Investigating the Effects of Monetary Policy in Post-Transition Economies: The Czech Republic and Poland

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Abstract

This thesis paper proposes a structural VAR model to identify monetary policy influence in the transition period for the Czech Republic and Poland. The analysis of the impulse responses and the variance decompositions puts forward the significant, especially for Poland, though transitory, role of the monetary policy for the fluctuations of output. The non-trivial importance of the exchange rate in explaining price level fluctuations, on one hand; and the significant monetary reaction to exchange rate and foreign interest rate movements, on the other; emphasizes the exchange rate as a significant transmission mechanism. External influences are identified as an important source for the variation in output, prices and exchange rates for the two countries.

1. Introduction

Monetary policy authorities need to be precisely aware of the channels and the size of their influence on the working of the economy. To attain their primary and secondary objectives, however, central bankers should be additionally aware of the sources of influence, both external and internal, affecting their economies.

At the outset of the transition period, the monetary authorities in the Central and East European Countries (CEECs) have been confronted with many more uncertainties and conundrums than any of the central banks in the developed countries usually experience. Despite being the forerunners among the CEECs, the Czech Republic and Poland had to resolve the same array of difficulties as the other transition countries did. Namely, the policy-makers did not have any market data as well as experience on the likely effects of their actions on both financial and macroeconomic variables. In the beginning of the new century, this problem is not less acute provided that policy actions

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have a lagged effect on the economy; still, in the course of macroeconomic stabilization, an enormous amount of structural changes have taken place that could inevitably distort the inference of the true policy effect.

Following the accession of new member states to the European Union (EU) in 2004, the literature on monetary policy in transition countries has proliferated on the topic of optimal monetary policy regimes on the way of adopting the Euro. Needless to say, the issue of consistent monetary policy in a highly uncertain environment is of enormous importance. Thus, addressing the question, which is the most advantageous policy regime in the forerun to the eventual euro adoption, is generally very tempting. The scope of my paper is slightly different, though, not less important. I attempt at answering how the policy-makers have influenced their economies from the beginning of the transition period until now. In doing this, I do not confine myself to inspecting the relationship between the actions of the central bank and the macro economy only in time periods that were marked by specific policy rule because: (i) such time spans are relatively short and (ii) even in the separate time periods, the ongoing structural changes have tainted the relationship between policy instruments and macroeconomic variables in peculiar manners.[1] Thus, in my study, I proceed as if there had been only one monetary policy rule. A second question I am going to address in my study is what is the influence of external shock(s) on the two post-transition economies. The issue is relevant provided that it allows policy-makers to figure out to what degree they should track changes taking place outside their own countries.

In order to answer the above stated questions, I employ a structural VAR model with block exogeneity restrictions founded on the general framework developed by Cushman and Zha (1997), Zha (1999) and very alike the structure adopted by Kim (2002). These models were originally applied to explore the economic processes taking place in industrialized small open economies. The small open economy is regarded as one, which is subject to numerous external shocks and for whom the prices are defined on the world markets. Currently, many emerging markets and developing countries are sufficiently integrated into the financial markets, and naturally the mobility of capital across their borders has increased. As a result, the Cushman and Zha's model could easily be applied to studying developing countries after some modifications.

In examining the role of the monetary authorities in the economies of the Czech Republic and Poland, I explicitly define these countries' monetary policy functions. This allows the separation of the policy reaction function from production sector responses to both unexpected policy actions at home and changes of the foreign state. To anticipate the results, the proposed identification, manages to distinguish the monetary policy shocks from other shocks in the system. Furthermore, by examining the effects of a tightening monetary policy to the economy, I find out the variables' responses that are consistent with theoretical as well as other empirical structural VAR models: the rise of

[1] By taking this stance, I run into the danger of providing biased estimates about the effects of policy actions on the financial and production sector.

the interest rate and the fall of the money aggregates are followed by exchange rate appreciation, fall of the price level and the output. There is evidence that the fall in output is transitory. Finally, external influences are identified as an important source for the variation in output and exchange rates for the two countries.

The paper belongs to two branches of the literature. The first branch is the extended general structural VAR model applied on studying the monetary transmission in CEECs as in Jarociński (2004) and Maliszewski (2002). The aim of the first work is to explicitly compare the responses to monetary shocks between the East and the West European countries in a unified framework. The author finds that a monetary policy shock leads to stronger interest rate movements as well as a deeper and more lagged price fall in the East compared to the responses in the West. The second paper elaborates on the differences in the monetary policy regimes in the Czech Republic and Poland. To accomplish this goal, the author relies on a model that allows for parameter changes of policy reaction functions and financial variables equations, while leaving the coefficients of equations describing the behavior of macroeconomic variables constant across regimes. The paper detects differences in the policy regimes, though, small. The fact that policy regime changes have not produced considerable differences in the macroeconomic variables' responses is statistically tested in *Section 3.1*of my paper. The way my work differentiates from the two described papers is: first, I include a monetary aggregate in my model; and second, I explicitly discuss the foreign influence on the macroeconomic variables in the Czech Republic and Poland. Broadly, my estimates of the monetary policy effects on inflation and output are very similar with the results of Jarociński (2004) and Maliszewski (2002), both point estimates as well as error bands. The most obvious difference is that the response of output in my model is smaller, in the short and in the long runs, compared to the other two papers. Second, the inflation responses in Jarociński's paper cast doubt for the presence of the price puzzle in his estimates. Conversely, I do not detect a price puzzle in my estimates.

The second branch of the literature, that my work belongs to, is the structural small open economy VAR in the vein of Cushman and Zha (1997), Kim and Roubini (2000), Maćkowiak (2003), Maćkowiak (2005) and others. In studying the influence of the US economy on Canada and a number of emerging market countries, respectively, the authors of the first and the third papers include a large list of US variables in their models. To account for the size and the independence of the US America compared to the smaller countries, the authors do not allow the variables of the small countries to affect the US variables either contemporaneously or with lags. Analogously, the included German interest rate in my system, which represents the foreign influence on the two transition economies, is restricted in the manner of the first and the third paper. In my case, the imposition of this restriction is not difficult to justify given the asymmetry between Germany and the developing CEECs in their international influence. Alike Kim and Roubini (2000) who include two foreign variables in their model, my system with a single foreign variable is viable of attributing the exchange rate the importance of a transmission mechanism, while supporting the view that the effect of monetary policy on the economy is significant, though transitory.

The paper continues as follows: *Section 2* elaborates on the model's identification and inference under it; *Section 3* presents the results; *Section 4* extends the discussion on the results by elucidating the monetary policy function; *Section 5* concludes. Since there are many studies that extensively discuss the institutional set-up and history of transition experienced by the two transition countries, I consider providing an additional section on this issue in the main paper's text unnecessary. Nevertheless, I have included a brief overview on the topic in Appendix A. Appendix B explains shortly the Bayesian inference technique used in the paper. Appendix C contains the data description.

2. The Model

2.1. A structural VAR with block exogeneity

The term 'structure' in economics modelling has been given several distinct meanings. The definition that I propose is at closest to the wording of Sims (1986) and the Cowles economists. A structural model can be employed in decision-making and policy analysis, as it is able to predict the effects caused by interferences to the economy. If ***H*** is the various courses of actions we might take, the model should produce forecasts what ***Z*** is. At minimum, explaining the 'structure' term comes to defining the distinction between the reduced form and the structural form of the model. The reduced form is known as the probability distribution $p(X;\beta)$ for the data ***X*** as a function of the reduced form parameters β, while the structure is displayed as a conditional distribution $q(Z|H;\alpha)$ of the ***Z*** results given the ***H*** actions, depending on the α unknown structural parameters. Thus, the conditional distribution is considered to be the fundamental representation of the economy.

The structural model has the following general linear stochastic dynamic form:

$$A(l)y_t = c + \varepsilon_t \tag{1}$$

where y_t is a $n \times 1$, $t = 1,..T$, $A(l)$ is a $n \times n$ matrix-valued polynomial in positive powers of the lag operator l, $A(0)$ is non-singular, c is a $n \times 1$ vector of constants and ε_t is a $n \times 1$ vector of Gaussian structural shocks with the following properties:

$$\mathrm{E}\left[\varepsilon_t \varepsilon_t' \middle| y_{t-s}, s > 0\right] = I_n, \quad \mathrm{E}\left[\varepsilon_t \middle| y_{t-s}, s > 0\right] = 0. \tag{2}$$

Important feature of the above-displayed system is the normalization of the structural disturbances of (2) into an identity covariance matrix. We assume that the disturbances are behaviourally distinct sources of fluctuations in the ε_t vector that are the causes for variation in the economy. The y_t and the structural disturbances vectors could be decomposed as follows:

$$y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix}, \quad A(l) = \begin{bmatrix} A_{11}(l) & A_{12}(l) \\ 0 & A_{22}(l) \end{bmatrix}, \quad \varepsilon_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}. \tag{3}$$

The y_{1t} and y_{2t} vectors are respectively the domestic and the external blocks with number of variables in them equal to n_1 and n_2 $(n_1 + n_2 = n)$. Setting $A_{21}(l) = 0$, the block exogeneity restriction, implies that the small country block of variables does not affect the foreign block either contemporaneously or with lags. It is important to notice that the concept of block exogeneity implies the Granger causal priority restriction discussed in Sims (1980). The distinction between the two concepts comes from the condition that that Granger causal priority is defined for the familiar reduced VAR form. Granger causal prior variables arise quite naturally in macroeconomic models of small open economies. Zha (1999) discusses how failing to impose this restriction could lead to very misleading inferences. In my case, this would imply that disturbances borne in the Czech Republic and Poland are transmitted to Germany. Nevertheless, before imposing the Granger causal priority restriction I test for its statistical validity in the data. The restriction is accepted for the two studied countries.

2.2. Identification

The identification is a necessary condition when the researcher wants to recover the structural from the reduced form parameters (although sometimes she can work directly on the structural form). Most of the structural VAR literature imposes linear restrictions on the contemporaneous coefficients matrix $A(0)$, except the orthogonality restriction in (1) and the normalization of the shocks in (2), to establish the crucial identification. Likewise, in my paper I trace out the monetary reaction functions of the Czech Republic and Poland to behavioural disturbances leaning on a nonrecursive exactly identified contemporaneous structure.

Models with block exogeneity restrictions and exactly identified contemporaneous structures, as the one that I impose on my model, could be estimated by the procedures implemented in Blanchard and Watson (1986), Bernanke (1986) and Sims (1986). Despite the excess restrictions on the lagged variables, by defining the reduced form (4), we can simply compress the problem of estimating the likelihood function for the whole system into an estimation of the separate likelihood functions for the individual blocks. The idea of separating the likelihood into n blocks belongs to Zellner (1962) who developed his SUR model, in which the contemporaneous correlations of residuals are zero (in my case, ε_{1t} and ε_{2t} are by assumptions independent from each other, and y_t does not affect them contemporaneously either). Zha (1999) introduced the technique of estimating separate country VARs, which affect each other only in one direction, block by block.

I denote $A_d(0) = diag(A_{11}(0), A_{22}(0))$ as the diagonal contemporaneous coefficient matrix of $A(l)$. When multiplying the structural form (1) by $A_d(0)^{-1}$ from the left and rewriting the whole system, I obtain the usual reduced form representation:

$$y_{1t} + \sum_{l=1}^{p} B_{11}(l) y_{1t-l} + \sum_{l=1}^{p} B_{12}(l) y_{2t-l} = k_1 + v_{1t}$$

$$y_{2t} + \sum_{l=1}^{p} B_{22}(l) y_{2t-l} = k_2 + v_{2t}, \tag{4}$$

where

$$k_1 = A_{11}(0)^{-1} c_1, \quad k_2 = A_{22}(0)^{-1} c_2$$

$$B_{11}(l) = A_{11}(0)^{-1} A_{11}(l), \quad B_{12}(l) = A_{11}(0)^{-1} A_{12}(l), \quad B_{22}(l) = A_{22}(0)^{-1} A_{22}(l)$$

for *l=1,2,..,p* and *t=1,2,..,T*

$$v_{1t} = A_{11}(0)^{-1} \varepsilon_{1t}, \quad v_{2t} = A_{22}(0)^{-1} \varepsilon_{2t}. \tag{5}$$

The system in (4) is normalized into domestic and foreign blocks, which correspond to the ones in (3). The normalized disturbances $v_t's$ are characterized by their block orthogonality:

$$\mathrm{E}\left[v(t)v(t)' \middle| y_{t-s}, s > 0\right] = diag\left(\Sigma_{11}, \Sigma_{22}\right),$$

$$\Sigma_{11} = A_{11}^{-1}(0) A_{11}^{-1}(0)', \quad \Sigma_{22} = A_{22}^{-1}(0) A_{22}^{-1}(0)'. \tag{6}$$

The necessity of identification stems from the lack of uniqueness when transforming system (4) into the fundamental system (3). Such indecisiveness can be described as follows. Given any orthonormal matrix *W* satisfying $W'W = I_n$, we can replace $\{\varepsilon_t, A(l), B(l)\}$, where $B(0) = I_n$ by construction, respectively by $\{W\varepsilon_t, WA(l), B(l)W'\}$ and obtain a new linear representation of the same old form (1) and (4), with the same time-series properties of the data, y_t. Clearly, if $A(0)$ were known, then it would be possible to estimate *A(l),* with *l=1,2,..p*, from the reduced form coefficients. However, the only available independent information for determining the structural contemporaneous coefficient matrix is contained in the estimates for the covariance matrices of the reduced form innovations Σ_{11} and Σ_{22}. Since the domestic block does not influence the foreign one and the likelihoods of the two blocks can be estimated separately from each other, the $A_{22}(0)$ matrix can be calculated directly from Σ_{22}. Given that A_{21} is left unrestricted and the coefficients of $A_{12}(0)$ are set to zero, to recover $A_{11}(0)$ from Σ_{11}, I still need to impose identification on $A_{11}(0)$ matrix. Because of its symmetry, the covariance matrix Σ_{11} has only $n_1(n_1+1)/2$ free parameters, while $A_{11}(0)$ has n_1^2 free elements. Thus, to resolve the indeterminacy between the reduced and structural parameters I should find at least $(n_1^2-n_1)/2$ identifying restrictions for the $A_{11}(0)$ coefficient matrix.

The structural model is formulated separately for the two transition countries: the Czech Republic and Poland. The data vector for the Polish economy model, respectively the Czech model, y_{1t} is represented as {*M, R, E(·/DM), CPI, IP*}' and y_{2t} is {*R**}. *M* is the monetary aggregate M2, *R* is the market call rate for the Czech Republic and for Poland, *E(·/DM)* is the nominal exchange rate against the Deutsche Mark (the price of the Deutsche Mark in terms of domestic currency), *CPI* is the consumer price index, *IP* is the industrial production index and *R** is the German short term interest rate. The data sample covers 12 years starting from January 1993 until December 2004. All variables are expressed in logarithms, with the only exception of the interest rates, which are expressed in decimal points. The Industrial Production, the Monetary Aggregate and the Consumer Price Index data have a strong seasonal component. I have de-seasonalized the series using the X-12-ARIMA module of *Demetra.*[2] The data is explained in detail in *Appendix B*.

Monetary aggregates, interest rates, prices and country's industrial production variables are widely used in the monetary business cycle literature. To my best knowledge, the structural VARs in the literature related to the CEECs have been rarely estimated with monetary aggregates included. That is done, to a large extent, because money has lost its ability of determining output and inflation fluctuations once the interest rates enter the model specification. Further, for the last years the money velocity in the two transition countries has been repeatedly driven by monetary policy regime switching, by contagion effects of international financial crises and by shocks from the uncertainty in the levels of initial transition inflation; which altogether results in a less reliable statistical relationship between money and other macroeconomic variables. Nevertheless, there are several reasons why the inclusion of money is necessary in the statistical model. First, in the past decade of macroeconomic stabilization and transition towards a market economy, the monetary authorities in the Czech Republic and Poland have closely observed the evolution of the money stock in circulation. Further, Leeper and Roush (2003, p.2) claim that "*whether money enters an econometric model and how it enters matters for inferences about the impacts of the policy.*" Additionally, incorporating the money stock in the model ought to help us isolate the monetary policy

[2] *Demetra* is freely available software produced by the Statistical Office of the European Committees (Eurostat). Further information can be obtained at: http://forum.europa.eu.int/irc/dsis/eurosam/info/data/demetra.htm.

shock from other market money shocks such as the money demand shock. Therefore, money is present in my model.

In the long run, real forces such as the asset position, productivity and wealth of a certain country, as well as world tastes influence the real exchange rate.[3] A model incorporating the nominal exchange rate is going to provide an important quantitative description of the identified monetary shocks on the value of the domestic currency. The inclusion of the German interest rate is justified by the prerequisite of separating exogenous monetary policy changes and international inflationary pressure. When formulating its policy, the domestic monetary authority takes inevitably a very wide range of economic variables into account. Since in many respects the formulated policy is a reaction to these variables, to account for the monetary exogenous changes, it is necessary to control for the systematic part of the policy rule. To identify the component of the domestic monetary policy that is a response to a foreign monetary policy disturbance, Kim and Roubini (2000) and Kim (2002) among others include the foreign short-term interest rate in their models. Cushman and Zha (1997), Del Negro and Obiols-Homs (2001), Maćkowiak (2003), Peersman and Smets (2001) and others incorporate a bigger foreign block in their systems. My identification is very alike that of Kim (2002) as I do not try to disentangle the effect of other foreign variables, or an explicitly formulated foreign monetary policy rule, other than the foreign interest rates on the domestic economy. The inclusion of only one foreign variable is also predetermined from the short sample period I dispose with.

Table 1 summarizes restrictions on the contemporaneous structural matrix for the proposed model. The vector of structural disturbances is as follows: $\{\varepsilon_{md}, \varepsilon_{ms}, \varepsilon_{i}, \varepsilon_{cpi}, \varepsilon_{ip}, \varepsilon_{r*}\}$, which is money demand shocks, money supply shocks, information market shocks, *CPI* shocks, *IP* shocks and German interest rate shocks, respectively. The production sector equations are not displayed, as they were not given a separate meaning.

Table 1. Contemporaneous coefficients in the structural model

Money Demand	$a_{11}M + a_{12}R + a_{14}CPI + a_{15}IP + a_{16}R^* = \varepsilon_{md}$
Money Supply	$a_{21}M + a_{22}R + a_{23}E(\cdot/\text{DM}) + a_{26}R^* = \varepsilon_{ms}$
Information market equation	$a_{31}M + a_{32}R + a_{33}E(\cdot/\text{DM}) + a_{34}CPI + a_{35}IP + a_{36}R^* = \varepsilon_{i}$
Production sector	Normalized in the upper-triangular order of *CPI* and *IP*
Foreign sector	R^*

In the money market, the money demand equation is treated as an equation with informational content similar to Kim (2002). I prefer this setting rather than the standard money demand form, where money demand balances are dependent on real income and

[3] In the short run, however, the nominal exchange rate is remarkably erratic as it absorbs enormous amount of different news, generated both in and out of the country.

the opportunity cost of holding money, for two reasons. Firstly, money stock as well as exchange rate is determined on continuous clearing auction-like markets, which makes these financial variables respond immediately to any information available. Secondly, *M2* is a broad aggregate and part of its deposits pays an interest rate. Thus, it is more difficult to interpret the nominal interest rate as the opportunity cost of holding a broad aggregate as *M2*. The coefficient governing the response of money to the exchange rate is arbitrarily set to zero in order to normalize the equation.

The money supply equation is assumed to be the reaction function of the monetary policy. The monetary policy is allowed to set the interest rate after observing the current value of money, the exchange rate and the German interest rate. Data for prices and output is not available within the same month, as it is a product of a complex data-gathering and processing practice, meaning that monetary policy could react to *CPI* and *IP* only with a delay of a month. Sims (1986) and Sims and Zha (1998a) acknowledge that the information delays assumption is an informal way of restricting the model, as the policy-makers have other sources about the state of the economy, except the published ones, which they would inevitably utilize.

The third equation in *Table 1* is named the information market equation by Sims and Zha (1998a). The name derives from the fact that in an efficiently working market, the exchange rate under a flexible exchange rate regime embraces all the available information instantaneously. Under a fixed, or a predetermined exchange rate regime, the exchange rate itself is a policy variable determined by the policy. As a result, the monetary authority commits itself to conducting its policy under a pre-specified target δ of its domestic currency's depreciation (or appreciation respectively). Nevertheless, the underlying principle for the third equation under different exchange rate regimes remains still valid, though it is more the money stock, than the exchange rate, that exhibits stronger responsiveness to all the news. This result draws from an equilibrium condition, where the monetary supply should also grow at the targeted rate δ. Even within the fixed exchange rate category, however, there are still many cases to consider regarding the wide diversity of exchange rate arrangements the small open economies are inclined to choose. The policy-makers in the Czech Republic and Poland also considered several exchange rate regime options before letting their currencies float in 1997 and in 2000, respectively. To keep the results of the model as stylised as possible and leaning on the assumption that I can approximate the different policy regimes in a single policy rule, I consider a single contemporaneous identification, regardless of the currency regimes the two countries have adopted in the transition years. Finally, to mention another positive feature of the discussed information equation I stress the following point. Although the monetary authority does not react contemporaneously to prices and output, its feedback rule is going to be endowed with information about the state of the world through the exchange rate channel, albeit indirectly.

The production sector is characterized by two equations – one for the consumer prices and the other for the industrial production. Following the example of Sims and

Zha (1998a) among others, I postulate *CPI* and *IP* responding to domestic monetary policy and financial signals only with a lag. Sims and Zha's dynamic stochastic general equilibrium set up is a justification for the proposed structural identification. The motivation follows from the argument that firms do not adjust their output and prices instantaneously in response to unexpected changes to monetary policy or financial variables due to inertia, adjustment costs and others. The sluggish (or production) sector block is normalized by upper triangular Choleski decomposition in the order of *CPI* and *IP* respectively; the two equations within the block are given no distinct behavioural interpretation. Finally, in Theorem 4 Zha (1999) provides a prove that under both exactly identified and overidentified contemporaneous structures a policy shock is invariant to an arbitrarily triangular identification, as the one assumed for the sluggish sector.

It is a well-known fact that the estimated impulse responses in VAR analysis tend to be quite sensitive to alternative identification schemes. Following the literature, I judge the reasonableness of my identification assumptions by comparing the model's estimated dynamic responses to monetary policy innovations with the results derived from the empirical as well as the general equilibrium theory. Additionally, to check the robustness of my benchmark model I tried a number of different model specifications. The results from the proposed identification come at closest to how unexpected monetary policy shocks are believed to influence the economy.

Ideally, the restrictions imposed to identify a structural VAR model would all stem from a full-fledged macroeconomic reasoning. Generally, however, it is rarely the case. Apart from the *formal* restrictions that I have already described, the economists resort to *informal* as well. Leeper et al. (1996) have been the first to try to justify them. They state that we all have our prior beliefs about the dynamic response of the economy to a money supply shock. The shock raises short-term interest rates, lowers money stock in the short-run, lowers prices and reduces real output. Unfortunately, not all impulse responses would confine to the above description even after imposing identifications that seem intuitive and/ or theoretically compelling. If the model happens to deliver disappointing results, it is usually respecified until it finally conveys what the conventional wisdom says. An analyst would naturally advertise and defend his prior beliefs, however, he should not forget that there is a possibility of being wrong. In this respect, Faust (1998) and Uhlig (2005) discussed the risk of becoming answers from such theorizing that are inevitably tainted by our *a priori* argumentation. To overcome such circularity they considered methods by which they explicitly state their prior plausibility restrictions in advance. So, the analyst "lets the data speak", however, invariably he makes it possible for his prior beliefs being revised.

Like many other structural identification schemes in the literature, mine is also arguably subject to the *a priori* theorizing critique. I tried altering the indicated informational set or changed some of the contemporaneous restrictions. From these exercises, I noticed that my structural coefficients estimates for Poland gained slightly in precision by substituting *CPI* and *E(·/DM)* with the producer price index and the weighted nominal exchange rates against the U.S. Dollar and the Deutsche Mark, respectively.[4] Although slight model's changes can contribute for move towards reasonableness in the impulse response, in the estimation of my model I adhere to the specification previously explained. I do it firstly because of sake of uniformity between the informational sets for the two countries in transition, and secondly, because the resulting dynamic responses, with this model's specification, are further supported by analogous results of very identical identification schemes in the literature. Again referring to Leeper et al. (1996), I would mention that the history of empirical work in identifying monetary policy consists largely of expanding model's scale - both introducing richer set of variables, as well as complexity of interactions between them. The mastering of the model at one scale is simply the prerequisite to expansion to the next level of complexity. Contemplating about all successful investigations on small open economies that have been produced after the work of Cushman and Zha (1997), I can conclude that probably it will not be long before the next level small open economies models appear.

2.3. Inference

The model's approach to inference is Bayesian. From a Bayesian point of view, the likelihood principle makes it clear that in measuring model fit and interpreting different hypothesis the likelihood function is our source for all the relevant sample information; that is, once the sample is observed, it is fixed and non-random. Thus, the reporting of statistical results should invariably be perceived as disclosing the likelihood function shape. Classical procedures such as the maximum likelihood estimation satisfy the likelihood principle, however many others do not. Because of the differences between the two approaches, Sims (1998) asserted that in areas that involve nonstationarity considerations or nonparametric kernel regressions the usual symmetry of Bayesian probability statements and classical confidence statements breaks down. Underlying this assertion is the fact that with normal errors and a flat prior the Bayesian posterior is normal even if the true data generating process is a random walk, which was explored by the Sims and Uhlig (1991) Monte Carlo "helicopter tour" experiment.

In the Bayesian framework, the likelihood function is a posterior probability density under a flat prior. Since I use a flat prior on the structural parameter space, the results of my paper ought to be appealing even to people who do distrust making statistics combined with subjective uncertainty (prior densities do not necessarily have to be subjective; they could be extracted from historical data as well). After all, classical econometricians are also interested in information contained in the likelihood function.

The inference technique is displayed in Appendix B. Because of its popularity the reader is assumed to be familiar with it.

[4] Maliszewski (2002) weights the logarithms of nominal E[zloty/DM] and E[zloty/USD] in the ratio 0.50 to 0.50. He supports the validity of his newly weighted index with the fact that the Polish currency was pegged until 2000 to a basket of other currency. See the discussion about the Polish Monetary Policy below.

3. The Results

3.1. Model Specification

To find the most suitable lag length for my model I compare the VAR's fit for models with p equal to 3, 6, and 9 for each country. The 'decision' criterion that I employ for judging the better lag length size is the Laplace approximation to the log marginal likelihood for each estimated model. Kim (1998) studies the necessary conditions for a correct Bayesian information criterion in a nonstationary environment. The Laplace approximation satisfies these conditions and respectively, the criterion is a valid method for choosing among alternative models' specification even when nonstationary data is used. The approximated log marginal likelihoods that I obtain after estimating the VARs with the respective lag lengths are: [2289.8; 2332.0; 2281.7] for the Czech Republic and [2299.2; 2297.2; 2190.2] for Poland. (Here the data has been trimmed by six and three data points for the VAR estimation with lag length of size three and six respectively, in order to assess each model on the same data size.) The Bayesian criterion favours lag length of size six for the Czech Republic and size three for Poland. Nevertheless, I prefer setting lag length size to six. I do not try to reduce the number of lags because richer lag parameterisation assures that (or is more conductive to): (i) structural disturbances are white noise[5] and (ii) there is rich enough dynamics in my system to guarantee sensible structural estimates.

Next, I test the robustness of the model with the chosen lag length. I check the presence of serial correlation in the estimated models' residuals (without block exogeneity imposed). Relying on the methods described by Lancaster (2004, chapter 2), both graphical and based on the predictive distribution, I do not detect serial correlation in the respective residuals. Despite the rich lag structure, I do still find some evidence of non-Gaussian behaviour in the macroeconomic variables, with one-two outliers of about three standard deviations for both countries. Nevertheless, such fit is not worse than those of VAR models applied to time-series of developed countries.

Then, I test how stable across time the estimated models' coefficients are. In *Table 2,* I display the Laplace approximations to the log marginal likelihoods of a model with constant parameters and another one whose coefficients are variable (two model estimated separately for 1993:1 - 1998:12 and 1999:1 – 2004:12, respectively) for the abovementioned three lag length sizes. The comparison of the second and third columns of the table emphasizes the stability of the VAR coefficients for Poland with respect to any lag length, while detecting instability for the Czech Republic's coefficients. Despite the evident structural break in the Czech data sample, for reasons stated in my introduction, I prefer to proceed further as if I have not detected any such break. Therefore, the results for the Czech Republic should be treated with caution. Because of the number of different monetary policy rules adopted from the beginning of the

[5] See Hamilton (1994, p.327) for extensive explanation of the point.

transition period, some readers may disagree with treating the entire sample as an approximation of a single regime. However, if the monetary policy rules have not follow some highly non-linear function, the approximation of the monetary rule in a single linear function could not be very erroneous. For my comfort, a comparison of the impulse responses for the Czech Republic obtained by estimating VARs for different sub-periods disclosed some slight quantitative but not qualitative differences between them.

Table 2. The Laplace approximations of the log likelihood functions for restricted and unrestricted VAR models with different lag lengths: the Czech Republic and Poland

	Granger causality restriction	The sum of Laplace approximations of two VARs for the data sample split into two	Unrestricted VAR
The Czech Republic			
Lag Length three	2782.6	2730.7	2628.7
Lag Length six	2593.3	2557.2	2504.0
Lag Length nine	2384.0	2364.1	2337.1
Poland			
Lag Length three	2677.0	2507.0	2517.0
Lag Length six	2470.5	2375.3	2376.9
Lag Length nine	2261.3	2199.8	2232.9

The econometrics theory postulates that in the presence of long-run relationship between the variables, one should further impose cointegration restrictions on them. Since in my short data sample such variables' relationship is difficult to define, opting to impose it can lead to wrong inference. However we can easily check if the Granger causality restriction is statistically accepted by the data. In *Table 2,* I display the Laplace approximations to the log marginal likelihoods of a model whose foreign block is influenced neither contemporaneously nor with lags by the small country data set. The comparison of the first and third columns of the table discloses the importance of the Granger causality restriction. This plain statistical procedure supports further our main assumption that external variation can have an enormous impact for the functioning of the small economies.

In *Table 3*, I report the estimated contemporaneous coefficients together with their standard errors (numbers in the brackets). Although many of the coefficients are statistically significant at or about the 0.05 levels, there are still others that have big standard errors. This seems to be due to the prevalent correlations between the variables, rather than erroneous identification. However, large standard errors do not necessarily imply large error bands around the Maximum likelihood estimates of the impulse responses. One can see this in *Figures 1,2,3* in which the impulse responses of the Czech Republic and Poland, together with the 68 percent probability bands around them, are displayed.

Table 3. Estimated Contemporaneous Coefficients: the Czech Republic and Poland

The Czech Republic	
Money Demand	$20.64M + 113.78R - 45.83CPI + 2.60IP - 11.37R^* = \varepsilon_{md}$
(stand. error)*	(25.45) (61.18) (15.90) (1.84) (9.14)
Money Supply	$-61.44M + 69.15R - 13.16E(\cdot/\text{DM}) + 34.50R^* = \varepsilon_{ms}$
(stand. error)	(34.62) (85.82) (62.47) (329.25)
Information equation	$-37.68M + 12.11R + 39.83E(\cdot/\text{DM})$ - $35.59CPI$
(stand. error)	(105.508) (89.01) (20.69) (24.60)
Information equation	$-0.95IP + 191.36R^* = \varepsilon_i$
(stand. error)	(4.85) (113.19)
Poland	
Money Demand	$113.60M + 15.32R - 15.97CPI - 9.11IP + 58.56R^* = \varepsilon_{md}$
(stand. error)	(45.45) (12.44) (18.10) (4.91) (42.45)
Money Supply	$-23.75M + 43.27R - 27.97E(\cdot/\text{DM}) - 45.52R^* = \varepsilon_{ms}$
(stand. error)	(59.57) (30.85) (37.94) (93.81)
Information equation	$-44.63M + 36.27R + 53.16E(\cdot/\text{DM})$ - $20.70CPI$
(stand. error)	(32.75) (32.57) (20.35) (14.67)
Information equation	$-1.39IP - 93.08R^* = \varepsilon_i$
(stand. error)	(4.27) (82.13)

*Standard errors are computed from the inverse second derivative matrix of the log likelihood at its peak.

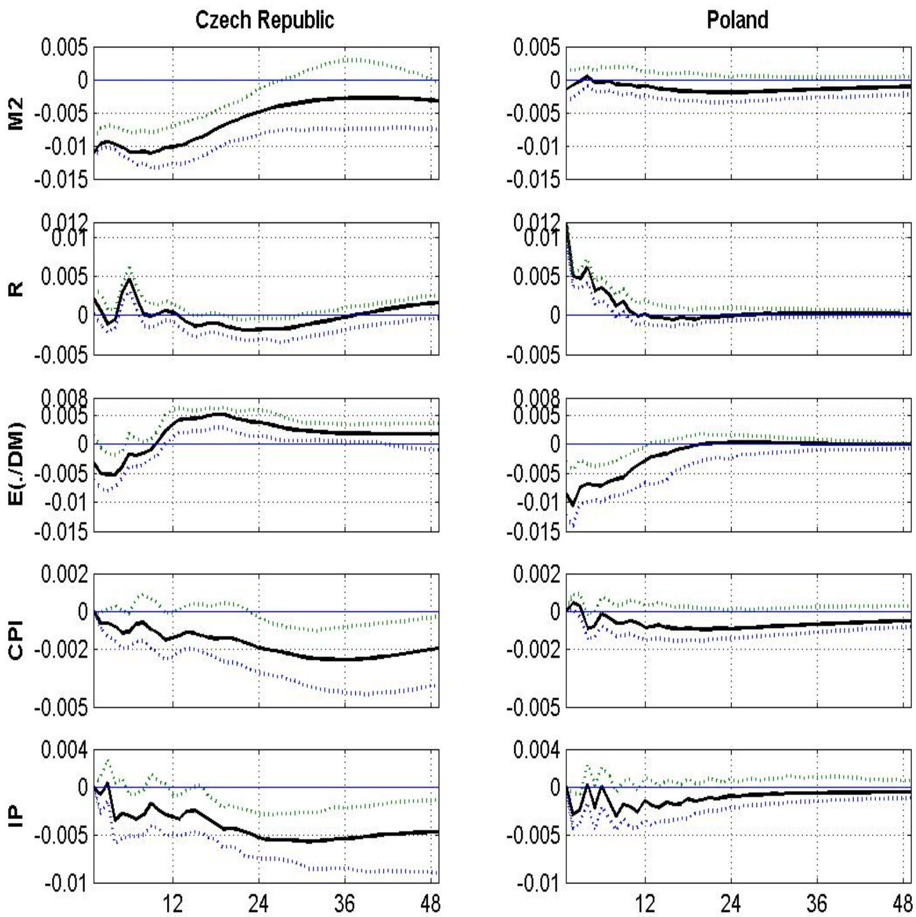
In *Table 3*, the monetary policy equations for both countries have reasonable economic interpretations. The interest elasticity of money supply and the elasticity of money supply with respect to the exchange rate are positive, implying that the monetary authorities increase the interest rate when they observe unexpected increase in the monetary aggregates or exchange rate depreciation. The positive contemporaneous coefficient of the foreign interest rate in the Czech policy functions seems unreasonable as it suggests that monetary tightening abroad induces the CNB to decrease the domestic interest rates. Nevertheless, the estimate is extremely imprecise. The coefficient in the German interest rate in the Polish monetary rule has the right sign.

To summarize, the model's fit is good. The Granger causality restriction restrictions imposed do not invalidate the use of the model in answering the central questions stated in the introduction.

3.2. Impulse Responses to Monetary Policy Shocks

In *Figure 1*, we can observe the estimated impulse responses of both the Czech Republic and Poland over 48 months to one standard deviation negative domestic money supply shock. On both sides of the mean impulse responses lay the 68 percent error bands.[6] The responding variables are named at the left side of each row. The plots in a single row have the same scaling displayed also on the left. On impact of the monetary policy shocks, the short-term interest rate rises immediately and the money supply falls in the two countries. The interest rate response in Poland is statistically significant and lasts for approximately one year. The interest rate is completely subdued to its initial position in the beginning of the second year.

Figure 1 Responses to a Monetary Supply Shock in the Czech Republic and Poland



The solid black lines are estimated Maximum likelihood estimates. The dotted blue lines denote 68 percent error bands.

It is a fact that the interest rate response due to one standard deviation monetary shock in the Czech Republic is significant only for half a year. This could well be a consequence of the currency crises in 1997 and, on the second place, the linear

[6] The error bands are estimated from 1500 posterior distribution draws by the briefly described inference Bayesian method in Appendix B.

approximation of the exchange rate regimes into one. In the Czech Republic due to deflationary pressure the interest rate goes below zero in the beginning of the second year. The fall in money is persistent over much of the 4-year horizon in the Czech Republic, while it is on the border of significance in Poland for the same time. It is also noticeable that the magnitude of the interest rate response in Poland is three times bigger than the one in the Czech Republic, approximately 11 basis points compared to 3 basis points in the Czech Republic.

Having in mind the width of the error bands displayed, we can observe that the contractionary monetary policy shock leads to a smooth and persistent decline in the price level of both countries. The prices tend to increase minimally after the initial shock in Poland, however, this upward movement is insignificant. The prices in the two countries do not converge to their original level over the entire 4-year horizon. Now, let us consider the reaction of the industrial production to the negative monetary policy shock. The output starts declining almost immediately in both countries. The fall of the industrial production in the Czech Republic is statistically significant for the entire displayed horizon without showing any mean reversal tendency. In Poland respectively, the output deviates from its mean original level for slightly longer than two years; consecutively, the mean impulse response returns to the zero line at the end of the 4-year horizon.

Consider next, the dynamic behaviour of the exchange rate over time following the negative monetary shock. The positive innovation in the domestic interest rate relative to the foreign interest rates induces a statistically significant appreciation of both currencies. The point appreciation of the Czech currency has a one-and-a-half-times larger magnitude than that of the initial rise of the Czech interest rate; in Poland, the magnitude of the zloty appreciation equals the initial domestic interest rate innovation. After the initial appreciation, in approximately a quarter period, the two currencies start quickly and significantly depreciating, before landing back to their original levels in three quarters for the Czech Republic and in six quarters for Poland.

On the whole, the impulse responses in both countries to a contractionary monetary policy shock are broadly satisfactory and comply with the standards set by the analytical Mundell-Fleming-Dornbusch model (Rogoff 2002), the empirical literature for developed countries Cushman and Zha (1997), Kim (2002), Kim and Roubini (2000) and the empirical studies on developing countries and emerging markets Del Negro and Obiols-Homs (2001), Jarociński (2004), Maćkowiak (2003) and Maliszewski (2002). It was elucidated that, in the short run, it is the real interest rate rise and money supply contraction that adversely affected the economy. The positive interest rate differential between domestic and foreign interest rate leads to the appreciation of the domestic currency ('overshooting'), which is followed by fast depreciation driving the exchange rate to its initial position. There is no significant long lasting appreciation detected that would be contradictory to the *uncovered interest rate parity* condition. In the long run in Poland, the money supply and arguably the price level and the output went back to their initial position before the negative monetary shock took place. Thus, both the short run and the long run results seem credible for the small open economy.[7] In the long run in the Czech Republic, the output never returns to its initial pre-shock position. This phenomenon undermines either my linear approximation policy rule or the theory of the non-neutrality of money. Because of the complexity of the transition period in the Czech Republic, it is difficult to judge which of these two facts takes precedence over my presumably flawed results.

It is interesting to observe how my results on the monetary policy transmission compare with the two analogous studies on the Czech Republic and Poland: Jarociński (2004) and Maliszewski (2002). Of special interest is whether the inclusion of money has significant influence on recovering the monetary policy effects on inflation and output. A direct comparison is nevertheless difficult because of the different assumptions each of the two studies make. Broadly, my estimates of the monetary policy effects on inflation and output are very similar with the results of Jarociński (2004) and Maliszewski (2002), both point estimates as well as error bands. Probably, the most obvious difference is that the response of output in my model is with 0.001% smaller in the short and in the long runs compared to the other two papers. Second, the inflation responses in Jarociński's paper cast doubt for the presence of the price puzzle in his estimates. Conversely, I do not detect a price puzzle in my estimates.

3.3. Impulse Responses to Foreign Interest Rate Shock

In *Figure 2*, I elaborate on the effects of the German interest rate shocks on the workings of the Czech and Polish economies.[8] I use the model previously explained and estimated, and report the reaction of the domestic variables to a one standard deviation positive German interest rate shock. A few words before proceeding to the results are necessary. The included foreign block in my model is much smaller than analogous foreign blocks in the small open economy literature. Therefore, I inevitably miss to account for variables that do have an enormous effect on the small economies. By including the German interest rates in my system, I account for the German as well as partly for the world's monetary tightening. Depending on the monetary policy rule of the

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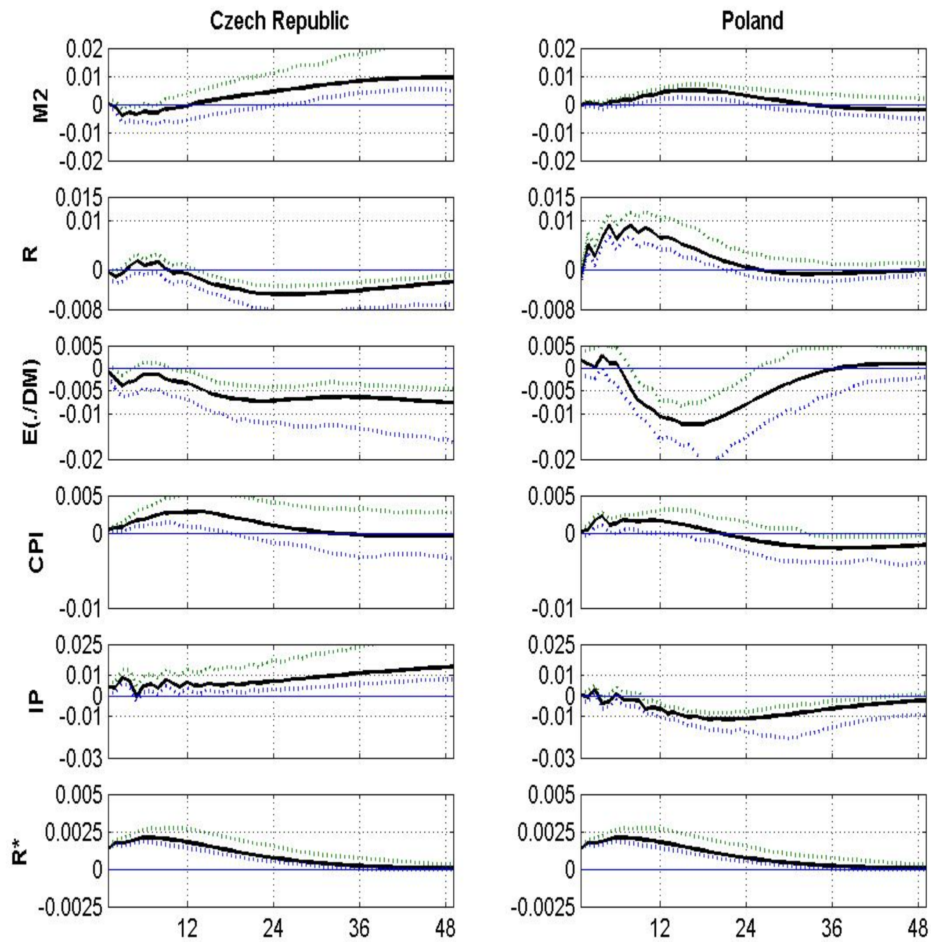
[7] Further, to check the robustness of the identified impulse response functions, I estimated a model with first, all-commodities world prices and second, the US interest rate included additionally in the foreign block. It is natural to suspect that the CNB and NBP scrutinise a large array of world variables when fulfilling their ultimate price stability goal and the inclusion of the world prices and US interest rate in my model, separate or altogether, comes quite naturally. The impulse response functions to the contractionary monetary shock with the two additional variables included did not change qualitatively. All these exercises naturally support the assumption that my model manages first, to identify a monetary policy shock and second, to estimate consistent with the theory responses of the macroeconomic variables in my model to it.

[8] Since I have only one variable in my foreign block, one should be careful about the interpretation of the foreign interest rate shock, especially in regard to the production sector, which was not given any interpretation. After some contemplation, one can figure out that changes in world output, for example, are inevitably fed in the output and the price equations, provided that no variables were introduced to account for these change. This remark is even more meaningful with respect to the variance decompositions later discussed. Therefore, it seems more natural to say that the included foreign variable represents the stance of the world economy, rather than the German monetary policy with respect to the domestic output and price.

Bundesbank and subsequently the ECB, I can capture additionally some international inflationary pressure in my estimation. Nevertheless, the information, from the six variables included, can be insufficient for obtaining answers regarding the behaviour of domestic output, for example. The economies of the Czech Republic and Poland have gone through large transformation in the last 15 years. Further, the Czech Republic went through a currency crisis in 1997. Altogether, the existence of all these conditions makes it difficult to gauge the effects of foreign innovations to the domestic economy, especially in the case of Czech Republic. Tempted by suspicion on my whole identification approximation, I tried incorporating world price commodity index as well as US interest rate in the overidentified model; however, the results delivered from the bigger model did not change enough to prefer it with respect to the benchmark one.

Figure 2 Responses to a German Interest Rate Shock in the Czech Republic and Poland



The solid black lines are estimated Maximum likelihood estimates. The dotted blue lines denote 68 percent error bands.

In the Czech Republic, with the increase of the German interest rate, we observe immediate appreciation of the koruna. The appreciation is significant for the entire plotted period. The response of the Czech interest rate to the tightening abroad is slow increase and smooth reversal shortly after. Because of the rise of domestic interest rate, the money aggregate decreases very slightly on the market. That is, we hardly observe strong domestic tightening. Usually, an inflationary effect at home is transmitted via exchange rate depreciation. In the absence of any depreciation, change of Europe's equilibrium prompted by the German monetary tightening, seems the plausible explanation for the channelled price level increase in the Czech Republic. The size of the inflation is, though, tiny. On impact of the German interest rate shock, the output starts increasing. As a whole, the described variables' responses are greatly disturbing and, further, difficult to justify. Firstly, the behaviour of the exchange rate contradicts the common sense regarding the relationship between foreign interest rate and domestic currency. Secondly, hardly is there any answer to - how persistent monetary tightening abroad and at home brings about long-lasting output increase.

In Poland, to avoid currency depreciation, the NBP increases the domestic interest rate. The response is persistent and in several months four times bigger compared to the magnitude of the foreign interest rate increase. Due to the response of the Polish central bank, the exchange rate remains approximately at the zero line for some time, before appreciating, mainly because of the strong overreaction to the foreign shock. It is not surprising that prices increase, provided that the Polish bank is inflation and depreciation averse. The combination of monetary contraction (if we can treat the foreign interest rate increase as contraction), both abroad and at home, together with appreciating domestic currency result in persistent and not trivial output fall over the 4-year time horizon.

To summarize, the results for Poland are consistent with conclusions drawn from the literature on both developed and developing small open economies. In contrast, drawing conclusions from the impulse responses about the Czech economy when hit by a foreign shock is mildly to say problematic. One reason for such incoherence is the inability of my identification to address the manifold aspects of the disturbances that accompanied the transition process in the Czech Republic. I speak in *Appendix A* about the liberalization of the financial and capital markets in the country; this phenomenon together with the improved county's risk rating and the ongoing privatisation have streamed enormous amount of capital inflows into the Czech market. The inability of the CNB and the fiscal authorities to respond timely on the expanding domestic demand obviously results in external balances that are reflected in *Figure 2* (Böhm and Źdárský (2005)). Inspecting closely the data, I discovered that there has been huge appreciation pressure on the koruna in the periods 1995-1997 and 1999-2002; that is, the ensuing monetary tightening during the EU recession in 2002 hardly eased the Czech currency. Having this in mind, I can assert why the foreign shock identification comes at odds in my six-variable model. I do not have sufficiently long and stable data sample to uncover completely the effects of foreign disturbances on the economy of the Czech Republic.

However, if in my estimation I discard the problematic periods in my data sample, I would have no degrees of freedom to draw whatever a conclusion.

3.4. Sources of Domestic Variables Fluctuations

In *Table 4,* I display the portion of the forecast error variance of the exchange rate, the price level and the output attributable to exchange rate, interest rate and German shocks, for the Czech Republic and Poland. At the upper part of the table, the horizons at which the forecast errors were estimated are denoted. To account for the uncertainty associated with the Maximum Likelihood estimates of the forecast errors, the 16th and 84th percentiles of the posterior around the estimates are reported.

Table 4. Forecast error variance decomposition of the output, the price level and the exchange rate due to the exchange rate, interest rate and foreign shocks

Shocks \ Months	**1**	**12**	**24**	**48**
The Czech Republic				
1) Variance decomposition of the output				
Foreign shock	2.35	18.9	24.9	46.1
5th and 95th percentiles *	0.34 8.11	9.65 41.8	11.2 56.7	22.5 74.3
Exchange rate shock	0.00	3.34	4.25	4.60
5th and 95th percentiles	0.00 0.00	2.91 7.56	2.96 9.02	1.53 7.25
Interest rate shock	0.00	3.97	8.62	11.76
5th and 95th percentiles	0.00 0.00	1.01 9.43	3.54 15.71	3.84 20.02
2) Variance decomposition of the price level				
Foreign shock	2.70	20.45	22.92	14.74
5th and 95th percentiles	0.44 5.96	6.58 36.6	8.29 42.6	9.67 42.73
Exchange rate shock	0.00	24.43	19.69	15.76
5th and 95th percentiles	0.00 0.00	12.28 33.53	7.89 26.46	5.23 24.03
Interest rate shock	0.00	4.65	8.17	23.2
5th and 95th percentiles	0.00 0.00	0.82 13.47	0.9 17.02	4.19 30.64
3) Variance decomposition of the exchange rate				
Foreign shock	0.22	8.73	34.0	51.81
5th and 95th percentiles	0.08 4.34	4.40 33.43	19.35 50.23	30.58 65.42
Exchange rate shock	85.12	66.42	32.09	17.12
5th and 95th percentiles	63.29 91.18	32.61 61.96	17.65 37.25	8.58 23.61
Interest rate shock	7.89	15.45	22.72	15.15
5th and 95th percentiles	6.4 27.52	4.40 29.30	9.54 28.48	6.43 20.97
Poland				
1) Variance decomposition of the output				
Foreign shock	0.03	14.47	56.83	67.84
5th and 95th percentiles *	0.02 2.21	8.16 26.78	33.99 68.12	37.27 79.21
Exchange rate shock	0.00	2.95	1.67	1.41
5th and 95th percentiles	0.00 0.00	2.11 7.86	1.19 6.13	0.86 6.78
Interest rate shock	0.00	4.17	2.88	2.21
5th and 95th percentiles	0.00 0.00	2.47 9.50	1.44 8.27	0.96 7.66
2) Variance decomposition of the price level				
Foreign shock	0.10	14.83	16.67	31.95
5th and 95th percentiles	0.07 3.06	4.62 31.47	7.32 35.42	14.04 59.94
Exchange rate shock	0.00	2.50	7.64	9.38

5th and 95th percentiles	0.00	0.00	1.11	6.60	1.63	15.08	1.84	15.62
Interest rate shock	0.00		2.19		5.67		6.96	
5th and 95th percentiles	0.00	0.00	1.16	6.83	1.38	13.05	1.37	13.47
3) Variance decomposition of the exchange rate								
Foreign shock	0.65		15.21		46.90		49.24	
5th and 95th percentiles	0.04	3.44	6.42	27.73	15.84	60.57	23.40	69.71
Exchange rate shock	69.63		37.57		22.57		21.40	
5th and 95th percentiles	51.27	86.38	19.61	47.16	11.51	33.16	8.83	29.41
Interest rate shock	16.76		23.55		14.44		13.71	
5th and 95th percentiles	2.12	35.41	6.93	32.86	5.39	22.66	4.30	20.12

* The 16th and 84th percentiles of the posterior (smaller size numbers) are estimated from 1500 posterior distribution draws of the inverted Wishart and Normal Distributions.

Despite not being sharply determined, the estimated variance decompositions allow us to draw the following conclusions. First, at the short horizon, fluctuations in output and prices are generated due to movements in the domestic production sector; while in the long horizon, output and price fluctuations are attributable to a large extent on foreign influence.[9] Quantitatively, my variance decomposition estimates for Poland regarding price level and output fluctuations are very similar to those of Maćkowiak (2005). The analogous estimates for the Czech Republic are smaller in size than the respective variance decomposition numbers provided by Maćkowiak. Given that the Czech Republic is a small and open to trade country, we would have expected larger foreign influence on the domestic market. Again, this fact reminds us to be cautious when interpreting the results for the Czech Republic. Second, in consensus with the conventional wisdom, the monetary policy shock's contribution in explaining output movements is about 11.7 percent at the point peak. This result is consistent with the structural VAR literature's finding that monetary policy shocks are not the dominant source of output fluctuations, both for developed and developing countries. Third, foreign shocks explain much of the fluctuations of the exchange rate, both in the short and in the long run. Monetary policy shocks have also a sizeable influence on the exchange rate dynamics, though smaller compared to the influence of the foreign shocks.

4. Monetary Policy Functions

In the following section, I assess whether the estimated Czech and Polish policy reaction functions could be regarded as the behaviour of the monetary authorities. Without any doubt, the central bank authorities observe much broader set of information than the one introduced in my model. Further, their job is much more complicated than running several regressions and then taking decisions dependent on the form of their loss functions and the results of the regressions. Nevertheless, we can try to approximate the monetary authority's conduct in its crudest shape through a highly condensed form of reality as my model is meant to be. The approximation is given by the second equation

[9] See Maćkowiak (2003) for the influence of the U.S. States monetary authorities on the emerging markets through an explicitly identified U.S. States monetary policy function.

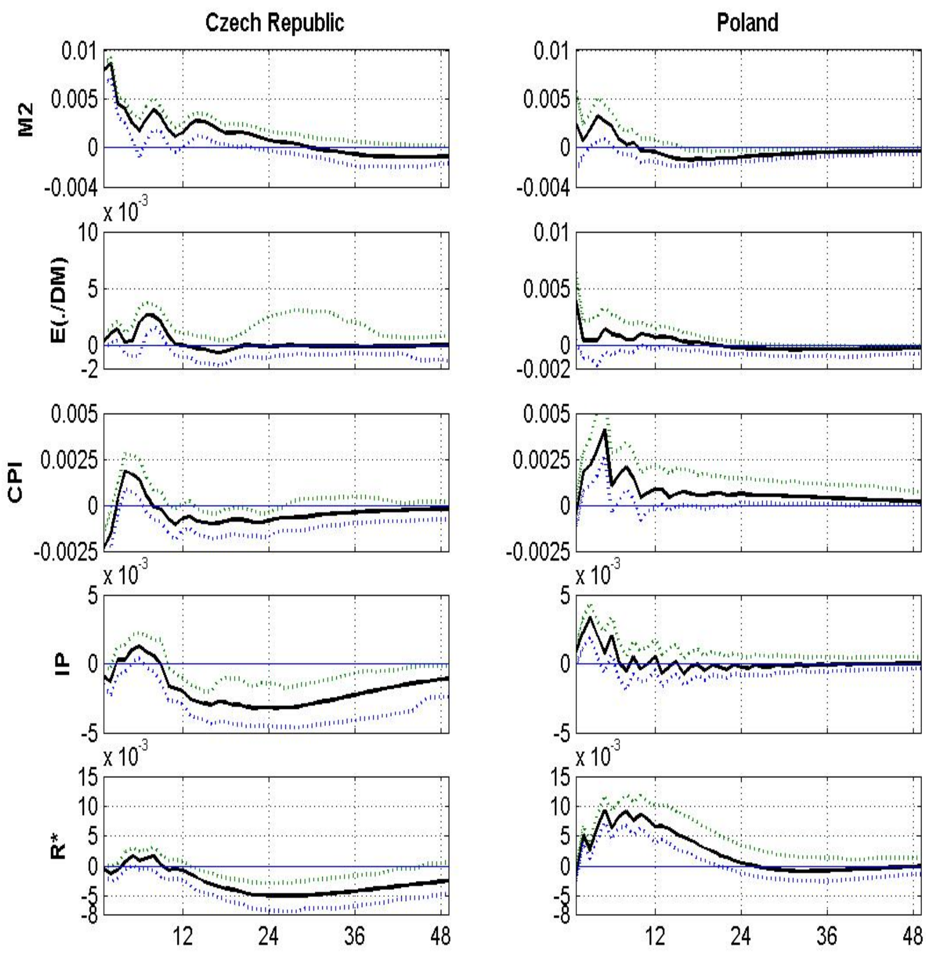
for the domestic block in (4). That is, the monetary authority is believed to set the interest rate after examining the current values of money, exchange rate and German interest rate as well as the lagged values of each one of the variables in the structural system. Generally, it is impractical to look at all the coefficients in this equation and meanwhile care about the uncertainty each single coefficient brings about when trying to define the behaviour of the monetary policy. A much easier exercise is to examine the changes of the interest rate over time in response to variations in the other variables. Following Kim (2002), in *Figure 3*, I report how the authorities influence the policy instrument over time related to its steady state, to a one percent increase of each variable from its steady state. Again, the mean impulse response functions are plotted together with their respective 68 percent error bands over 4-year horizon. The variable names are given on the left side in the figure.

In the Czech Republic, the CNB increased the interest rate with one basis point to one percent depreciation of the koruna. Within 3-4 months, the bank further increased the interest rate with 2 additional basis point nevertheless the interest rate trend was soon reversed. The CNB reacted to one percent upward move of the price level by increasing the interest rate in five months to two basis points. The monetary authority did not react immediately to the price level increase, which could be interpreted as forward-looking price stabilization. This implies that the CNB responds to expectations of future price level increases, not to contemporaneous ones. The mean interest rate response to consumer prices drops below the zero line afterwards, remaining generally significant for one and a half year. There is not much evidence on output counter-cyclical measures exercised by the CNB. On the whole, the central bank increased interest rate to 1.5 basis points in 4-5 months after one percent increase in output; nonetheless, the interest rate was soon decreased even below the zero line. Further, the CNB increased the interest rate in reaction to an upward change in the *M2* monetary aggregate. The response is significant and persistent for approximately two years. It is difficult, however, to determine the reason for the response to money, provided that excess liquidity on the market can lead to exchange rate depreciation, inflation or both. The Czech central bank increases the interest rate with a short lag following a German interest rate upward move. The response is significant for approximately six months.

In Poland, we find nontrivial and persistent interest rate rise following increase of the German interest rate, exchange rate depreciation and increase in the monetary aggregates. There is evidence on output stabilization, since the reaction to the industrial production is statistically significant in spite of being of a small magnitude. The interest rate response to inflation dynamics, despite being small and lagged, is statistically significant for the whole horizon.

To conclude, the estimated reaction functions illustrate that the two central banks were both very responsive to exchange rate depreciation as well as monetary aggregate climb. The result that the monetary policy responds significantly to domestic currency movements is additionally supportive of the claim that exchange rate has dominant role in the monetary transmission mechanism. In particular, the NBP seems to have followed closely the behaviour of the German Bundesbank. The unsatisfactory response of the Czech interest rate to a German interest rate increase is marred by transition uncertainties prevalent in the transition country. Otherwise, the results are consistent with previous studies on the monetary reaction function of developed countries. The estimated policy functions of the French and Danish Banks by Kim (2002) are qualitatively similar to the ones I find in my study on the behaviour of the Czech and Polish monetary authorities.

Figure 3 Estimated Full Monetary Reaction Function in the Czech Republic and Poland



The solid black lines are estimated Maximum likelihood estimates. The dotted blue lines denote 68 percent error bands.

5. Conclusion

In this paper, I applied a small open economy structural VAR model to investigate the effects of the Czech and Polish monetary policies on their economies in the transition period. The proposed identification is quite appealing because of its viability: (i) to distinguish between money supply and money demand shocks (ii) to allow the foreign block in the model being unresponsive to fluctuations in the domestic block. The results suggest the insignificant role of the monetary policy for the fluctuations of the output in the long run. The non-trivial importance of the exchange rate in explaining price level fluctuations, on one hand; and the significant monetary reaction to exchange rate and foreign interest rate movements, on the other; emphasizes the exchange rate as a significant transmission mechanism. The huge fraction of the movements in the two developing countries explained by foreign disturbances is coherent with results of papers related to the significance of spill-over effects between both developed and developing countries.

The odd findings about the foreign influence on the working of the Czech economy question my model's identification as well as my assumption that I can approximate the different policy regimes in the transition period in a single policy rule about this country. To address these problems I will consider developing models nesting time-variant coefficients as well as wider range of priors in my future work.

Appendix A: Monetary Policy in Transition

A.1. Initial Conditions

Many readers are presumably not acquainted with the monetary framework in the Czech Republic and Poland during the central planning regime. Even if they are, several words on the monetary policy at that time are going to inevitably sharpen the outlines of the departure of the policy nowadays from the monetary model in the previous regime. The proposed description is a very rough simplification, as going into details is not the intent of my paper.

Like in every other country where planning was exercised on a central level, financial markets played hardly any role for distributing the scarce recourses.[10] The central planner allocated production targets to companies, which were funded by the central bank in order to execute their jobs. Central banks had little autonomy and followed the decisions of the governments. Thereby, the interest rate did not have its market role as the price of the credit simply because the state credit was rationed mainly on the state's plans. Except for the household decisions, money was not regarded as anything different than a unit for accountancy. The structure of the financial system was rudimentary. Bank deposits, currency and occasionally government bonds represented the assets available on the financial markets. The monopolistic banking system was known as monobank system, because all banks were owned by the central bank, respectively by the state, and were not autonomous in their policies. The instruments for monetary control were credit ceilings and interest rate ceilings. No foreign exchange rate market present and foreign exchange rate controls imposed, on both capital transactions and current account transactions, made the domestic currency basically nonconvertible.

The major element of the transition in the two countries was the creation of a two-tier banking system out of the former state banks. In Czechoslovakia, the socialist central bank was divided into a two-tier system shortly after the change of the regime in 1989. The loan portfolio of the former state bank was inherited by the largest of the newly founded commercial banks.[11] In 1993, Czechoslovakia separated into two independent countries, the Czech Republic and the Slovak Republic. The Czech National Bank (CNB) was founded, out of the split Czechoslovak National Bank, and bestowed the traditional role of a central bank (Act No. 6/1993 Coll).[12] Respectively, the number of commercial banks decreased in both countries. The old socialist banking system in Poland was also dismantled immediately after the fall of the old regime. The central bank act of the National Bank of Poland (NBP) that originated in the late 1980s was replaced in 1997.[13] The regional offices of the NBP were given the statute of commercial banks, each active in the region where it operated. Additionally, four state banks with

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[10] Slovenia was an exclusion from the case since the country conducted a policy named market socialism.
[11] For details, see Kutan and Brada (2000).
[12] The Act on the Czech National Bank; source: http://www.cnb.cz/en.
[13] The Act on the National Bank of Poland; source: http://www.nbp.pl.

specialized functions were transformed into commercial banks. The central bank acts of the two countries explicitly accorded the two central banks a scope for independence from other institutions. The Acts have been amended several times after their enforcement and generally demonstrate convergence to the requirements of the Maastricht Treaty (Krzak and Schubert (1997)).

Despite differences in the initial conditions and in the aspects of policies implemented, both Czech Republic and Poland experienced close similarities in their course towards disinflation and macroeconomic stabilization. Kutan and Brada (2000) emphasize that the two countries embarked on the process of transition with unrealistic prices and exchange rates, and open or repressed inflation. To enhance the competitiveness of their economies, the authorities set the initial nominal exchange rates at levels well below the believed market ones, expecting that in any case the rates would reach their realistic levels on the way to joining the EU. Regardless of existing variances in the formulation of the ultimate central banks' goals, the essence of these goals was price stability. Further, the first three years of transition were also the period of building the necessary infrastructure for open market operations. It is clear from the description of the communist regime that such infrastructure did not exist at the outset of the transition. Krzak and Schubert (1997) describe extensively the success of the infrastructure building and its role in making the open market operations the most important monetary instrument.

A.2. Monetary and Exchange Rate Policy in the Czech Republic

In the beginning of the transition, the policy-makers, both in the Czech Republic and in Poland, were in favour of rigid exchange regimes (see *Table 5* and *6*). After the split of the Czechoslovak Federation in 1993, the Czech koruna was pegged to a basket composed of Deutsche Mark and U.S. Dollar. Given that Germany and U.S. America were known for their long record of successful inflation combating; the objectivity behind the pegging was the attraction of foreign capital, inflation reduction by fixing of domestic prices to foreign goods and transparency of pegging as a policy anchor. Except for targeting the exchange rate, the monetary authority in the Czech Republic had an intermediate policy target as well. The monetary aggregates, mainly M2, were the second policy objective and had to be adjusted accordingly. Nevertheless, the bank did not adhere strictly to its intermediate targeted paths, facing significant uncertainties about the behaviour of money demand at that stage (Maliszewski (2002)).

Several months after the liberalisation of prices, the rate of inflation decreased to almost 10 percent. After 1994, the high nominal interest rate, the exchange-rate peg and the ongoing privatisation were seductive to large amounts of capital inflows. Because of the massive inflows, the CNB was compelled to go into massive and costly sterilizations. Except for a short while, the widening of the tolerance bands to +/-7.5 percent in 1996 did not produce the desired effect of impeding the capital inflows. The combination of tight monetary policy and loose fiscal policy exacerbated further the situation. The results were high interest rates, non-decreasing inflation and continuous liquidity growth. A speculative attack on the koruna in May 1997, generated by the Asian crises, emphasized the untimely strategy of the CNB in addressing the inflexibility of the hard peg. After giving up the peg and taking appropriate measures against a further sharp devaluation in the domestic currency, the CNB witnessed a regain of the koruna's loss in the first half of 1998.

Table 5. Exchange Rate Regimes in the Czech Republic

	Exchange Rate Regime (Classification)*	Currency Basket	Tolerance Band
Sept. 1, 1990 – Dec. 31, 1993	hard peg (3)	DM 100%	+/- 0.5%
Jan. 1, 1994 – Feb. 29, 1996	hard peg (3)	DM 65%, USD 35%	+/- 0.5%
March 1, 1996 – May 26, 1997	soft peg (4)	same	+/- 7.5%
May 27, 1997 - present	managed float	-	-

* The exchange rate classification number is based on the "fine course" determined by Rogoff et al., 2003, p. 55, and it ranges from the least flexible, class 1, to most flexible exchange rate arrangements, class 13.
Source: Orłowski (2005).

After the exit from the peg, the CNB decided that future monetary programs would be created on the basis of inflation targeting. The purpose was to provide a transparent nominal anchor that could be directly manipulated with the monetary policy toolkit and to regularly present information to the public about the undertaken measures and achieved goals. The CNB needed policy credibility and the inflation targeting materialized a promise to achieve it. However, the introduction of direct inflation targeting calls for a model on the economy, which can disclose important statistical relationship between monetary policy instruments and other macroeconomic variables, for example inflation. Such a model then enables the policy-makers to take the right interest rate decisions leading to hitting the inflation target (Jonas and Mishkin (2003)). Because of the parameter uncertainties in such models due to short time-series and sweeping changes in the transition period, there were voices raised in favour of a more flexible inflation targeting framework.[14] Nevertheless, in 1998 the CNB announced a policy of DIT in its strict form. Orłowski (2005) claims that for that period *"a firm commitment to disinflation embodied in the early strict variant of DIT was critical for the indisputable success of the new policy, in spite of numerous technical difficulties in its formulation and implementation."*

In searching for the policy inflation target, the CNB introduced the concept of net inflation index defined as a rate of increase in consumer prices excluding administered and regulated prices as well as the impact of indirect tax increases. In this form, the index was highly controllable by the bank, however, not so transparent to the public.

[14] Svensson (1999) made the distinction between strict and flexible variants of the direct inflation targeting (DIT). A flexible inflation targeting is defined as one, which aims at achieving specific levels of other macroeconomic variables except that of inflation, given that inflation targeting does not conflict with the latter goals.

There were later modifications of the DIT framework: first, making the objective target more forward-looking and second, replacing the net inflation index target with the consumer price index. By 2002-2003, the price stability was achieved and the CNB started considering increasing the flexibility of the DIT framework. Since January 2005, the inflation target was set to 3 percent headline inflation without any specified tolerance bands.

A.3. Monetary and Exchange Rate Policy in Poland

The outset of the stabilization in Poland did not start under the same favourable conditions as those found in the Czech Republic. In 1989, the inflation went above 50 percent per month and the government deficit peaked at nearly 8 percent of the GDP (Kutan and Brada (2000)). Devaluation of the zloty from 5560 zl/USD to 9500 zl/USD and the pegging of the currency at the latter rate were one of the main elements of the undertaken stabilization measures. Conversely to expectations, neither was the inflation tamed, nor the acceleration of the output growth observed. Subsequently, the hard peg was abolished and the zloty was pegged to a basket of currencies. Alike CNB, the National Bank of Poland defined the broad money growth as its intermediate monetary target without strictly holding on to the broad money growth rule. Although the government borrowing from the NBP was formally restricted, 40 percent of the fiscal deficit in 1992 and in 1993 and 30 percent of it in 1994 was financed by the NBP Maliszewski (2002). The large foreign capital inflows in 1995 and the subsequent monetary expansion compelled the NBP to widen the tolerance crawling peg band to +/-7 percent. The central bank act published in 1997 eliminated the possibility of direct lending by the NBP to the government, granting the bank the necessary independence to achieve its ultimate goal, which is derived from the Maastricht Treaty.

Table 6. Exchange Rate Regimes in Poland

	Exchange Rate Regime (Classification)*	Currency Basket	Tolerance Band
Jan. 1, 1990 – May 17, 1991	hard peg (2)	9500 PLZ/USD	-
May 17, 1991 – Apr. 30, 1993	crawling peg (5)	USD	+/- 1%
May 1, 1993 – May 15, 1995	crawling peg (5)	5-currency basket	+/- 1%
May 16, 1995 – Feb. 24, 1998	crawling band (9)	basket	+/- 7%
Feb. 25, 1998 – Dec. 31, 1998	crawling band (9)	basket	+/- 10%
Jan., 1999 – Apr. 11, 2000	crawling band (9)	basket	+/- 15%
April 12, 2000 - present	free float	-	-

* The exchange rate classification number is based on the “fine course” determined by Rogoff et al., 2003, p. 55, and it ranges from the least flexible, class 1, to most flexible exchange rate arrangements, class 13.

Source: Orłowski (2005).

The international financial turmoil in 1997 and in 1998 did not create the enormous pressure on the zloty that was exerted meanwhile on the koruna. Nevertheless, the system with soft pegs and crawling devaluation was unable to address the inflation problem that was prevalent in Poland even at the end of the 1990s. Under the rule of the Monetary Policy Council (MPC), one of the directing bodies of the NBP established in 1998, as of January 1999, inflation targeting was declared the new monetary policy strategy. In contrast to the CNB, the NBP started targeting the headline consumer price index from the very beginning of the DIT. Further, to make its medium term goals public, the MPC announced its targeted inflation rate of 4 percent for the end of 2003. Because of the conflict between DIT and crawling band system, the NBP widened the bands to 15 percent in March 1999. In April 2000 the polish currency was let floating. After several interest rate increases in 2000, the strategy of disinflation bore its fruits in 2002-2003. Since the beginning of 2004, the NBP has pursued a continuous inflation target at the level of 2.5 percent with +/- 1 percent tolerance bands around that level.

Appendix B: Inference Technique

Since the estimation of the foreign block is straightforward, I skip it from further discussion without any loss of generality. From equation (1) and (4), it is obvious that the likelihood function for the domestic block is proportional to:

$$\left(\prod_{t=1}^{T}|A_{11}(0)|\right)\exp\left[-\tfrac{1}{2}trace\left(\sum_{t=1}^{T}(y'_t-x'_t\,B_1)'(y'_t-x'_t\,B_1)\right)\right]$$

$$\propto\left(\prod_{t=1}^{T}|A_{11}(0)|\right)\exp\left[-\tfrac{1}{2}trace\left(S_1(\hat{B}_1)A_{11}(0)'A_{11}(0)\right.\right.$$

$$\left.\left.+\sum_{t=1}^{T}\left(B_1-\hat{B}_1\right)x_{1t}x'_{1t}\left(B_1-\hat{B}_1\right)A_{11}(0)'A_{11}(0)\right\}\right], \tag{8}$$

where

$$y'_t\equiv\left[y'_{1t}\quad y'_{2t}\right],\quad x'_t\equiv\left[y'_{1t-1}\,..\;\;y'_{1t-p}\quad y'_{2t-1}\,..\;\;y'_{2t-p}\;1\right],$$

$$B_1\equiv\left[-B_{11}(1)'..\;\;-B_{11}(p)'\;\;-B_{12}(1)'..\;\;-B_{12}(p)'\;\;k_1\right],$$

$$\hat{B}_1=\left(\left(\sum_{t=1}^{T}x_{1t}x'_{1t}\right)^{-1}\left(\sum_{t=1}^{T}x_{1t}y'_{1t}\right)\right),\quad S_1(\hat{B}_1)=\sum_{T=1}^{T}\left((y'_{1t}-x'_{1t}\,\hat{B}_1)'(y'_{1t}-x'_{1t}\,\hat{B}_1)\right). \tag{9}$$

Fact. Under the diffuse prior $|A_{11}(0)|^{k1}$ *on the parameter space* $(A_{11}(0),B_1)$*, the joint posterior distribution of these parameters can be expressed as:*

$$L(A_{11}(0),B_1)=p(A_{11}(0))\,p(B_1|A_{11}(0)), \tag{10}$$

where

$$p(A_{11}(0))\propto|A_{11}(0)|^{T}\exp\left[-\tfrac{1}{2}trace\left(S_1(\hat{B}_1)A_{11}(0)'A_{11}(0)\right)\right], \tag{11}$$

$$p\left(vec(B_1)\middle|A_{11}(0)\right)=\varphi\left(vec\left(\hat{B}_1\right),\left(A_{11}(0)'A_{11}(0)\right)^{-1}\otimes\left(\sum_{t=1}^{T}x_{1t}x'_{1t}\right)^{-1}\right), \qquad (12)$$

and k_1 *is the number of estimated coefficients in the equations of the first block .*

The term in (11) is the marginal posterior distribution of $A_{11}(0)$*; (12) is the conditional distribution of* B_1 *given* $A_{11}(0)$*. The conditional distribution is normal with mean* $vec\left(\hat{B}_1\right)$ *and variance the second term of the normal p.d.f.* $\varphi()$ *in (12). The value of* A_{11} *at the peak of its marginal posterior density is the ML estimate.*

The described fact is a replication of Theorem 1 in Zha (1999). It gives us an algorithm to compute the maximum likelihood estimates of the model and the error bands of the impulse response functions. With the non-recursive exactly identified structure on $A_{11}(0)$, there is a one-one mapping between $A_{11}(0)$ and Σ_{11} displayed in (6). Converting the structural covariance matrix into a matrix of structural parameters involves solving a system of non-linear equations due to the non-recursive structure of $A_{11}(0)$. Under the Jeffreys prior on the covariance matrix, the marginal density of Σ_{11} is of an inverse-Wishart form and Σ_{11}^{-1} has the following Wishart distribution:

$$Wishart(S_1^{-1}(\hat{B}_1))\text{, with } (T-(np+n_2+n)) \text{ degrees of freedom.} \qquad (13)$$

Thus, the usual two-step inference is carried on in the following order: first, generate Monte Carlo samples of Σ_{11}^{-1} from the inverse-Wishart distribution and then convert the drawn Σ_{11}^{-1} back to $A_{11}(0)$ as postulated in (6); second, sample B_1 from Gaussian distribution, conditional on the drawn $A_{11}(0)$. Finally, one is able to translate the generated samples of A_{11} and B_1 into samples of structural parameters and impulse responses.[15] From the samples of the impulse responses, one is able to calculate their respective error bands. The error bands that I display throughout this paper correspond to the 16th and 84th percentiles of the posterior. The error bands have the standard Bayesian interpretation that the dynamic responses could be detected between them with 68 percent probability, given the data sample.

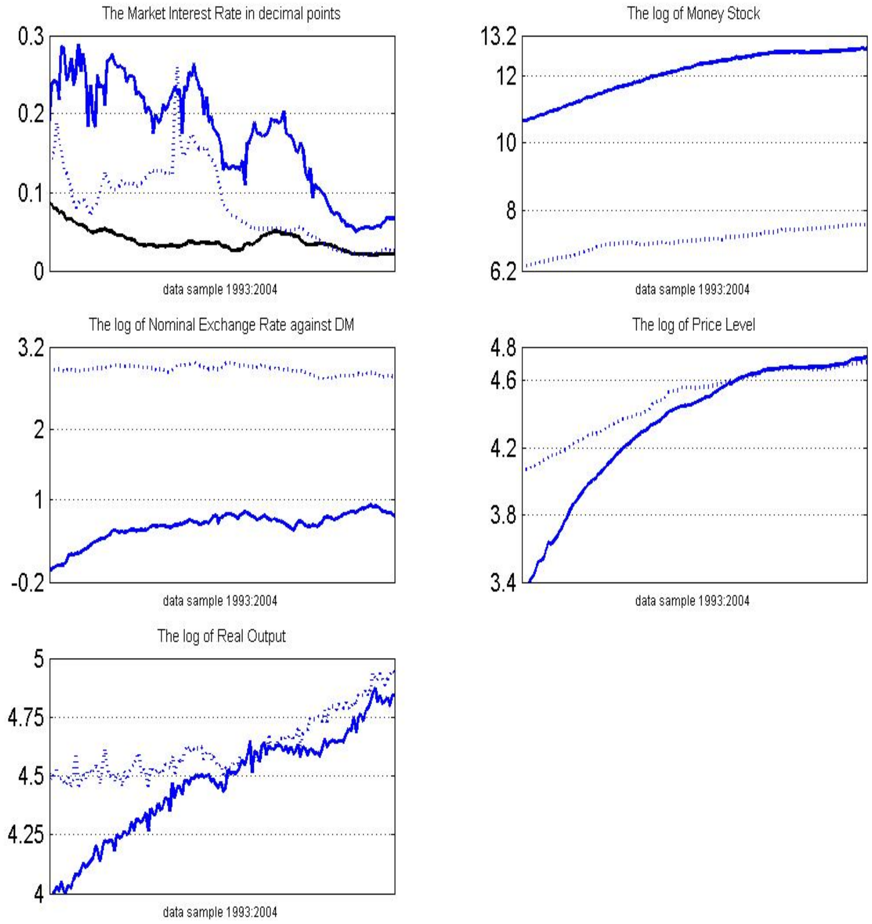
[15] The technique for generating draws from an inverse-Wishart and Gaussian distributions is described in Appendix B in Bauwens, Lubrano and Richard (1999). Following Sims and Zha (1998a), the use of the diffuse prior on $A_{11}(0)$ matrix, in the reduced form, translating into a flat on $A_{11}(0)$ in the structural parameter space, is meant to make the marginal posterior p.d.f. on the same matrix proportional to its concentred likelihood, thereby getting rid of differences between posterior modes and ML estimates.

Appendix C: Data Description

The data used is described in detail here. The data is monthly and respectively extracted from two sources: Deutsche Bundesbank (DB), International Financial Statistics (IFS) databases. Respectively, the identifier for each series is given in the parenthesis. The industrial production, the money aggregate and the price index data are seasonally adjusted by the X-12-ARIMA module of *Demetra*.

	Foreign Block
R*	Money market rates reported by Frankfurt banks / Three-month funds / Monthly average: (DB, su0107);
	The Czech Republic
M2	Czech monetary aggregate M2: (IFS, 93535L..ZF...);
R	Czech money market rate: (IFS, 93560B..ZF...);
E(kr/DM)	Nominal Czech exchange rate against the Deutsche Mark calculated from: nominal Czech exchange rate against the US Dollar – (IFS, 935..RF.ZF...) and nominal Deutsche Mark against the US Dollar – (IFS, 134..RF.ZF...);
CPI	Czech consumer price index: (IFS, 93564...ZF...);
IP	Czech industrial production: (IFS, 93566..CZF...);
	Poland
M2	Polish monetary aggregate M2: (IFS, 96435L..ZF...);
R	Polish treasury bill rate: (IFS, 96460C..ZF...);
E(zl/DM)	Nominal Polish exchange rate against the Deutsche Mark calculated from: nominal Polish exchange rate against the US Dollar – (IFS, 964..RF.ZF...) and nominal Deutsche Mark against the US Dollar – (IFS, 134..RF.ZF...);
CPI	Polish consumer price index: (IFS, 96464...ZF...);
IP	Polish industrial production: (IFS, 96466...ZF...).

Figure 4 All the data series of the Czech Republic and Poland for the period from January 1993 until December 2004 plotted



The solid black line is the German data. The dotted blue lines are the Czech data series. The solid blue lines are the Polish data series.

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