# THE EFFECTS OF MONETARY POLICY IN THE CZECH REPUBLIC: AN EMPIRICAL STUDY

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# The Effects of Monetary Policy in the Czech Republic: An Empirical Study*

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**Abstract**

In this paper, we examine the effects of Czech monetary policy on the economy within VAR and the structural VAR framework. Subject to various sensitivity tests, we find that contractionary monetary policy shock has a negative effect on the degree of economic activity and price level, both with a peak response after one year or so. Regarding the prices at the sectoral level, tradables adjust faster than non-tradables, which is in line with microeconomic evidence on price persistence. There is a rationale in using the real-time output gap instead of current GDP growth as using the former results in much more precise estimates. There is no evidence for price puzzle within the system. The results indicate a rather persistent appreciation of domestic currency after monetary tightening with a gradual depreciation afterwards.

**Abstrakt**

V této studii zkoumáme vliv české měnové politiky na ekonomiku v rámci VAR a strukturálního VAR modelu. Výsledky ukazují, že restriktivní měnově-politický šok má negativní efekt na ekonomickou aktivitu a cenovou hladinu, u obou s maximálním dopadem v horizontu zhruba jednoho roku. Na sektorální úrovni nalézáme, že ceny obchodovatelného zboží se přizpůsobují rychleji než ty neobchodovatelné. Přesnější odhady jsme obdrželi, pokud jsme ve VAR modelu použili mezeru výstupu místo růstu HDP. Naše výsledky nenachází tzv. cenovou hádanku. Výsledky ukazují, že po zpřísnění měnové politiky měnový kurz delší dobu apreciuje a poté pozvolně oslabí.

**Keywords:** monetary policy transmission, VAR, real-time data, sectoral prices
**JEL Codes:** E52, E58, E31

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## 1 Introduction

Understanding the transmission of monetary policy to inflation and other real economic variables is key for central bankers to conduct monetary policy effectively. Not surprisingly, there is extensive theoretical as well as empirical literature studying the effects of monetary policy shocks on the real economy aggregates and prices. For a small open economy such as the Czech Republic, it is vital to analyze monetary policy transmission for several reasons. First, there is some mixed evidence regarding monetary policy transmission, and therefore it is worthwhile to update previous results and utilize a wider range of econometric techniques, incorporating real time and forward looking variables into the vector autoregression analysis. There is also no empirical evidence about monetary policy effects on the sectoral prices. Second, the Czech Republic is likely to enter the Euro area relatively soon and therefore will be subject to a common monetary policy. In this regard, evidence on current monetary policy transmission patterns may shed light on the likely behavior of the economy in a monetary union. Third, while monetary policy is conducted based on real-time data, existing empirical work on the Czech Republic utilizes only *ex-post* revised data.

More specifically, we examine in this paper the effects of monetary policy within vector autoregression (VAR) and structural VAR (SVAR). We assess the persistence and magnitude of monetary policy shocks on output and prices as this is directly linked to the ultimate objectives within the explicit inflation targeting regime, in which the Czech National Bank (CNB) has conducted its monetary policy since 1998.[1]

It is well known that output and prices are expected to fall after monetary contraction. Nevertheless, as regards to prices, a number of papers document that, to the contrary, prices rise after monetary contraction, which has been labeled as the "price puzzle". The literature typically argues that the price puzzle is a consequence of model misspecification, for example lacking a forward-looking component within traditional VAR models represented by variables such as commodity price or U.S. federal funds futures (Brissimis and Magginas, 2006). Alternatively, Giordani (2004) shows that using the output gap instead of GDP growth alleviates the puzzle. We aim to address these issues, a forward-looking information as well as the output gap, in our empirical exercise. Meanwhile, Barth and Ramey (2001) suggest that a fall in both prices and output would suggest that monetary policy affects the economy

[1] See Coats, Laxton and Rose (2003) and Kotlan and Navratil (2003) on the overview of Czech monetary policy.

mainly through the demand channel. On the other hand, falling output and rising price levels would indicate the prevalence of the supply or cost channel.[2]

In addition, the effect of monetary policy on exchange rate behavior is examined. Generally, immediate exchange rate appreciation after monetary tightening and then the gradual depreciation of domestic currency is expected according to uncovered interest rate parity. However, empirical evidence is mixed. Some authors find a rather persistent appreciation of domestic currency ("delayed overshooting", Eichenbaum and Evans, 1995), while others report that the exchange rate actually depreciates with monetary contraction and provide explanations for the so-called exchange rate puzzle (Kim and Roubini, 2000).

Next, we analyze if there are any systematic differences in the responses of tradables and non-tradable prices to a monetary innovation. Our prior assumption is that as non-tradable prices are less exposed to international competition and more labor-intensive the reaction of non-tradable prices, is likely to be more persistent [see e.g. Barro (1972) or Martin (1993) on models relating the degree of competition to price rigidity]. The negative link between the degree of competition and price rigidity is also documented empirically using microeconomic data at the level of price setter by Alvarez and Hernando (2006) and Coricelli and Horvath (2006).

Another important feature of monetary policy conduct is it is based on the information set available at the time of policy-making. This implies that using *ex-post* revised data (note these are typically more precise, but not available at the time of monetary policy action) may contaminate the estimated effects of monetary policy (Croushore and Evans, 2006). This is typically the case for output data. We therefore utilize the real-time estimates of the output gap available from the Czech National Bank (CNB hereafter).[3] Additional rationale for using the output gap is that in the environment of the changing potential of the economy, actual GDP growth does not necessarily give an accurate picture about the degree of economic activity.

[2] In case a firm has to borrow to finance its production, interest rates enter the firm's cost function. Consequently, monetary policy tightening increases the firm's costs, to which the firm may react by increasing the price of the products it sells. In general, see Coricelli *et al.* (2006) for some additional explanations to the price puzzle.

[3] Note that price indices are not revised *ex-post* by the Czech Statistical Office.

The paper is organized as follows. Section 2 discusses the related literature. Data are presented in section 3. Section 4 is focused on identification issues. Section 5 contains our results on the effects of monetary policy. We present conclusions in section 6 and the appendix follows.

## 2 Related VAR Literature

Vector autoregressions (VAR), as introduced by Sims (1980), are considered sorts of benchmarks in econometric modeling of monetary policy transmission. It has been argued that this class of models provides a certain mix between a mere "data-driven" approach and an approach coherently based on economic theory (see Fry and Pagan, 2005, on the applications of VARs for macroeconomic research). In terms of monetary policy analysis, VAR methodology has been further developed among others by Gerlach and Smets (1995); Leeper, Sims and Zha (1998); and Christiano, Eichenbaum and Evans (1999). The latter provides a detailed review of the literature on this topic in the United States. Similarly, there has been extensive research undertaken in Europe to study various aspects of monetary transmission in the euro area countries (see Angeloni, Kashyap, Mojon and Terlizzese, 2003). The research on monetary transmission in the euro area either focuses on euro area-wide analysis (Peersman and Smets, 2001) or studies in a detail-specific country (Mojon and Peersman, 2001).

A number of approaches to deal with model misspecification related to monetary policy shock identification have been stressed in the literature. For example, Brissimis and Magginas (2006) show that by adding forward-looking variables such as federal funds futures to a standard VAR specification, one is able to obtain responses to the monetary policy that are consistent with the theory. The rationale for inclusion of federal funds futures is that it contains market expectations about future monetary policy action (this expectation element may also be found in commodity prices or money, to a certain extent).

In addition, Croushore and Evans (2006) emphasize the role of data revisions for monetary policy shocks identification. Monetary policy makers react to the information set available at the time, and it is often the case that GDP data are revised afterwards. As a result, using *ex-post* GDP data series may contaminate the estimated monetary policy effects. In addition, monetary policy makers often tend to react to the output gap rather than GDP growth. These concerns are especially appealing in our case. First, the main forecasting model of CNB (Quarterly Projection Model) indeed contains an output gap in its reaction function (Coats *et al.*, 2003). Second, GDP growth may still remain useful as the measure of the degree of economic activity, if the potential output is not changing much. However, in the case of the Czech economy, it is estimated that potential output growth sharply increased from some 2% in 1998 to around 5.5% in 2005 (Dybczak, Flek, Hajkova and Hurnik,, 2006).

Next, there has been a lot of research focusing on the sensitivity of responses of aggregate variables such as aggregate inflation and output to monetary policy within the VAR framework. However, much less is known about the responses to the monetary policy on the more disaggregate level. Erceg and Levin (2006) find that the durable goods sector is more sensitive to the interest rate changes than the non-durable goods sector in the U.S. Based on this empirical finding, they investigate the impact of the monetary policy on these two industries and find, as expected, that monetary policy effects are much stronger in the durable goods industry. Dedola and Lippi (2005) study the responses to monetary policy of various industrial sectors for a number of OECD countries. They find that the responses vary between the sectors in terms of their magnitude and persistence. This result is also confirmed by Peersman and Smets (2005), who find a number of significant differences between various industries in the euro area in terms of both the magnitude of output response, as well as the asymmetry of responses over the business cycle.

Bouakez, Cardia and Ruge-Murcia. (2005) is one of the few studies that examines the impact of monetary policy on disaggregate prices. Their results suggest that the monetary transmission affects household consumption in the construction and durable manufacturing sectors the most, but the impact of a monetary policy shock vanishes relatively quickly. They also find significant differences between the sectors' inflation in terms of variance decomposition, volatility and persistence. Bouakez *et al.* (2005) find that a response of services inflation to monetary policy shock is relatively pronounced and also the most persistent. Boivin, Giannoni and Mihov (2007) study the effect of macroeconomic fluctuations on disaggregate prices within the factor-augmented VAR framework. Among other things, their results indicate that the degree of market power explains the diversity of responses of disaggregate prices to monetary policy shocks.

In this paper, we address all the issues mentioned in previous paragraphs (namely, the use of forward-looking variables, real-time output gap estimates as well as disaggregate price indices). In addition, it is vital to note the related studies in Central Europe and the Czech Republic, in particular. In general, the number of studies analyzing the monetary transmission mechanism in the region using VAR methodology is growing gradually mainly due to data limitations [see Coricelli, Eger and MacDonald. (2006) for a survey of current findings on monetary policy transmission in Central and Eastern Europe including those undertaken within the VAR framework].

Several papers study the monetary policy effects for the Czech Republic within VAR framework. Using the sample period after the adoption of inflation targeting (1998-2004), Arnostova and Hurnik (2005) find that prices respond with a peak after around 5-6 quarters from the time of shock, albeit there is some evidence for a price puzzle in the first two quarters after the shock. Output falls after monetary contraction with a peak after one year or so. There is a delayed overshooting in the exchange rate, as it depreciates only after some 4 to 5 quarters after the monetary policy innovation. Extending the sample back to 1994, when the fixed exchange rate regime was in use, yields less satisfactory results as it is difficult to identify monetary policy shock across two monetary policy regimes. Next, Jarocinski (2006) provides a Bayesian VAR analysis of monetary policy effects in Western and Central Europe. Interestingly, Jarocinski finds that monetary policy is more potent in Central Europe, despite a lower level of financial development and smaller indebtness. Regarding the Czech Republic, he uncovers that there is a relatively strong appreciation of exchange rates as well as a larger price decline after a monetary policy innovation, as compared to other Central European countries. Elbourne and Haan (2006) study the interactions between the financial system and monetary transmission within the structural VAR framework for a group of 10 Central and Eastern European countries. For the Czech Republic, they find a hump shaped response of prices, an exchange rate appreciation, and a fall in industrial production after a monetary policy innovation. Next, financial structure is found to be of little importance for the monetary transmission.

## 3 Data

This section contains a description of our dataset. We restrict our sample to the data from 1998 onwards, i.e. since an inflation targeting framework has been adopted by the Czech

National Bank (previously, it operated a fixed exchange rate regime until May 1997). Our sample thus spans from 1998:1 to 2006:5 at the monthly frequency. While studies in this stream of literature often employ quarterly data, given the length of our sample we decided to work at the monthly frequency. As a result, we have 101 observations. The source of our data is the public database ARAD of the CNB (except for the output gap and forward rate, which are available only internally within the CNB).

We use GDP, $lgdp_t$, and the real-time output gap estimate, $outputgapreal_t$, as measures of economic activity.[4] GDP is traditionally used for this kind of exercise, but Giordani (2004) suggests using the output gap. In addition, by using the real-time output gap estimate we avoid the danger resulting from the use of *ex-post* data, which are not available to central bankers at the time of monetary policy formulation (Croushore and Evans, 2005). As GDP and the output gap is only available at the quarterly frequency, we interpolate these two using quadratic-match average procedure.[5] Note that all other variables we use are not revised afterwards.

Next, we employ the net price index, $lnet_t$, (net price index is a consumer price index excluding regulated prices). For our disaggregate analysis, we employ the tradable price index, $tradable_t$, and the non-tradable price index, $nontradable_t$. Note that the individual components underlying the consumer price indices are grouped into tradables and non-tradables categories in line with the internal CNB classification.

Further, the nominal CZK/EUR exchange rate, $lexrate_t$, and the three-month interbank interest rate (3M PRIBOR[6]), $pribor_t$, are used. To capture the external developments, the 1-year EURIBOR, $euribor_t$, and the commodity price index, $lcommodity_t$, are utilized. Forward rate agreement rate (9*12 FRA rate), $fra_t$, is to bring in a forward-looking element. Given that there are no futures or forwards in the Czech Republic that are directly linked to a monetary policy rate (2W repo) as it is the case in the U.S., we decided to use forwards on interbank

[4] See Coats et al. (2003, chapter 5) on the construction of the output gap used by the CNB. The output gap is the difference between actual and potential output, where the latter is estimated by the multivariate filter; more specifically, by the Kalman filter procedure, when the system of equations is in the state-space representation.
[5] We admit that interpolation introduces information at the time of policy making.
[6] Actual monetary policy instrument of the CNB is 2W repo rate. Since the repo rate is not changed continuously and is censored, we opt for 3M PRIBOR, which is very closely linked to the 2W repo rate; its correlation stands at 0.998 in our sample. In addition, 3M PRIBOR may capture also central bank communication. See Horvath (2007) on the discussion related to the use of the monetary policy rate vs. the interbank market rate in the Czech Republic.

rates that are very closely related to the policy rate. Finally, all data are in logs except the interest rates and the real-time output gap.

## 4 Identification

In this section, we discuss the VAR framework we adopt. Generally, given the data limitations we opt for a very parsimonious specification at first, and then analyze the sensitivity of our results under richer specifications.

There are two main estimation approaches we apply: recursive VAR and structural VAR. In addition, we consider four specifications, in which we use different set of variables to address the robustness of our results. Next, we also use GDP growth instead of output gap. All in all, this yields 16 distinct 'model specifications' (2 different estimation techniques, 2 measures of economic activity, and 4 different sets of variables).

The variables are ordered in a specific way as to represent the assumption that monetary authorities choose the interest rate taking into account the current level of prices and output (as in Mojon and Peersman, 2001). In addition, output and prices are assumed not to react immediately to the monetary policy shock but rather with a one-period lag. Mojon and Peersman (2001) follow a recursive specification to analyze the impact of a monetary policy shock in some of the euro area countries. Following their benchmark specification, which accounts for the openness of the economy, we can write the VAR model in the following way:

$$Y_t = A(L)Y_{t-p} + B(L)X_t + u_t \tag{1}$$

The variables included in this VAR model are divided into two groups, endogenous variables, $Y_t$, and exogenous, $X_t$. The VAR specification in (1) represents a so-called reduced form equation. In order to identify the original shocks we can apply the recursiveness assumption by imposing restrictions on a matrix linking the original shocks to the reduced form disturbances.

We have four main model specifications that we investigate in this paper (for convenience, we label them as Model 1-4 hereinafter; see Appendix 1 on page 17 for the list of all model specifications). In general, the generic specification is ordered as follows: measure of economic activity, price level, interest rate, and exchange rate. For sensitivity analysis, we augment the specification by a number of factors, variables capturing expectations and external developments. As regards to the measure of economic activity, we use a real-time output gap estimate and the actual GDP. Next, we also capture price pressures by including tradable and non-tradable price indices instead of the net price index.

Let us discuss each model in detail.[7] Model 1 is a simplest parsimonious specification, where it is assumed that the external shocks influence the Czech economy only via the exchange rate (i.e., $B(L)=0$). Admittedly, this is a simplistic specification, but its main advantage is the limited number of variables and thus its greater degree of freedom in comparison to other models. Model 1a) differs from 1b) only in the definition of economic activity. While in 1a) we use the real-time output gap estimate, $outputgapreal_t$, 1b) makes use of actual GDP growth, $lgdp_t$ (this applies also to the remaining Models 2-4).

Model 2 addresses the robustness of Model 1 augmenting it by the variables that capture external shocks in a fuller manner, as well as by including a more forward-looking component into the model. The inclusion of foreign variables that are considered exogenous is motivated by the need to control for the foreign shocks and thus, not to misinterpret domestic monetary shocks with the reaction of the central bank to external developments (Jarocinski, 2005).

Both Model 3 and Model 4 distinguish between tradable and non-tradable prices, while Model 4 additionally accounts in greater detail for external developments. We also considered other alternative specifications, where we included money and the commodity price index into the set of endogenous variables.[8]

Next, all models are estimated by structural VAR (SVAR). SVAR represents an alternative identification scheme that uses economic theory in order to recover the original residuals from the reduced-form VAR. For structural VAR, we apply here the AB-model of Amisano and Giannini (1997), which is defined as follows in a reduced form:

[7] Note that the ordering of variables is as depicted in Model 1-4 above, see also Appendix 1 on page 17.
[8] This reflects the specification used by Arnostova and Hurnik (2005). We find that money declines significantly after monetary policy innovation. The results are available upon request.

$$Y_t = A(L)Y_{t-p} + B(L)X_t + u_t \qquad (2),$$

$u_t = A^{-1}Be_t, e_t \sim (0, I_K)$, where I is identity matrix, K is the number of variables. A and B are $k \times k$ matrices to be estimated. In the case of Model 1a-1b and Model 2a-2b, they are specified as follows.

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 \\ a_{31} & 0 & 1 & a_{34} \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \qquad B = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix}$$

It follows from matrix A that the monetary authority does not consider contemporaneous prices while deciding on the monetary policy (i.e. $a_{32}=0$). However, monetary authorities are likely to react to contemporaneous output ($a_{31}$, as output can be regarded as an excess demand pressure indicator) and exchange rate shocks ($a_{34}$), which is a reasonable assumption for small open economies according to Kim and Roubini (2000). More specifically, exchange rate fluctuations influence the inflation forecast if they are deemed not to be transitory.

In Model 3a-3b and 4a-4b when we consider disaggregate prices (hence five variables), matrices A and B look as follows:

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 \\ a_{41} & 0 & 0 & 1 & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \qquad B = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 \\ 0 & 0 & 0 & 0 & b_{55} \end{bmatrix}$$

Following each VAR estimation, we perform stability checks in order to ensure the robustness of our results (the results of these tests are available upon request). It is important to note that the variables used in the VAR analysis do not need to be stationary. Sims (1980) among others argues against differencing even if the series contain a unit root. The main goal of the VAR analysis is to analyze the co-movements in the data. By differencing we could "throw away" some valuable information contained in the data. What matters for the robustness of the VAR results is the overall stationarity of the system [see  Lütkepohl (2006) for details].

## 5 Results

In this section, we discuss the estimated effects of the Czech monetary policy within the aforementioned specifications of Model 1-4. The number of lags has been chosen according to the Schwartz criterion and the parameter stability addressed by the CUSUM and CUSUM of squares test (the results are available upon request).

Figures 1-16 in Appendix 2 on page 19 present our results regarding the effects of contractionary monetary policy shock on several economic variables of interest to a monetary authority. These figures contain the impulse responses and the associated 95% confidence interval that was bootstrapped using 1000 replications according to the percentile method by Hall (1988). As shocks within a VAR are often contemporaneously correlated, a shock to one variable is likely to occur simultaneously with a shock to other variables included in the VAR. Therefore, shocks are orthogonalized by a Cholesky decomposition.

As regards to Model 1 (see Figures 1-4, Appendix 2 on page 19), we find that prices fall after monetary tightening with a bottom after about one year or so. This is in line with the targeting horizon of the CNB that is considered to be between 12 to 18 months. In terms of magnitude, our results show that one Cholesky standard deviation of interest rates (30 basis points monetary policy shock) decreases the log of prices by 0.14%-0.2% depending on the specification and estimation technique.[9] Notably, there is no evidence for a price puzzle.

The main rationale for using the real-time output gap estimate instead of current GDP growth in our empirical analysis is that using the former results in much more precise estimates. Typically, we avoid a price puzzle within the system. This is in line with our findings, albeit for Model 1, there is no price puzzle even if we use actual GDP data. Consequently, this means that we find no support for the cost channel of monetary policy. Specifically, the degree of economic activity falls after a contractionary monetary policy shock with a bottom after about one year (11-14 months). The results for Model 1 indicate that a monetary shock of 30 basis points decreases the output gap by 6%-7%.

[9] Several authors have raised the question of the accuracy of monetary policy shocks within VARs, see Boivin and Giannoni (2002) for related discussion.

Next, our results show a delayed overshooting in exchange rate behavior, i.e. a rather persistent appreciation of domestic currency after monetary tightening (lasting typically about 6 months) and a gradual depreciation afterwards. However, it has to be pointed out that the estimated confidence intervals are relatively wide, which brings some margins of uncertainty into interpreting the results. Nevertheless, we can see that irrespective of specification and estimation technique, the exchange rate depreciates over the longer-term horizon, with conforms to uncovered interest rate parity hypothesis (Kim and Roubini, 2000). As compared to the simple VAR, it seems that there is little real value added from using SVAR in Model 1.

Model 2 (see Figures 5-8, Appendix 2 on page 19), additionally contains exogenous variables capturing mainly the external developments and confirms, in principle, the results of Model 1. However, the confidence intervals are sometimes too wide to provide reliable inference about the effects of monetary policy shocks.

Next, Model 3 (see Figures 9-12, Appendix 2 on page 19) contains the estimates of the effect of monetary policy shocks on tradable and non-tradable prices. Generally, tradable prices react faster than non-tradables to monetary contraction. While the bottom response of tradable prices is around one year or so (even 9-10 months), the non-tradable prices' bottom response occurs only after one and a half year or more (the quickest maximum response is after about 20 months). This result complies with the findings based on micro level data (Alvarez and Hernando, 2006; Coricelli and Horvath, 2006), which show that the frequency of non-tradable prices' changes is relatively lower (and negatively affected by the degree of competition); hence, there is a slower response is likely to the monetary policy shock. On the other hand, the non-tradable prices' reaction is more pronounced. A monetary shock of about 0.3% decreases tradable and non-tradable prices by 0.15%-0.2% and 0.3%, respectively. In addition, Model 3 largely confirms the results of the effect of monetary policy on output and the exchange rate from Model 1. Also in this case, SVAR seems to provide little value added and generates the impulse responses close to those of VAR. The results from Model 4 (see Figures 13-16, Appendix 2 on page 19), including the exogenous variables, are largely in line with the findings for Model 3.

# 6 Concluding Remarks

In this paper, we analyzed the transmission of monetary policy shocks in the Czech Republic within the VAR and SVAR framework. In general, monetary transmission in the Czech Republic seems to be similar, in terms of persistence of responses of economic variables to monetary shocks, to the transmission in more developed countries, including the euro zone (see e.g. Mojon and Peersman, 2001). Generally, the results point to the usefulness of monthly data, as opposed to quarterly data, in cases where the time span under study is relatively short. Using the monthly data, we are able to obtain the results that are in line with economic theory. This is in contrast to some previous empirical studies on the Czech Republic that have employed the quarterly data.

All in all, subject to various sensitivity tests, we find that prices and output decline after monetary tightening with a bottom response occurring after about one year. Such a finding corresponds with the actual targeting horizon of the Czech National Bank. In addition, we document that the reaction of tradable prices is faster than those of non-tradables. While the maximum effect of monetary shock on tradables can be seen after a year or so, it is at least a year and a half for non-tradable prices. This result broadly confirms microeconomic evidence on the effect of competition on price rigidity (Alvarez and Hernando, 2006; Coricelli and Horvath, 2006).

Next, there is a rationale in using the real-time output gap estimate instead of current GDP growth as using the former results in much more precise estimates. Typically, we avoid a price puzzle within the system and hence we provide very little support for the cost channel hypothesis of monetary policy. Thus, our results support the notion that the price puzzle is associated rather with model misspecification than with representing the actual behavior of the economy. The impulse responses of GDP to interest rate shock are less precisely estimated, and thus our findings point to an importance of real-time data in monetary policy analysis. Finally, our results also indicate a persistent appreciation of the domestic currency after monetary tightening ["delayed overshooting", Eichenbaum and Evans (1995)], albeit the confidence intervals are in this case rather wide, with a gradual depreciation afterwards.

## References


Alvarez, L. and I. Hernando (2006): Competition and Price Adjustment in the Euro Area, Working paper No 0629, Bank of Spain.

Amisano, G. and C. Giannini (1997): Topics in Structural VAR Econometrics, 2nd ed., Springer-Verlag, Berlin.

Angeloni, I., A. Kashyap and B. Mojon (2003): Monetary Policy Transmission in the Euro Area, Cambridge University Press.

Barro, R. (1972): A Theory of Monopolistic Price Adjustment, *Review of Economic Studies*, pp. 17-26.

Barth, M.J. and V.A. Ramey (2001): The Cost Channel of Monetary Transmission. 2001 NBER Macroeconomics Annual, pp. l99-239.

Boivin, J. and P. Giannoni (2002): Assessing Changes in the Monetary Transmission Mechanism: A VAR Approach, Federal Reserve Bank of San Francisco Economic Policy Review, 8/1, pp. 97-111.

Boivin, J., Giannoni, P. and I. Mihov (2007): Sticky Prices and Monetary Policy: Evidence form Disaggregated U.S. data, NBER Working Paper No 12824.

Bouakez, H. Cardia E. and F. Ruge-Murcia (2005): Transmission of Monetary Policy in Multi-Sector Economy, University of Montreal Working Paper, Cahier de recherche CIREQ, 20/2005.

Brissimis, S. and N. Magginas (2006): Forward Looking Information in VAR Models and the Prize Puzzle, *Journal of Monetary Economics* 53, pp. 1225-1234.

Christiano, L., M. Eichenbaum and C. Evans (1999): Monetary Policy Shocks: What Have We Learned and To What End?, in: Taylor, J., Woodford, M., eds., Handbook of Macroeconomics. North Holand, pp. 65-148.

Coats, W., D. Laxton, and D. Rose (2003): The Czech National Bank's Forecasting and Policy Analysis System. Czech National Bank (available at www.cnb.cz).

Coricelli, F., B. Égert and R. MacDonald (2006): Monetary Transmission Mechanism: Gliding on a Wind of Change, BOFIT Discussion Papers No 8/2006, Bank of Finland.

Coricelli, F. and R. Horvath (2006): Price Setting Behavior: Micro Evidence on Slovakia, CEPR Discussion Paper No 5445.

Croushore, D. and C. Evans (2006): Data Revision and the Identification of Monetary Policy Shocks, *Journal of Monetary Economics* 53, pp. 1135-1160.

Dedola, L. and F. Lippi (2005): The Monetary Transmission Mechanism: Evidence from Industry Data of Five OECD Countries, *European Economic Review*, pp. 1543-1569.

Dybczak, K., V. Flek, D. Hájková and J. Hurník (2006): Supply-Side Performance and Structure in the Czech Economy (1995-2005), Czech National Bank Working Paper No 4/2006.

Eichenbaum, M. and C. Evans (1995): Some Empirical Evidence on the Effects of Monetary Policy Shocks on Exchange Rates, *Quarterly Journal of Economics* 110, pp. 975-1010.

Elbourne, A. and J. de Haan (2006): Financial Structure and Monetary Policy Transmission in Transition Countries, *Journal of Comparative Economics*, pp. 1-23.

Erceg, C. and A. Levin (2006): Optimal Monetary Policy with Durable Consumption Goods, *Journal of Monetary Economics* 53, pp. 1341-1359.

Fry, R. and A. Pagan (2005): Some Issues in Using VARs for the Macroeconometric Research, CAMA Working Papers Series No 19/2005, The Australian National University.

Gerlach, S. and F. Smets (1995): The Monetary Transmission Mechanism: Evidence From the G-7 Countries, *CEPR Discussion Paper*, No.1219.

Giordani, P. (2004): An Alternative Explanation of the Price Puzzle, *Journal of Monetary Economics* 51, pp. 1271-1296.

Hall, P. (1988): On Symmetric Bootstrap Confidence Intervals, *Journal of the Royal Statistical Society*, B50, 35-45.

Horvath, R. (2007): Time-Varying Policy Neutral Rate in Real Time: A Predictor for Future Inflation?, Czech National Bank Working Paper Series No 4/2007.
.
Hurnik, J. and K. Arnostova (2005): The Monetary Transmission Mechanism in the Czech Republic: Evidence from VAR Analysis, Czech National Bank Working Paper Series No 4/2005.

Jarocinski, M. (2006): Responses to Monetary Policy Shocks to East and West of Europe: A Comparision, Austrian National Bank, Working paper No. 124.

Kim, S. and N. Roubini (2000): Exchange rate anomalies in the industrial countries: a solution with a structural VAR approach, *Journal of Monetary Economics* 45, pp. 561-586.

Kotlán, V. and D. Navrátil (2003): Inflation Targeting as a Stabilization Tool: Its Design and Performance in the Czech Republic, *Finance a úvěr – Czech Journal of Economics and Finance* 53, pp. 220-242.

Leeper, E., C. Sims and T. Zha (1998): What Does Monetary Policy Do?, Brookings Papers on Economic Activity, Vol 2, pp.1-63.

Lütkepohl, H. (2006): New Introduction to Multiple Time Series Analysis, 2nd ed., New York: Springer.

Martin, C. (1993): Price Adjustment and Market Structure, *Economics Letters* 41, pp. 139-143.

Mojon, B. and G. Peersman (2001): A VAR Description of the Effects of Monetary Policy in the Individual Countries of the Euro Area, ECB Working Paper No 92.

Peersman, G. and F. Smets (2001): The Monetary Transmission Mechanism in the Euro Area: More Evidence from VAR Analysis, ECB Working Paper No 91.

Peersman, G. and F. Smets (2005): The Industry Effects of Monetary Policy in Euro Area, *Economic Journal*, pp. 319-342.

Sims, C. (1980): Macroeconomics and Reality, *Econometrica*, pp. 1-48.

Woodford, M. (2003): Interest and Prices: Foundations of a Theory of Monetary Policy, Princeton University Press.

# Appendix 1 – Model Specifications and Ordering of Variables

*Model 1.*

a)

$$Y_t^{'} = [outputgapr\ \ eal_t, lnet_t, pribor_t, lexrate_t]$$

$$X_t^{'} = [- - -]$$

b)

$$Y_t^{'} = [lgdp_t, lnet_t, pribor_t, lexrate_t]$$

$$X_t^{'} = [- - -]$$

*Model 2.*

a)

$$Y_t^{'} = [outputgapr\ \ eal_t, lnet_t, pribor_t, lexrate_t]$$

$$X_t^{'} = [euribor_t, lcommodity_t, fra_t]$$

b)

$$Y_t^{'} = [lgdp_t, lnet_t, pribor_t, lexrate_t]$$

$$X_t^{'} = [euribor_t, lcommodity_t, fra_t]$$

*Model 3.*

a)

$$Y_t^{'} = [outputgapr\ \ eal_t, lnontradab\ \ le_t, ltradable_t, pribor_t, lexrate_t]$$

$$X_t^{'} = [- - -]$$

b)

$$Y_t^{'} = [lgdp_t, lnontradab\ \ le_t, ltradable_t, pribor_t, lexrate_t]$$

$$X_t^{'} = [- - -]$$

*Model 4.*

a)

$$Y_t^{'} = [outputgapr\ \ eal_t, lnontradab\ \ le_t, ltradable_t, pribor_t, lexrate_t]$$

$$X_t^{'} = [euribor_t, lcommodity_t, fra_t]$$

b)

$$Y_t' = [lgdp_t, lnontradable_t, ltradable_t, pribor_t, lexrate_t]$$

$$X_t' = [euribor_t, lcommodity_t, fra_t]$$

# Appendix 2 – Results

## Model 1

**Figure 1: Simple VAR, real-time output gap**

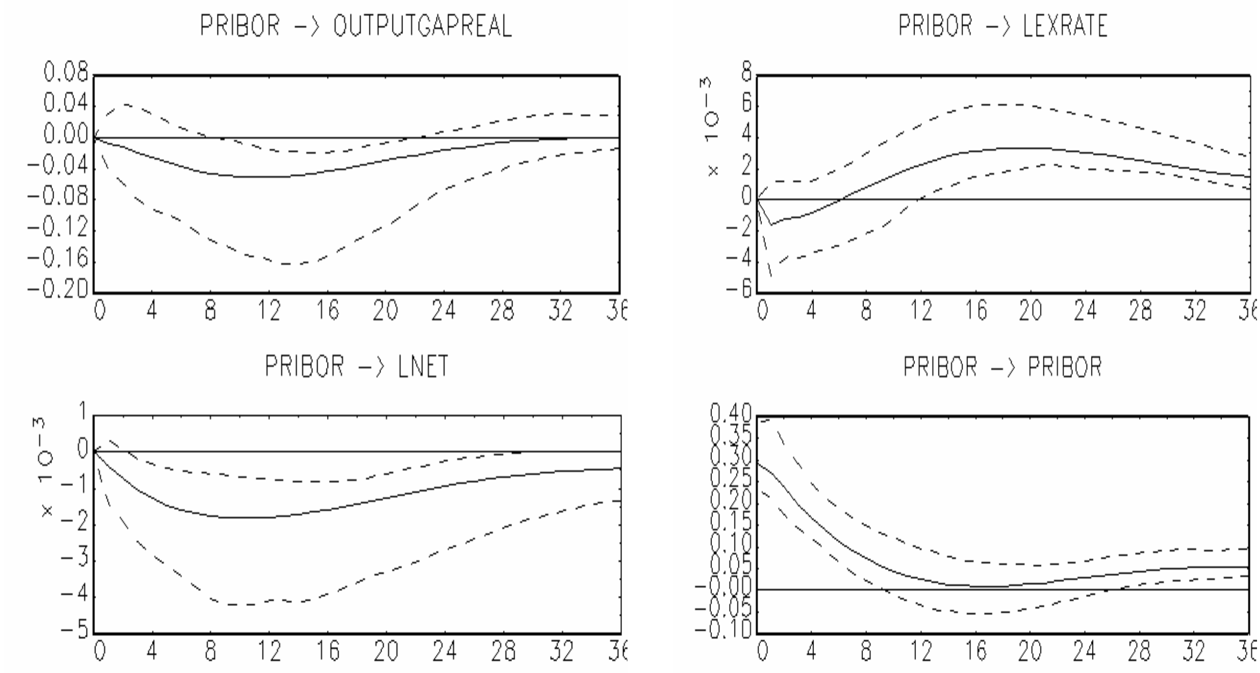



**Figure 2: SVAR, real-time output gap**

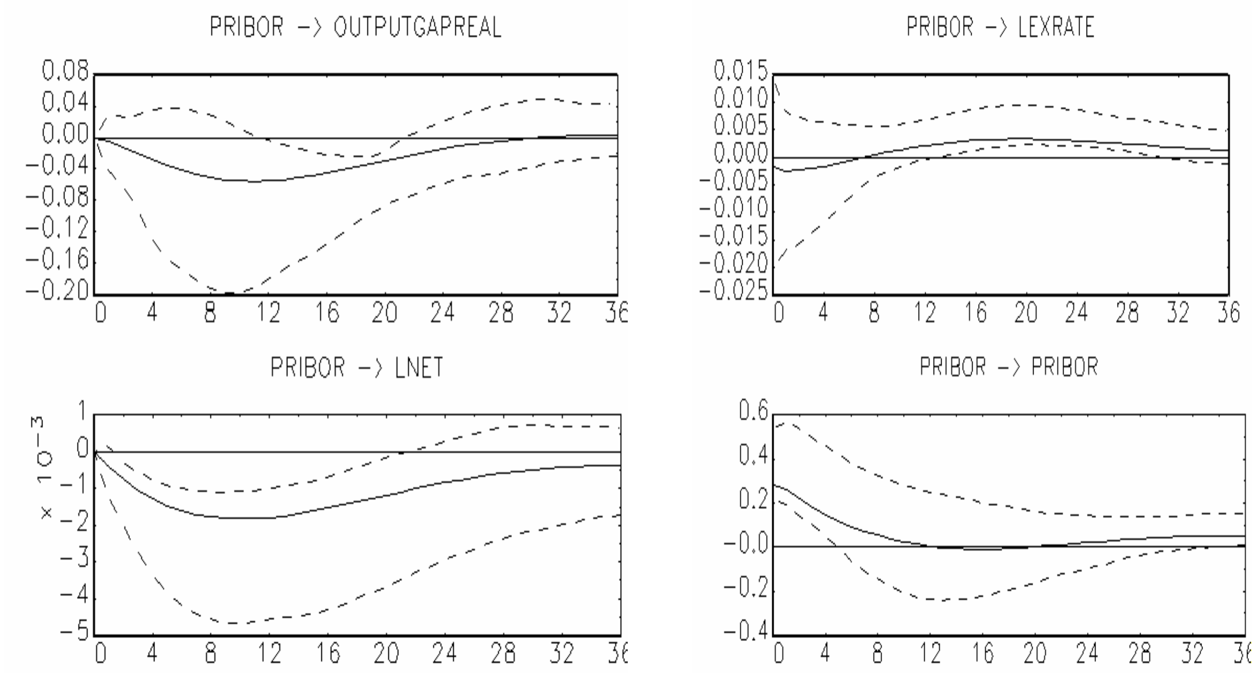


**Figure 3: Simple VAR, actual GDP**

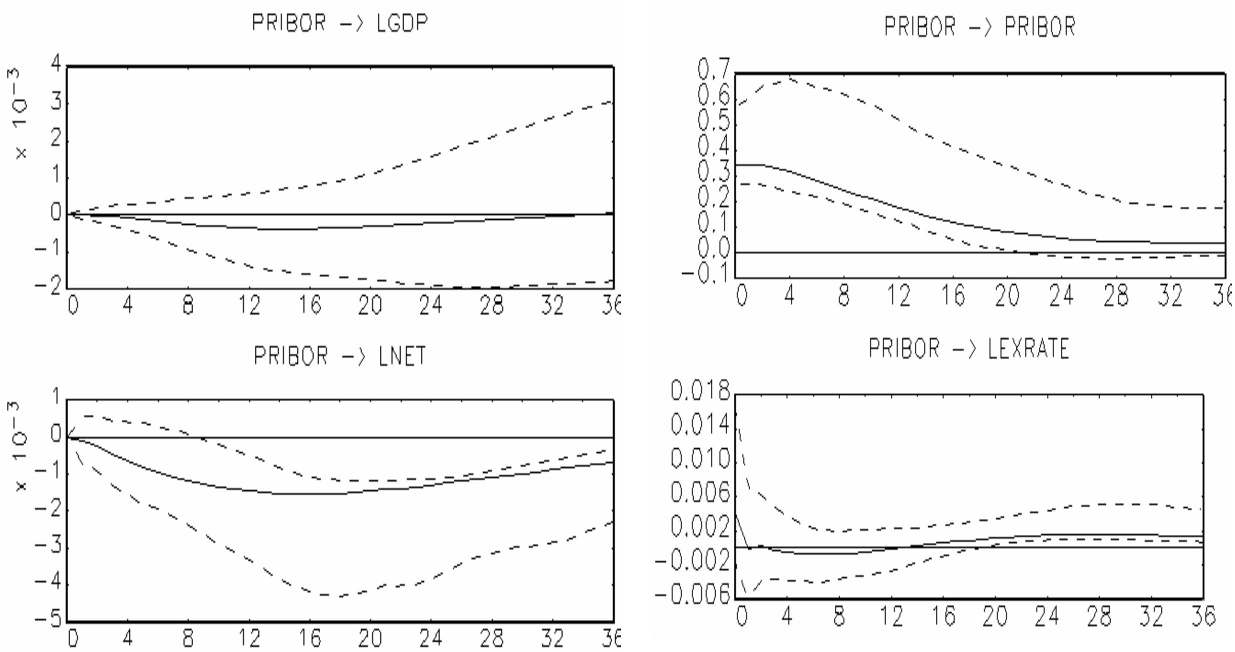
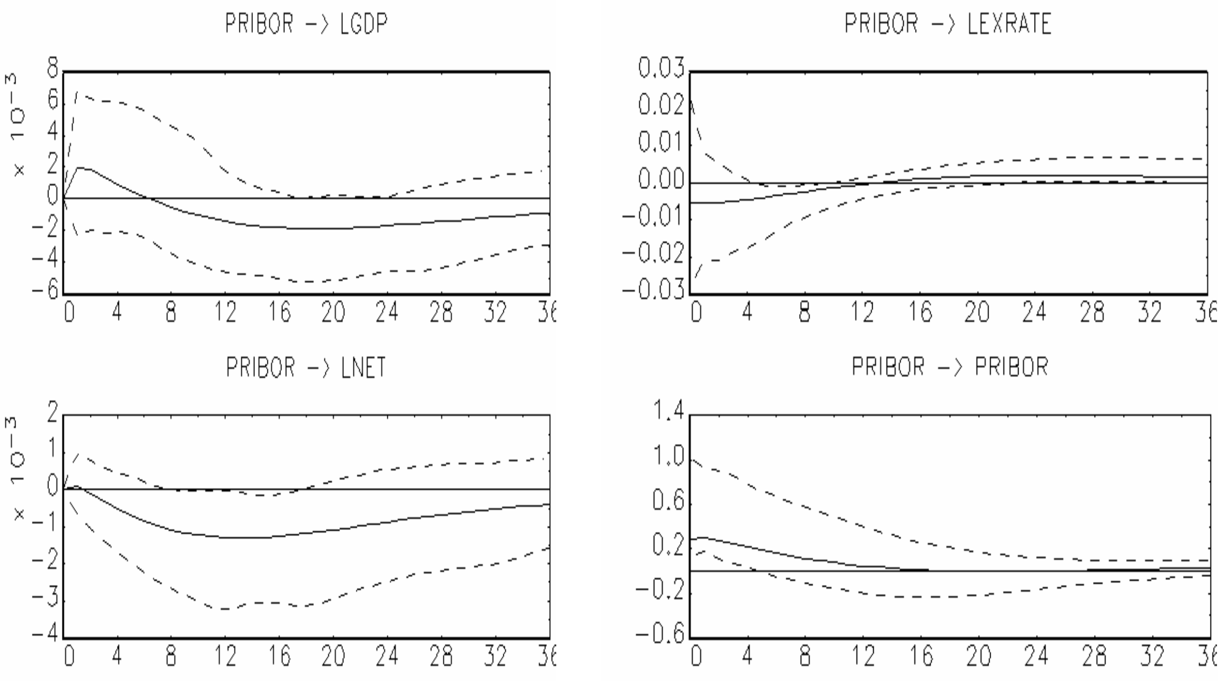



**Figure 4: SVAR, actual GDP**



# Model 2

**Figure 5: Simple VAR, real-time output gap**

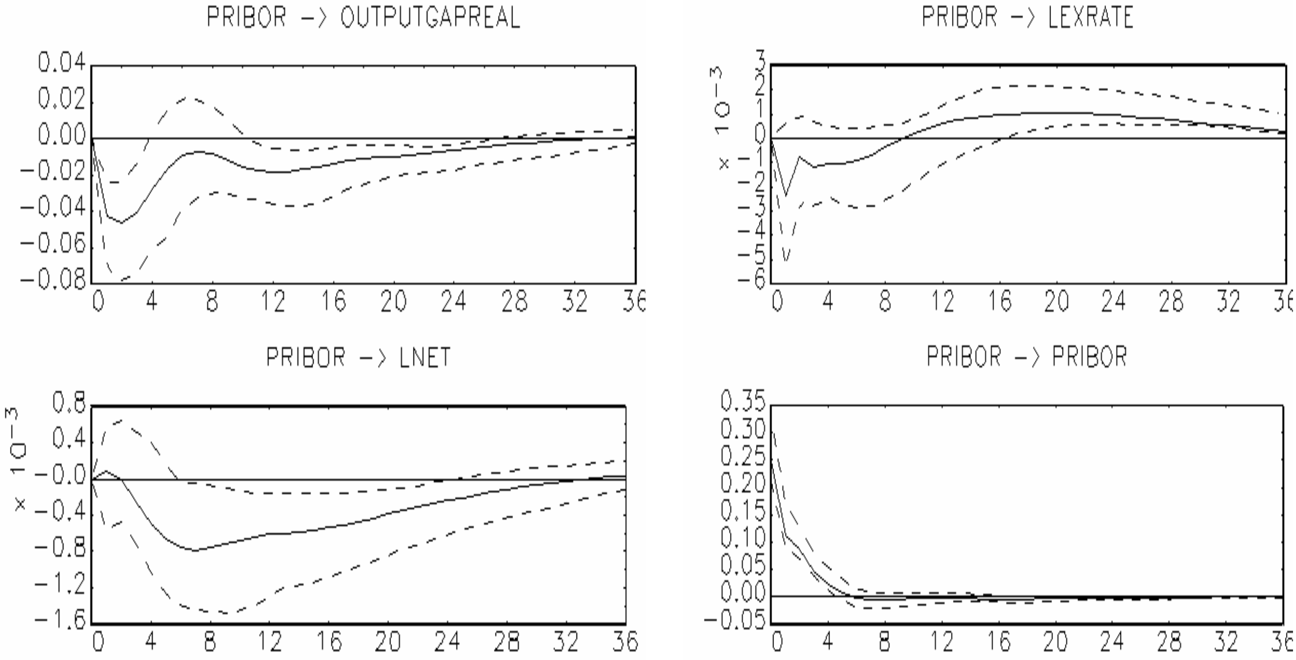



**Figure 6: SVAR, real-time output gap**

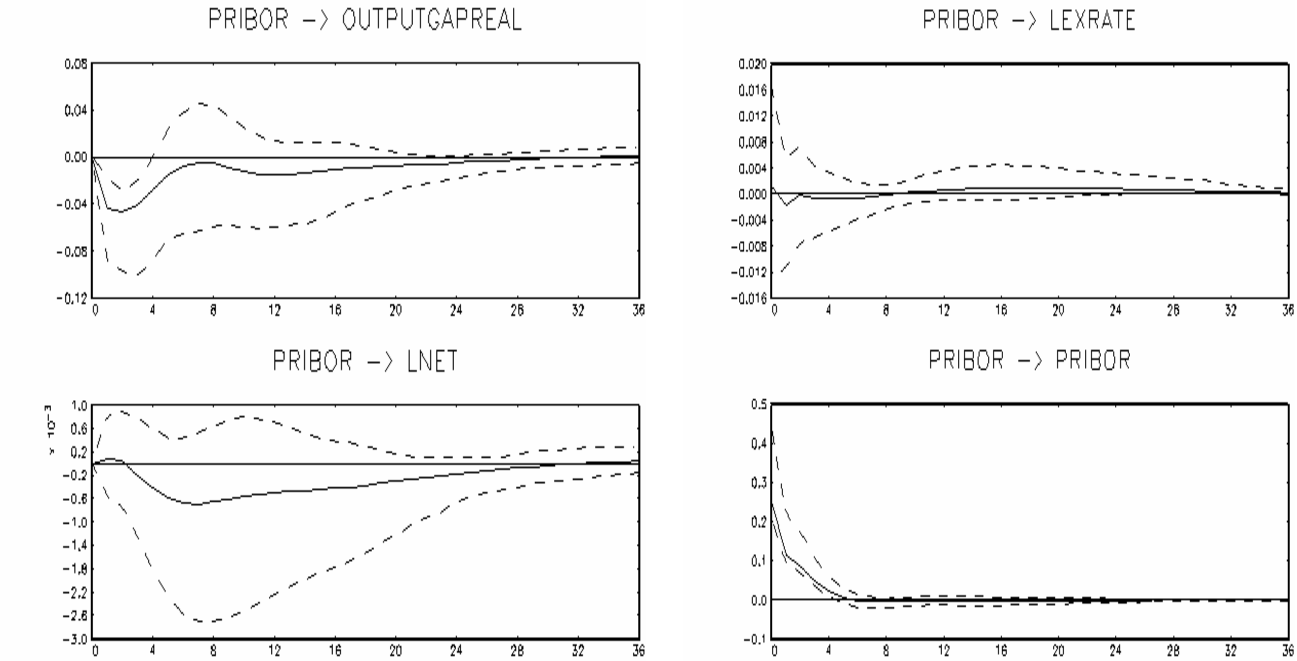


**Figure 7: Simple VAR, actual GDP**

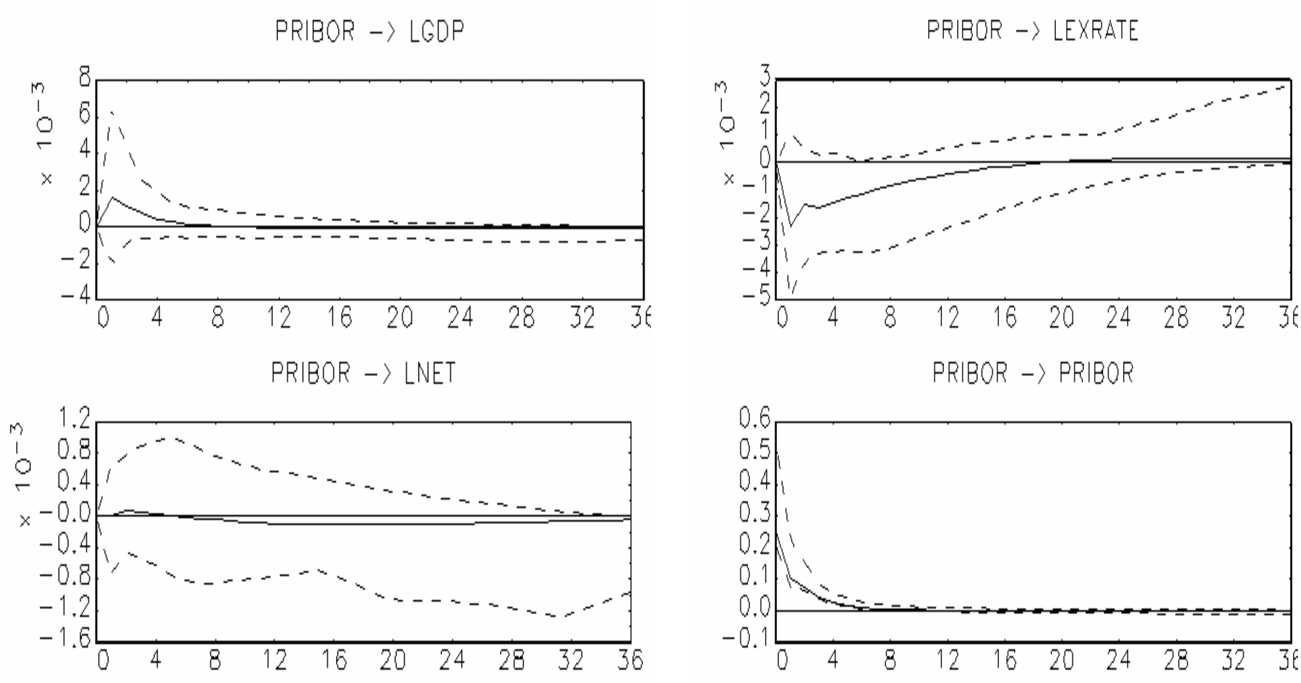
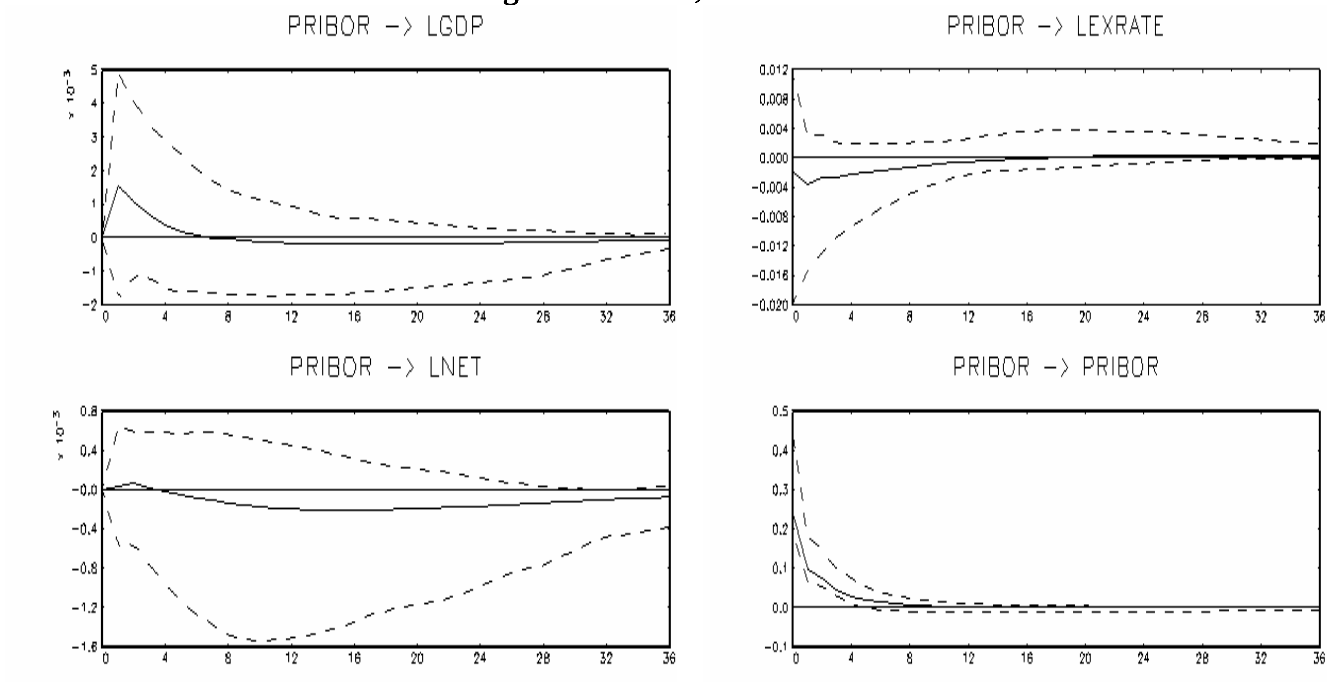



**Figure 8: SVAR, actual GDP**



# Model 3

**Figure 9: Simple VAR, real-time output gap**

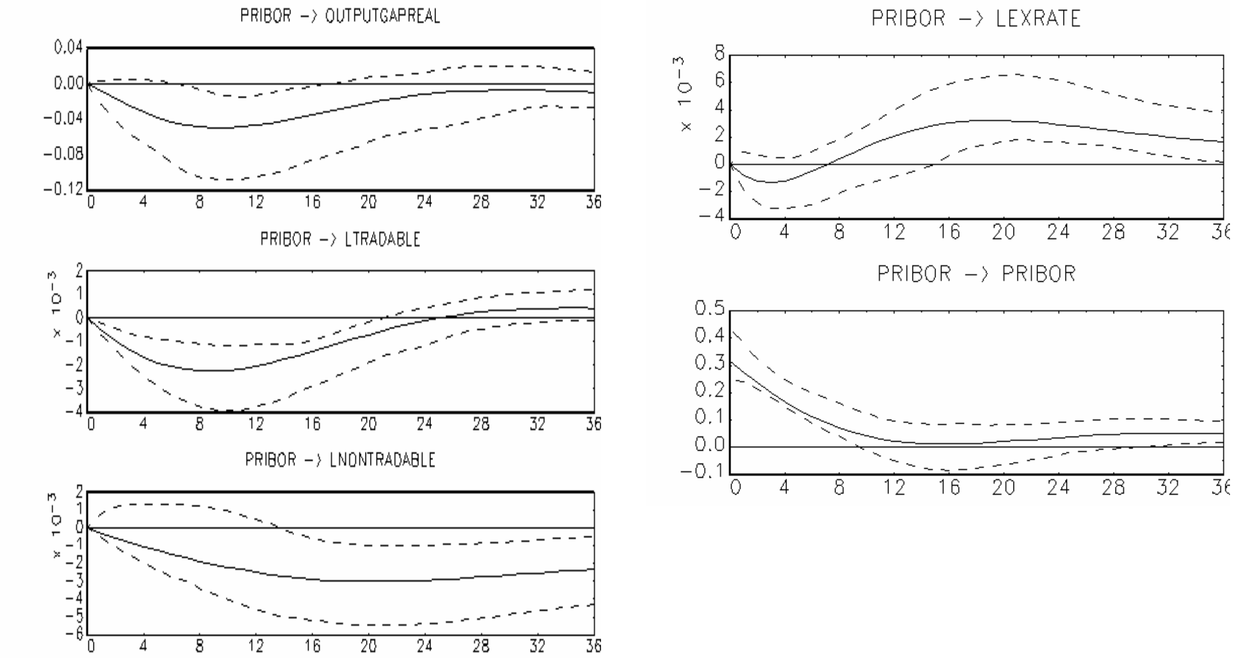



**Figure 10: SVAR, real-time output gap**

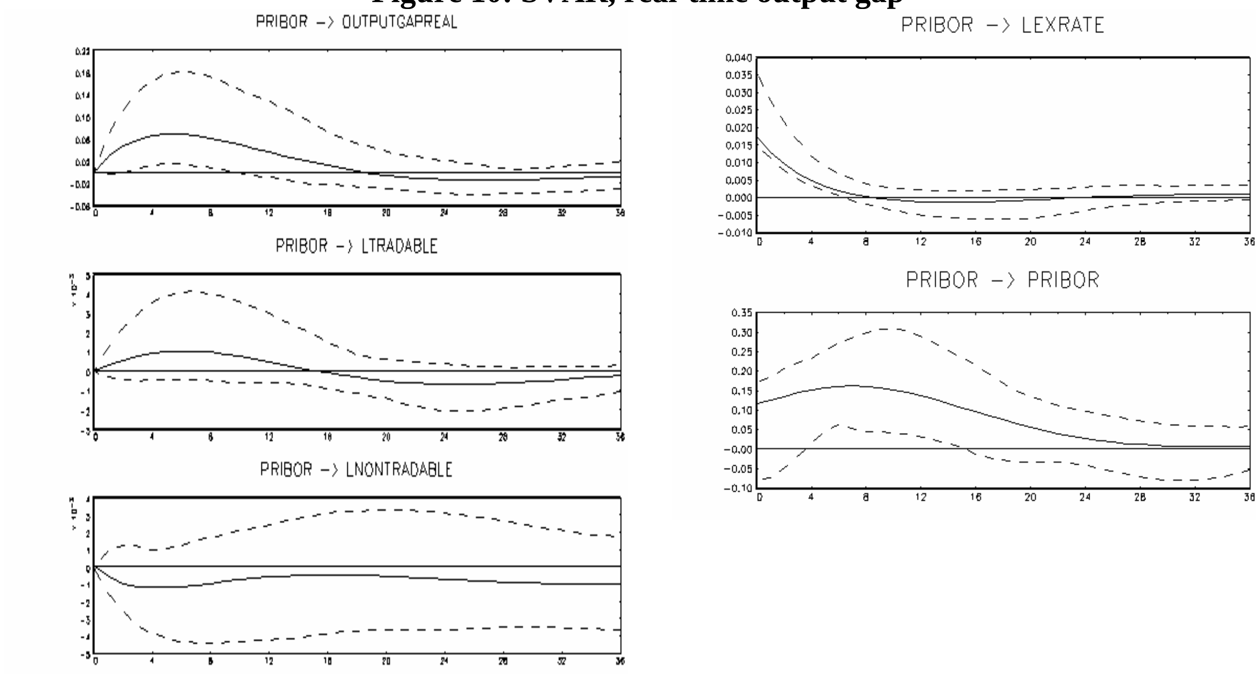


**Figure 11: Simple VAR, actual GDP**

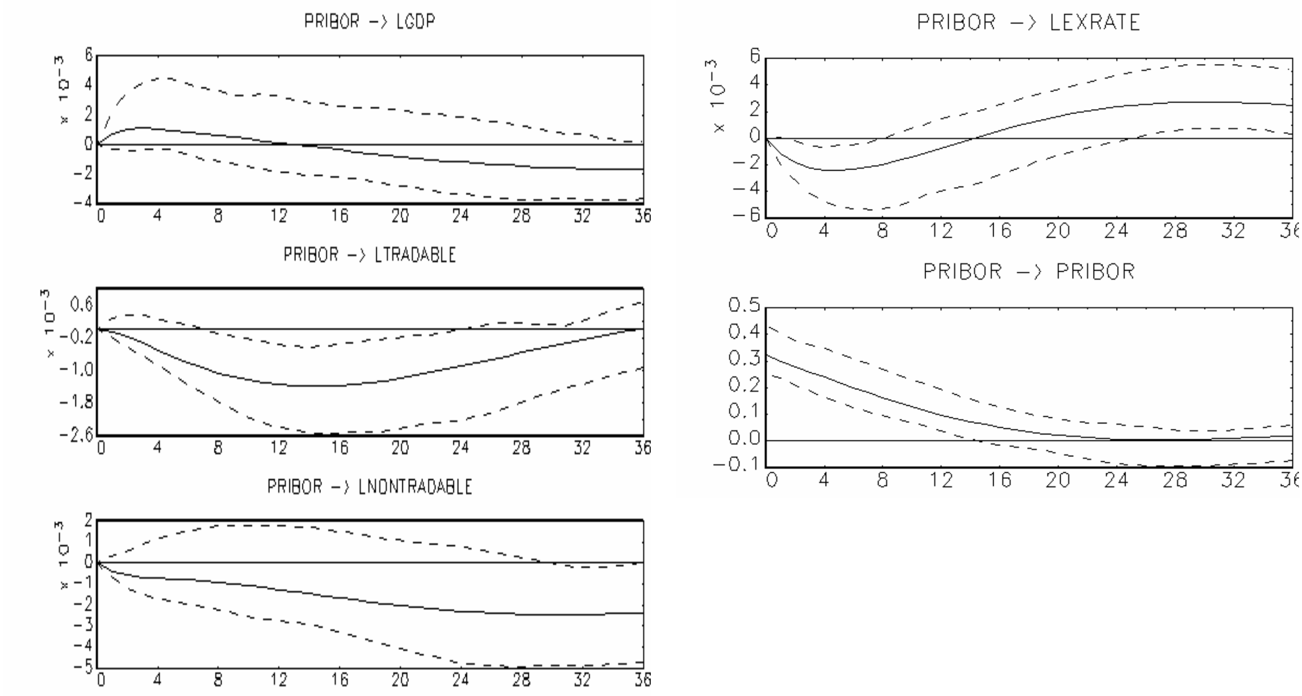
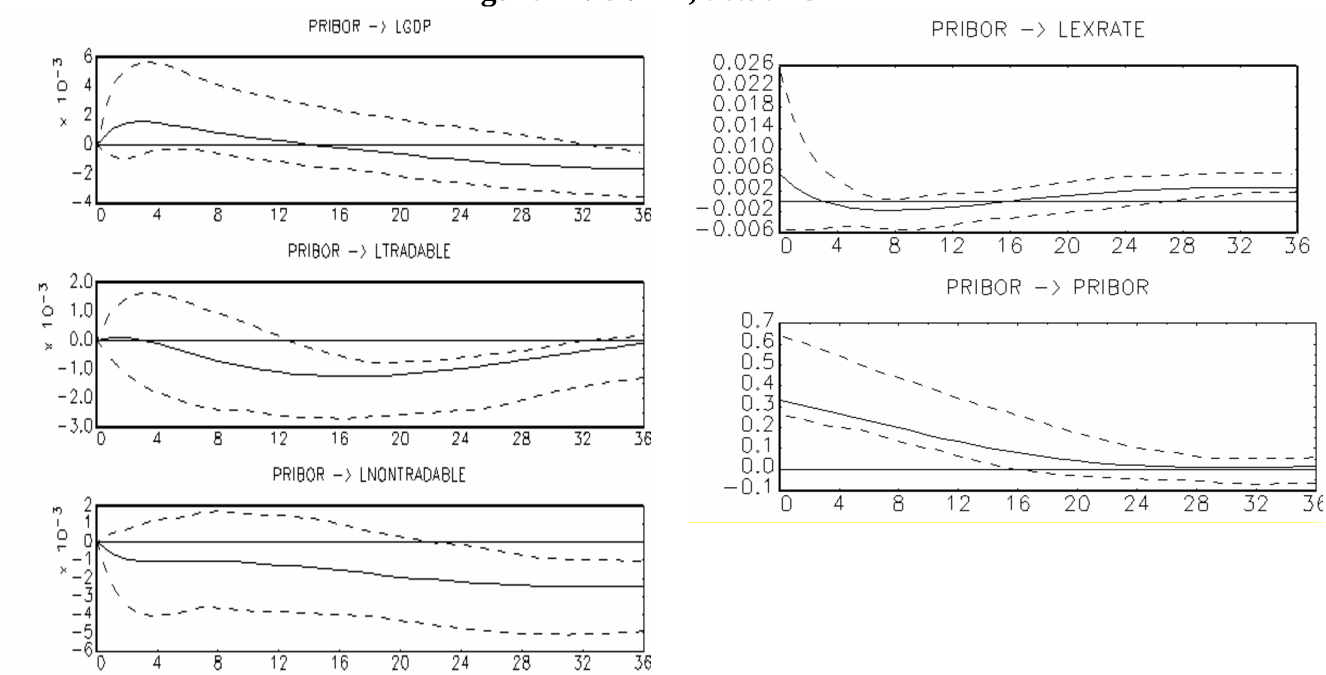



**Figure 12: SVAR, actual GDP**



# Model 4

**Figure 13: Simple VAR, real-time output gap**

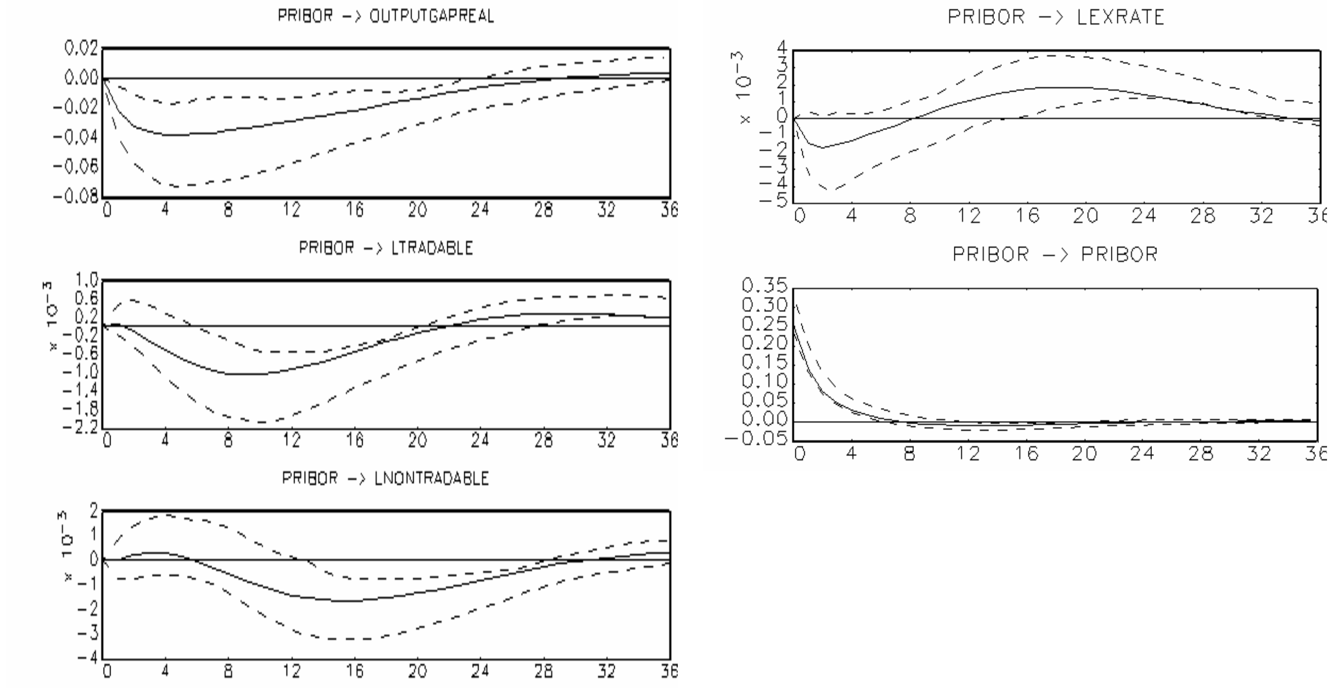



**Figure 14: SVAR, real-time output gap**

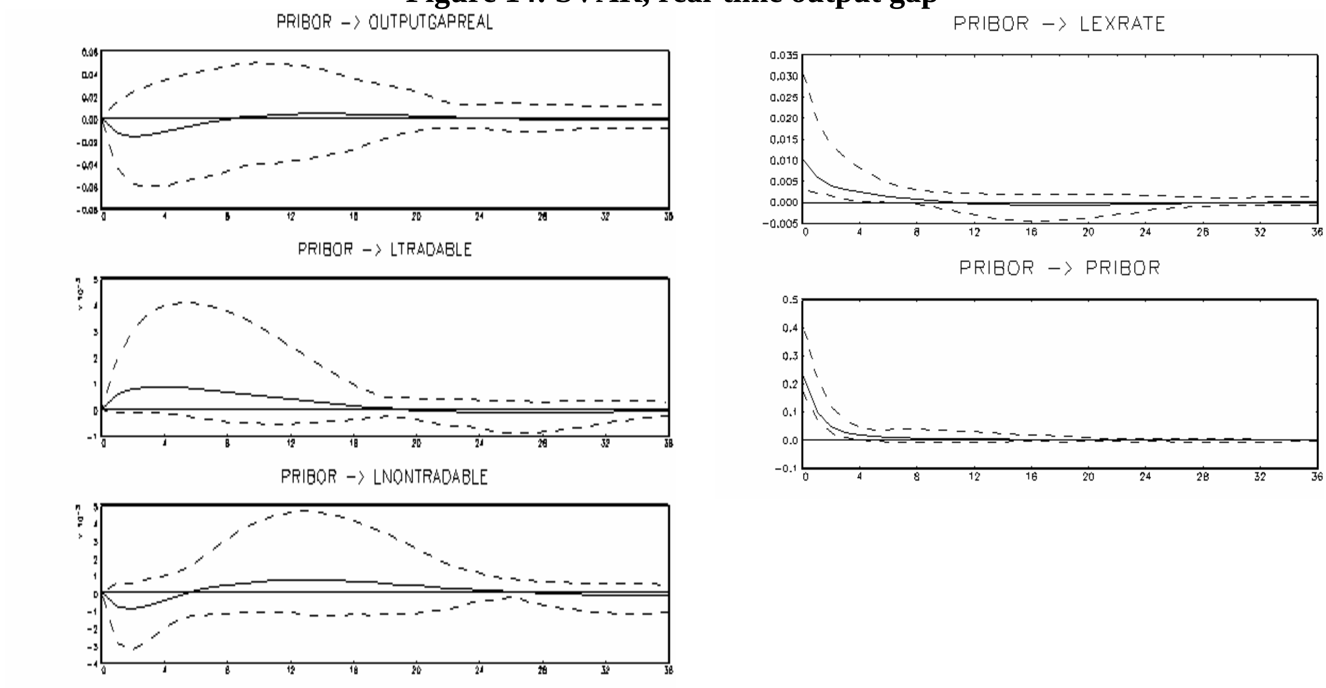


**Figure 15: Simple VAR, actual GDP**

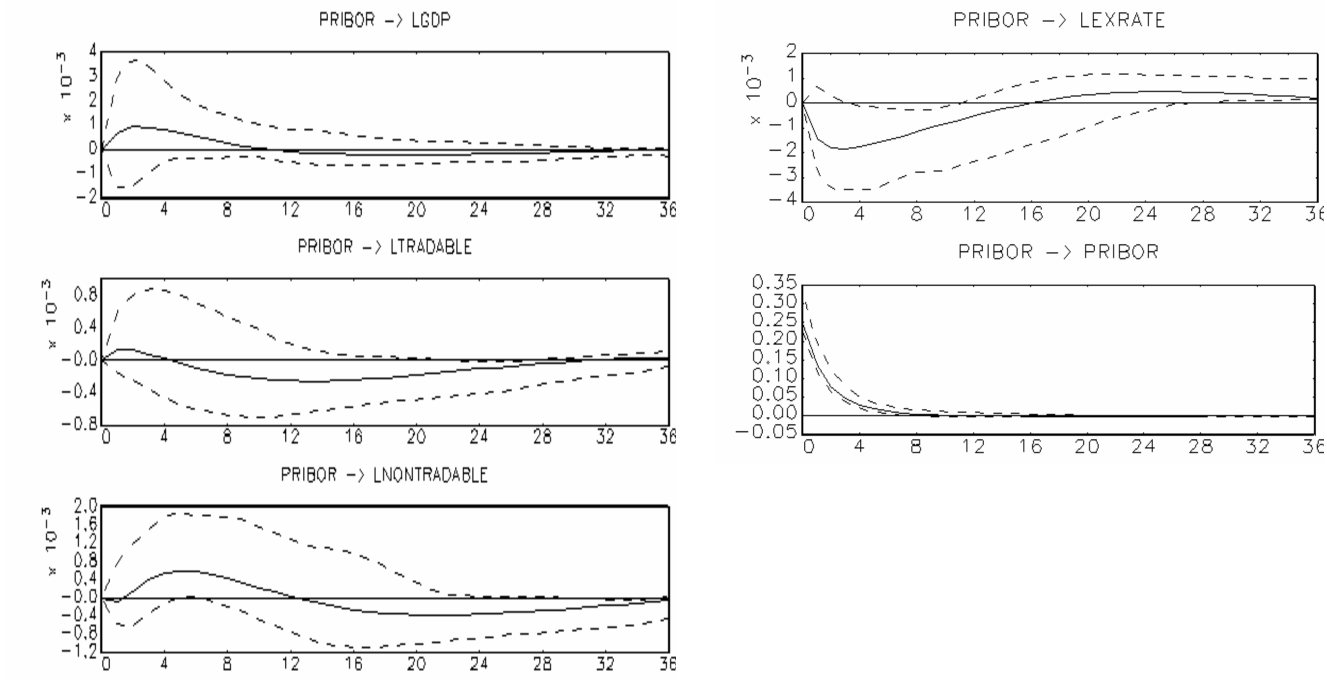
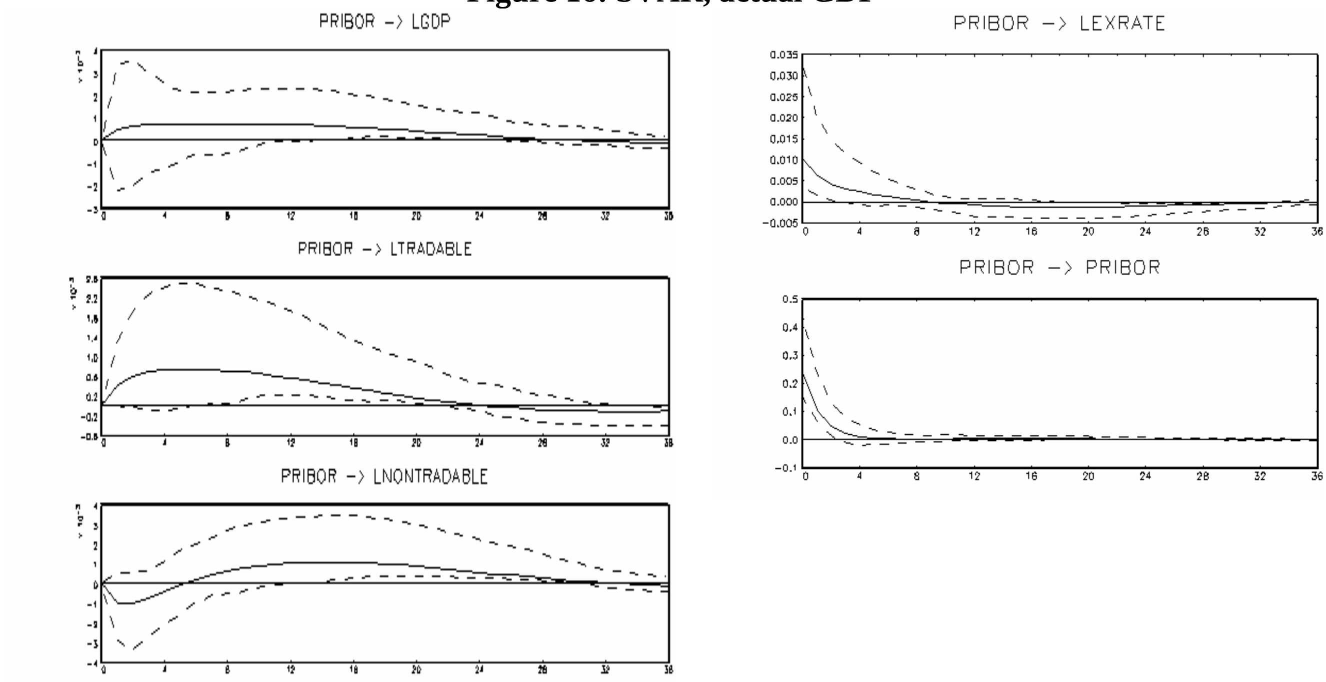



**Figure 16: SVAR, actual GDP**



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