in identifying the coefficients k_{34} and k_{45} that express simultaneity between the interest rate and the exchange rate instead of coefficients k_{41} and k_{42}. However, this change means that the interest rate does not react to the contemporaneous change in output and inflation. Bearing in mind the underlying economy structure and using the Sims and Zha (1998) and Kim and Roubini (2000) identification one thus claims that the monetary policy does not take into account the actual performance of output and inflation. Sims and Zha (1998) and Kim and Roubini (2000) argue that such a restriction is a very plausible one due to the fact that the latter available information for the monetary policy authority is only in a lagged form. However, this argument is weakened due to two reasons. First, using the quarterly data the information about inflation is at least partially available already during the current period. Second, as the VAR model is just a way how to write a solution of SDGE monetary model with a forward-looking type Taylor rule[3], the reaction of the monetary policy on the contemporaneous changes in output is necessary. Because of the mentioned arguments and the aim to compare the results with those obtained for EMU countries, the Choleski decomposition was chosen as an identification technique.

However, once the Choleski decomposition was decided to be a suitable identification technique, then in order to estimate the model any specific ordering must be chosen. In this respect we follow the ordering described in (3). Nevertheless, the ordering does not allow for simultaneous response of the interest rate on the exchange rate performance. As mentioned above, the chosen ordering reflects only the simultaneous response of the exchange rate on the interest rates movements. Although the Czech economy is surely a small open one, monetary policy expressed by the interest rates behavior should not respond to the exchange rate movements per se. Instead, as the monetary policy is conducted in an inflation-targeting regime, the monetary policy should take into account the ultimate effects on the inflation forecast. That is why the constrained simultaneous response of the interest rate on the exchange rate does not mean necessarily any substantial mistake. Smets and Wouters (1999) mentioned that the constraint imposed on simultaneity could be one of the price puzzle reasons. If we observe the price puzzle in our results we will be able to evaluate the bias caused by the simultaneity constrain.

3. Results

3.1 Estimation

The VAR model is estimated using two different data samples. The first one covers the period from the first quarter 1993 to the forth quarter 2003. The second one represents the period from first quarter 1998 to the forth quarter 2003. The use of a shorter data sample next to the longer one stems from several reasons. First, there was a change of the monetary policy regime from the fixed exchange rate regime to the inflation targeting one at the end of 1997. Such a change could have caused alteration in households and firms' decision making that must have been reflected in the values of estimated coefficients. As a result, the use of the whole data sample is fully related to the Lucas critique. Second, the longer data sample covers the period of exchange rate crisis that took place in May 1997. The crisis resulted in abandoning the fixed exchange rate regime and the Czech currency started to float. Besides, quite a strong depreciation was observable also during the autumn 1997 and summer 1998. Mojon and Peersman (2001) conclude that impulse response functions in the case of the monetary shock for countries that underwent the exchange rate regime shift, like Italy and Spain in their country

[3] For more details see Leeper and Zha (2001).

sample, express so-called the exchange rate puzzle. The exchange rate puzzle means that tightening of the monetary policy stance leads to a depreciation of the exchange rate. The reason for such a pattern is straightforward. The monetary policy authority tries usually to defend the fixed exchange rate regime by increasing the interest rates dramatically. As a result we observe in the data the simultaneous interest rates increase and exchange rate depreciation. The exchange rate depreciation following the monetary policy tightening then contributes also to the existence of the price puzzle. Similar performance can be expected in the case of results for the Czech economy.

The data used are in log levels and are seasonally adjusted, except for the interest rates that are just in levels and are not adjusted seasonally. As we do not provide an explicit long run analysis of the behavior of the economy, we only allow for implicit cointegrating relationship in the data following the methodology proposed by Christiano, Eichenbaum and Evans (1999)[4]. The available data sample is not long enough to perform more detailed analysis of the long-run behavior. Nevertheless, despite that we tested the data for the cointegrating relationship. The results show that there exists one cointegrating vector in the data series.

As the monetary policy rate we use the three-month interest rate. Although the central bank conducts the monetary policy via the two-week interest rate, the correlation between the two-week and three-month interest rates movements is quite strong, so the use of the three-month interest rate does not represent any problem for the analysis.

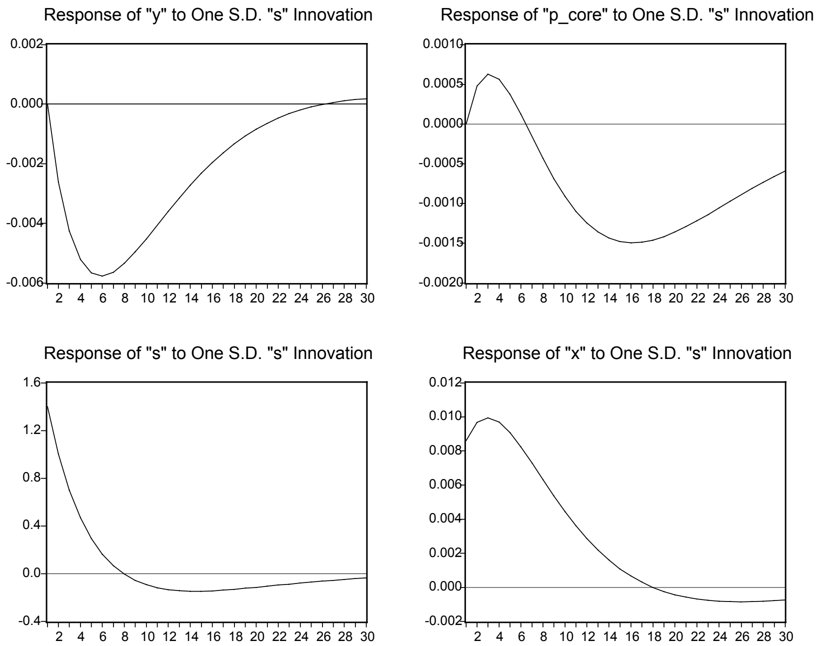
Using the standard likelihood tests we decide to use the lag of the first order for both data samples. However, the results of likelihood tests are ambiguous. Whereas the Akaike test prefers the lag of second order, Schwarz test prefers the lag of the first order. For both there is no significant serial correlation in v_t residuals. Although the lag of the second order is commonly used, facing the relatively short data sample, especially in the second part of our sample (i.e. 1998 to 2003), we decided to use the lag of the first order. However, the results for the lag of the second order are telling quite a similar story about the transmission mechanism properties.

3.2 Discussion of the results

We start the discussion of the results with the whole data sample from 1993 to 2003. The following Graph 1 shows the effect of domestic, one-standard deviation, monetary policy shock on domestic real GDP, prices and the exchange rate. Remember that the prices are measured using the core price index, which excludes the regulated and energy prices.

[4] See also Hamilton (1994)

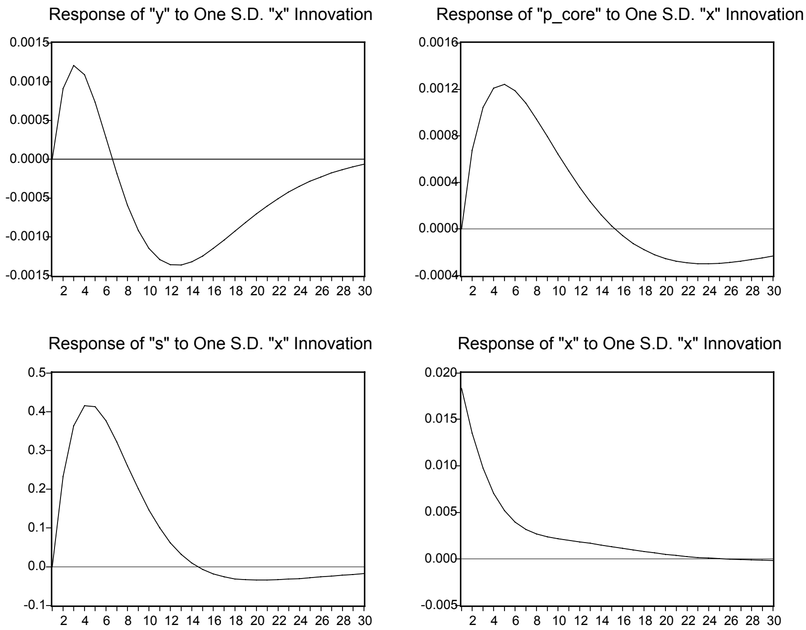
Graph 1



It is obvious that an unexpected, temporary rise in the interest rate tends to be followed by a temporary fall in the output. The effect on output reaches its bottom in approximately 5 to 7 quarters and returns to the baseline afterwards. As we have expected the response of the exchange rate is rather counterintuitive. The increase of the interest rate is followed by the exchange rate depreciation. It was already mentioned above that such an exchange rate performance was called "the exchange rate puzzle" and had been observed for countries that had undergone the exchange rate crisis during the relevant time period. The depreciation of the exchange rate could then be the reason why we observe rather a sluggish response of prices to the monetary policy tightening and subsequent fall in output. Moreover, we observe the initial price increase that is consistent with the existence of rather a fast passthrough due to the direct exchange rate channel. Only after approximately 6 quarters the effect on prices starts to be negative and reaches its bottom levels in 15 quarters. Also the return of prices to the baseline is slow, which means that the prices are quite persistent.

Besides the interest rate shock we also show the results of one-standard deviation exchange rate depreciation shock. The results for the exchange rate shock are captured by the Graph 2.

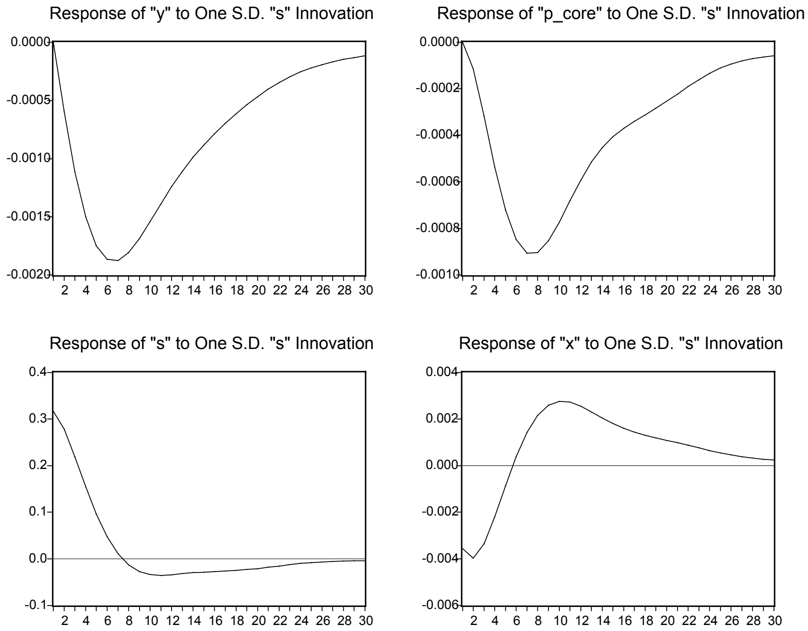
Graph 2



The responses to the exchange rate shock coincide with what the underlying theory predicts. We observe rising prices and the initial increase in output. Due to the monetary policy reaction resulting in the interest rate increase, we observe a subsequent gradual output decline and after approximately 7 quarters the output starts to be negative compared to the baseline. The output reaches its negative peak in approximately 11 to 13 quarters. Influence of the negative output then helps to return prices to the baseline.

We mention above that the results for the data sample 1993 to 2003 are only partially reliable. Constraint reliability stems from the exchange rate regime shift and subsequent monetary policy regime shift, which are both encompassed in the data sample used. This results in strong relevance of Lucas critique for the estimated model and in counterintuitive performance of the exchange rate to the monetary policy tightening. In order to avoid, at least partially, these problems we estimated the model using the data sample from 1998 to 2003, which excluded the most problematic year 1997. Graph 3 depicts the effect of domestic, one-standard deviation, monetary policy shock on domestic real GDP, prices and the exchange rate using the constraint data sample.

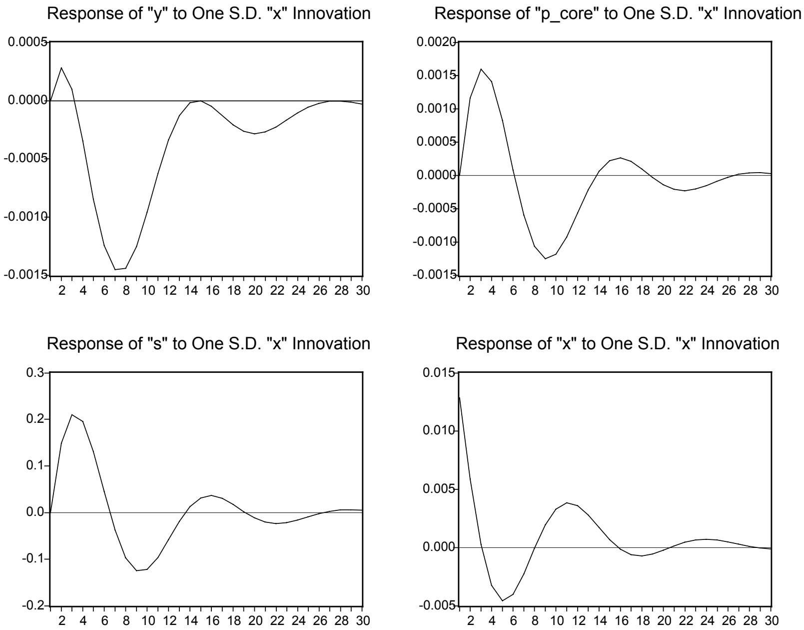
Graph 3



For constraint data sample we observe that an unexpected, temporary increase of the interest rate tends to be followed by a temporary fall in the output. The effect on output reaches its lowest values again in approximately 5 to 7 quarters and then returns to the baseline afterwards. In comparison to the full data sample case the exchange rate follows the immediate appreciation trajectory and reaches the appreciation peak in 2 quarters. Regarding the reaction of prices, the results show a gradual decline in prices, which reaches its peak in approximately 6 to 8 quarters. It is followed by a rather fast response of prices to the changes in the output and the core of the observed persistence lies in the output reaction. On the other hand, it should be mentioned that the almost simultaneity between the output and prices can arise from strong influence of the direct exchange rate channel.

The effects of the exchange rate are in more detail shown having imposed one-standard deviation exchange rate depreciation shock. The results for the exchange rate shock are captured by the Graph 4.

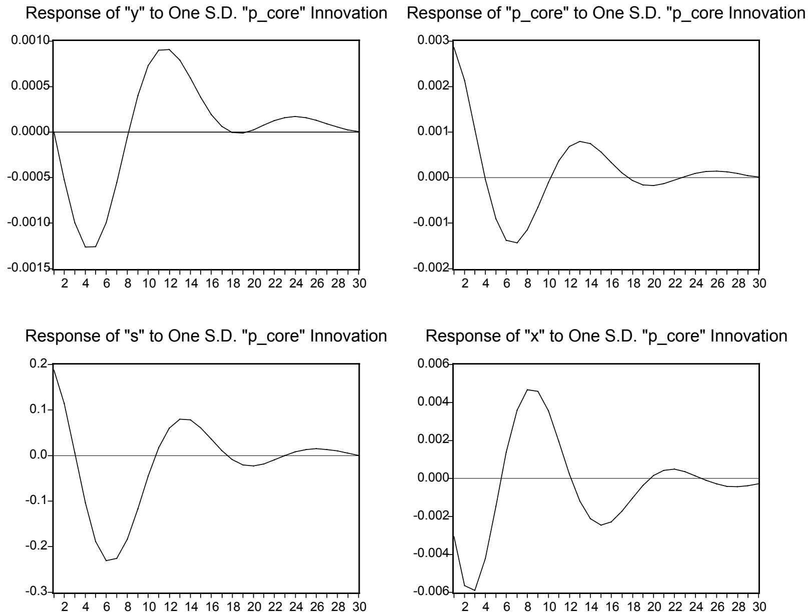
Graph 4



The exchange rate depreciation shock is connected with the initial increase in prices and slight initial increase in the output. The effect on prices reaches a peak in approximately 3 to 4 quarters. However, with one period lag we observe the counter monetary policy reaction that causes output and subsequently also the prices to decline. The observed cyclicity in results arises probably due to a high volatility of the exchange rate pattern and a relatively short data sample.

Comparing the results for both data samples the constrained data sample seems to help to solve the puzzles we observe for the whole data sample. In order to test the plausibility and reliability of results for the constrained data sample we impose also the one-standard deviation inflation shock and regard the intuitiveness of all responses. Graph 5 presents the relevant responses.

Graph 5



Unexpected and temporary shock in prices causes the immediate monetary policy reaction. We observe an increase of the interest rate accompanied by the exchange rate appreciation. Both the rise in interest rates and exchange rate appreciation are then pushing on the output to decline. One may wonder why the output decline is in comparison to the interest rate shock slightly faster. The reason could come from the immediate demand contraction because the households and firms are facing higher prices. Such a reaction is then encompassed in the data. However, the difference is not large.

4. International comparison

With the expected adoption of the euro, a question about the compatibility of ways the monetary policy affects the economy of the present euro area members and accession countries arises. Mojon and Peersman (2001) address a comparison of EMU member countries. Using their results as a benchmark we can claim that the results for the Czech economy are quite similar. Considering the responses to monetary policy shocks we find that the response of the output is very similar to the Euro area as a whole, and then to Germany, Austria, Finland, Italy, and Spain.

A faster response of the output, approximately in 2 to 3 quarters, was found out by Mojon and Peersman (2001) for the Netherlands, Belgium, France and Greece. On the other hand, similar response of prices is observable only for the Netherlands. Generally the prices are being more persistent. For example, results for Germany, Austria and Belgium show that the price response reaches its peak in 15 quarters of a year. For the rest of countries and the EMU as a whole the time of the response is even longer. This may signal higher price rigidities in many EMU member countries but, at the same time, it can also be just a consequence of the constraint role of the exchange rate from the point of view of any particular member country. However, the case of the Netherlands supports the first type of the explanation.

5. Concluding remarks

The aim of this paper is to show the basic properties of monetary policy transmission mechanism. We do not aim to explain the precise role of different channels. The identified VAR model then can serve as an information tool to get the basic transmission framework within the mutually interdependent environment. Consequently, in this paper we have estimated an identified VAR on Czech data. Using the standard Choleski decomposition as an identification technique and particular ordering covering the implicitly assumed economy structure we uncover plausible impulse responses of the main variables to an unexpected monetary policy tightening. A temporary rise in nominal short-term interest rates tends to be followed by the appreciation of the exchange rate, temporary fall in output and with approximately one quarter lag also by fall in prices. Effect on output reaches a peak after approximately 5 to 7 quarters and on prices after approximately 6 to 8 quarters. The almost simultaneous reaction of prices to the output fall might arise from the strong role played within the economy by the direct exchange rate channel.

Besides the monetary policy shock we also impose depreciation and inflationary shocks to test the plausibility a reliability of the estimated model performance. The exchange rate depreciation shock induces the immediate rise in prices and a slight immediate increase of the output. The effect on prices reaches a peak after approximately 3 to 4 quarters. However, with one period lag we observe the counter monetary policy reaction that causes the output subsequently also the prices to decline. In comparison, a temporary shock in prices causes the immediate monetary policy reaction. In the end we observe an increase of the interest rate accompanied by the exchange rate appreciation. The increase in the interest rates and the exchange rate appreciation then causes output to decline and the inflationary shock to disappear.

The international comparison shows a similar response of the output to a monetary policy shock as in many EMU member countries. However, the response of prices to the same type of shocks demonstrates similarities only in comparison with the Netherlands. The responses of the other EMU member countries show higher persistence in performance of the prices. The international comparison should be of course broaden, taking in to the account more accession countries with independent monetary policy. This topic should be covered by future research.

Although the present results cannot be certainly taken undoubtedly, they at least show the basic framework how the monetary policy is affecting the economy. The findings encourage a future research as they show that applying standard techniques to the Czech data can bring meaningful results that can be useful as a benchmark for the further analysis of the transmission mechanism in the Czech economy.

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