A VAR Framework in Analyzing the Effects of Anticipated and Unanticipated Monetary Shocks on Macro Aggregates: The Case of Turkey

Thesis submitted to the

Institute of Social Sciences

in partial fulfillment of the requirements for the degree of

Master of Arts

in

Economics

by

Fatma E. Karapaşaoğlu

Boğaziçi University

1999

The thesis of Fatma E. Karapaşaoğlu

is approved by:

Assoc. Prof. Dr. C. Emre Alper ---------------------------

(Thesis Supervisor)

Assoc. Prof. Dr. O. Cevdet Akçay ---------------------------

Assist. Prof. Dr. İsmail Sağlam ---------------------------

ACKNOWLEDGMENTS

First of all, I would like to thank sincerely to my supervisor, Assoc. Prof. Dr. C. Emre Alper for his keen interest and guidance during the preparation of this thesis. I wish to express my gratitude to the members of the examining committee, Assoc. Prof. Dr. O. Cevdet Akçay and Assist. Prof. Dr. İsmail Sağlam for their helpful comments and suggestions. I also wish to thank Ayhan Top from Yapı Kredi Bank for providing various journal papers for this thesis. Finally, and especially, I wish to thank my husband, İlker Aycı, for kindly sharing his time and comments with me.

ABSTRACT

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This study examines the effects of anticipated and unanticipated monetary policy on macro variables for Turkey, over the period of 1987-1998, using a vector autoregression framework following Cochrane (1998). Monetary policy is analyzed by means of two different shocks; one is the shock on money supply and the other is the shock on the interest rate. Expansionary monetary policy is found to affect output positively but not significantly in all estimations. On the other hand, contractionary monetary policy, measured by a positive interest rate shock, reduces output significantly in all estimations. Although the effect of monetary policy on output is significant, it can only explain a tiny fraction of the changes in real output. Estimation results indicate that there exists 'price puzzle' in Turkey, i.e., prices respond negatively to expansionary monetary policy and positively to contractionary monetary policy. The response of the exchange rate to monetary policy is found to be in the same direction as that of the price index in all estimations. Finally, if we assume that not only unanticipated monetary policy but both anticipated and unanticipated monetary policies have some effects on macro variables, responses of those variables to monetary shocks die out within a shorter time period.

Keywords: Vector autoregression, monetary transmission mechanisms, anticipated-unanticipated shocks

ÖZET

Parasal Şokların Makro Değişkenler Üzerindeki Etkilerinin Bir VAR Modeli Çerçevesinde İncelenmesi: Türkiye Örneği

Fatma E. Karapaşaoğlu

Bu çalışma, Türkiye'de 1987-1998 döneminde, beklenen ve beklenmeyen para politikasının makro değişkenler üzerindeki etkisini, Cochrane (1998) tarafından geliştirilen bir vektör otoregresyon (VAR) modeli çerçevesinde incelemektedir. Para politikası iki değişik şok yardımıyla incelenmiştir; bunlardan biri para arzındaki şoklar, diğeri ise faiz oranı üzerindeki şoklardır. Genişleyici para politikası reel üretimi ancak bazı tahminlerde pozitif olarak etkilemektedir. Diğer taraftan, faiz oranındaki artışla belirlenen sıkı para politikası, yapılan tüm tahminlerde, üretimi azaltıcı etki yapmıştır. Para politikasının reel üretim üzerindeki etkisi belirgin olmasına rağmen, üretimdeki değişikliklerin ancak çok küçük bir kısmı para politikasındaki değişmelerle açıklanabilmektedir. Tahmin sonuçları Türkiye için 'fiyat bilmecesi'nin geçerli olduğunu göstermiştir; fiyat endeksi genişleyici para politikasıyla düşmüş ve sıkı para politikasıyla yükselmiştir. Döviz kurunun para politikalarına tepkisi, tüm tahminlerde, fiyatların tepkisiyle aynı yönde gerçekleşmiştir. Son olarak, sadece beklenmeyen para politikasının değil de, hem beklenen hem de beklenmeyen para politikalarının etkili olduğu varsayılırsa, değişkenlerin tepkilerinin daha kısa sürdüğü gözlenmiştir.

Anahtar kelimeler: Vektör otoregresyon, parasal aktarım mekanizmaları, beklenen/beklenmeyen şoklar.

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I. Introduction

Analyzing the effects of monetary policy has been one of the most attractive research areas in the applied economics. The issue has been debated by politicians and researchers in the finance sector beside economists. What makes monetary policy interesting is its controversial power in affecting real aggregate economic activity.

The conduct of monetary policy is the responsibility of central banks. Central banks may differ in terms of policy targets and in terms of the weights associated with these targets in their objective functions. In general, these policy targets include the price level stability and the real output growth and, occasionally, the level of foreign reserves and the exchange rate. Of course, these targets cannot be achieved directly and central banks use different tools (instruments) through which they can affect the targeted variables. The instruments of monetary policy are open market operations and discount rate which affect monetary base and required reserve ratios the latter of which affects money multiplier and very rarely interest rate ceilings. These instruments directly affect money supply and the market interest rate, which in turn affect the targeted variables.

A traditional explanation of how an expansion in the money supply is transmitted to output, given by Mishkin (1995), is as follows: Any increase in monetary aggregates, reduces the nominal interest rate, and (given that expected inflation rate does not change) real interest rates. The decrease in the real interest rate then stimulates investment; so that output rises, and unemployment goes down.

The above transmission story of the expansionary monetary policy is based on the general static model in which the price expectations are exogenous. However, in the presence of endogenous price expectations that are rational, anticipated monetary policy does not affect output but the price level only. This result is due to the fact that expectations are formed according to a money supply model, and thus only the part of monetary policy that is not anticipated by the private sector changes output.[1]

Recent empirical research on monetary policy focuses on the effects of anticipated versus unanticipated changes in monetary aggregates. Lucas (1972) concludes that only unanticipated monetary actions can have real effects. This view implies that systematic monetary policies, predictably taken by central banks to offset recessions have no real effects. However, monetarists constructed various models in which anticipated monetary shocks can have real effects.[2]

Empirical literature on the effects of monetary policy does not seem to have a consensus. One can differentiate mainly two strands of methodologies in this area of research. The first one involves a two step procedure: In the first step, a monetary authority reaction function is estimated. Fitted values from this equation are interpreted as anticipated monetary shocks whereas residuals are interpreted as unanticipated monetary shocks. The second step involves the estimation of output growth equation using anticipated and unanticipated data obtained in the first step. The second methodology involves estimation using autoregressive systems. A vector autoregression (VAR) or a near-VAR[3] model is used to analyze the effects of shocks

[1] For a detailed explanation of how the formation of expectations changes theoretical results of monetary policy see for example Branson (1989).

[2] Overlapping contract models (Taylor, 1979), sticky price models (Rotemberg 1982,1994), limited participation models (Grossman and Weiss, 1983; Rotemberg, 1984) are known examples.

[3] See Apppendix 1, for technical information on VAR.

to different variables on the variable of interest. In a VAR system, all variables are endogenous and treated symmetrically. Impulse-response functions obtained from a VAR estimation are used to examine the effects of unanticipated shocks to real aggregate economic activity. However, Cochrane (1998) offers a method to distinguish between anticipated and unanticipated shocks.

Mishkin (1982) and Fackler and Parker (1990) use the first methodology. Mishkin (1982) examines effects of monetary policy on the U.S. economy between 1954 and 1976 using quarterly data with a narrow and also a broad definition of money supply, M1 and M2, as monetary aggregates. Lagged values of monetary aggregates, inflation rate, nominal GNP growth rate, real GNP growth rate, unemployment ratio, treasury bill rate, growth rate of real government expenditures, growth rate of federal debt and balance of payments on current account are used as explanatory variables in money growth equation. Output growth equation is estimated using two different lag specifications and results differ for each lag length. His results concerning the ineffectiveness of monetary policy depends on the lag structure.

Fackler and Parker (1990) also use a two step procedure to analyze the effects of the monetary policy for U.S. economy between 1873 and 1930 (between the Civil War and the Great Depression). Exogenous variables used to estimate money growth equation are the commercial paper rate, a corporate bond rate and the deflator for net national product. Both M2 and monetary base are used as dependent variables. In order to estimate output growth equation, various measures of output are used: net national product, gross national product, commodity output, index of industrial production and the unemployment rate. Fackler and Parker (1990) concludes that even though the unanticipated money expansion affects output, anticipated money expansion does not.

Todd (1990), Sims (1992) and Cochrane (1998) are some of the researchers using autoregressive systems. Todd (1990) analyzes the robustness of VAR results to different specifications and concludes that some results obtained using VAR are not robust across different specifications. Also temporal aggregation does distort the estimates of relationship among variables and that there may be substantial differences between monthly and quarterly models.

Sims (1992) constructs VAR systems for France, Germany, Japan, the U.K. and the U.S. using monthly data including a short term interest rate, M1 as monetary aggregate, consumer price index, industrial production index, exchange rate and commodity price index. Main results of Sims (1990) are: i) There exists a persistent negative response of money stock and output to positive innovations in interest rates; ii) the response of prices to interest rate shocks initially positive in all countries and persistent only for Japan and France; iii) money innovations show some consistency in their effects on prices and the effects are all positive; iv) the response of output to money innovations are small or predominantly negative in all countries, except in Germany and money shock innovations therefore are not a good candidate for interpretation as a monetary policy shock; v) a monetary contraction is expected to increase the value of domestic currency other things being equal. This final result holds for Japan, the U.K. and U.S. in response to interest rate innovations. But in France and in Germany, interest rate innovations are followed by large and persistent declines in the value of domestic currency. Sims (1992) names the positive response of prices to an increase in interest rates as "price puzzle". Sims' explanation of the price puzzle is that the information monetary policy authorities have about inflationary pressures is richer than what can be obtained from the variables in the model. Monetary authorities take necessary measures to dampen the effects of inflation, and prices then rise by less than they would without the policy action (monetary contraction in this case).

Cochrane (1998) employs impulse response functions obtained from a VAR system in order to test whether the assumption that anticipated money affects output changes the VAR based results. He estimates two different VAR using quarterly data for U.S. between 1959 and 1992. The variables used are M1, M2, federal funds rate, consumption, GDP, GDP deflator and commodities price index. In the first VAR Cochrane uses the following variables and ordering: M2, federal funds rate, consumption, GDP, GDP deflator. In the second VAR, the variables in order are consumption, GDP, GDP deflator, commodity price index, M1 and federal funds rate. Results in Cochrane (1998) are: i) Assuming only unanticipated money affects output results in long and large responses of output to a monetary shock; ii) assuming both anticipated and unanticipated monetary shocks can affect output shortens and dampens the response of output.

Aside from the discussion on the effects anticipated/unanticipated monetary policy on real economic activity, another crucial issue is the effect of monetary policy in developing countries. Sargent and Wallace (1981) argue that, if fiscal policy dominates monetary policy; i.e. monetary authority is not independent in determining money supply, then tight monetary policy does not help control inflation, given some conditions. In Turkey, like in other developing countries, fiscal policy dominates monetary policy and leaves less option to monetary authority in terms of targets and instruments. For example, Alper and Üçer (1998) indicate that, the lead-lag relationship between monetary aggregates and inflation disappeared after mid-1980s and strong inertia in inflation dynamics has become central to understanding high inflation in Turkey.

Next, we report the results of some empirical research on the effects of monetary policy in Turkey. Alper (1997) and Yamak and Küçükkale (1998) (henceforth YK) analyze the effects of monetary policy for Turkey. Alper (1997) uses the methodology employed by Kydland and Prescott (1990) and calculates correlation coefficients of the cyclical deviations of each series in consideration with the cyclical deviations of real GNP. The results indicate that foreign exchange rate, interest rates, price level and inflation were all countercyclical while monetary aggregates were acyclic for Turkey. These results suggest that a supply driven economic model is appropriate for Turkey rather than a demand driven one and monetary policy is expected to be ineffective.

YK investigate the effects of anticipated and unanticipated monetary policy on output in Turkey within the period of 1980-1995. They follow McGee and Stasiak (1985) and use a near-VAR model with different lags for each variable. The variables in the system are real output (measured by the industrial production index), M1, nominal government expenditures, consumer price index and Turkish lira value of U.S. dollars. They use correlation coefficient between the residuals of output and money equations as the indicator of the effect of unanticipated money, and coefficients of lagged money in output equation as indicators of effects of anticipated money. YK conclude that anticipated money has significant effects on output but unanticipated money is not effective in determining output in Turkey.

The thesis aims at discovering the effects of the changes in monetary aggregates on the macro variables (output, price level, exchange rate, interest rate and consumption) for the Turkish economy using different methodologies. First, a two step procedure is applied following Mishkin (1982), and then the results of YK are replicated. Finally a VAR system is estimated, following Cochrane (1998), to analyze how anticipated/unanticipated assumption affects the conclusions on monetary policy in Turkey.

Organization of the thesis is as follows: In the second section theoretical background comprising of monetary transmission mechanisms, central bank reaction function and anticipated/unanticipated money model is given. The third section describes data and its characteristics. Section four explains how empirical methods are applied, section five discusses results of the VAR estimation. Finally section six summarizes results and gives some prospects for further research.

II. Theoretical Background

II.A. Monetary Transmission Mechanisms

A monetary transmission mechanism is the way through which the effects of a monetary action are carried over to other variables in the economy. "To be successful in conducting monetary policy, the monetary authorities must have an accurate assessment of the timing and effect of their policies on the economy, thus requiring an understanding of the mechanisms through which monetary policy affects the economy."[4]

Mishkin (1995) differentiates among mainly four channels for monetary transmission. Any monetary policy action following those transmission mechanisms ultimately affects real output though following different ways. Transmission mechanisms include interest rate effects, exchange rate effects, other asset price effects and the so-called credit channel. Relative importance of these mechanisms for an economy depends on the relative weight of the variables explaining the mechanism in the economy. These mechanisms are explained in detail below.

1. *The Interest Rate Channel*

This channel is the traditional Keynesian view of how a monetary tightening is transmitted to the real economy. Expansionary monetary policy causes the short term nominal interest rate to decrease. Then through a combination of sticky prices and

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[4] Mishkin (1995), pp. 3.

rational expectations, the long term real interest rate falls as well, at least for a time. It causes investment and hence the national income to increase.

2. *The Exchange Rate Channel*

When domestic real interest rates fall because of an expansionary monetary policy, domestic currency deposits become less attractive relative to deposits dominated in foreign currencies leading to depreciation of the domestic currency. As a result of the depreciation, imports decrease and exports increase, yielding an increase in net exports and hence in national income.

3. *Other Asset Price Effects*

Tobin's "q theory of investment and wealth effects on consumption" provides a mechanism through which monetary policy affects the economy via its effects on the values of equities. Tobin's q is the market value of firms divided by the replacement cost of capital. Monetary policy also affects equity prices. When the money supply rises, the public has more money than it wants. Public can spend more in the stock market, increasing demand for equities and consequently raising their prices. Or (a more Keynesian story) fall in interest rates makes equities more attractive relative to bonds, thereby causing the price of equities to rise; i.e. Tobin's q to increase. If q is high then market value of business firms is higher than new plant and equipment capital. In this case firms can issue equity and buy new investment goods and new investment increases national income.

4. *Credit Channel*

Credit channel emphasizes how asymmetric information and costly enforcement of contracts create agency problems in credit markets. Expansionary monetary policy causes bank deposits to rise and banks to have more loans to lend. As a result, investment and national income increase. This type of credit channel is also called the bank lending channel.

Another type of credit channel is the balance sheet channel. This channel operates through the net worth of business firms. Expansionary monetary policy generates cash flows; i.e. it increases net worth of firms by decreasing interest rates. Higher net worth means higher value for collaterals which decreases adverse selection. Higher net worth also decreases the moral hazard problem; so business owners do not engage in riskier projects.

Next we analyze how monetary transmission mechanism is linked to the central bank behavior. Suppose that a monetary policy action is taken to change the short-term interest rate. In turn, the change in the short term interest rate has an effect on both the exchange rate and on the long-term interest rate. Given the rigidities in the economy, these changes in nominal rates affect real rates. The changes in real rates then have a short-run effect on real net exports, real consumption and real investment and thereby on output. In the intermediate to long-run, all variables return back to their fundamental levels. Those policy results are also observed by central bank, and used as information for the next policy action. The links of the monetary transmission actually form a circle being closed by linking movements in real output and inflation back to the short-term interest rate through a policy rule or a reaction function.

Central bank behavior is not only described by a one time change in the money supply, but also described by the actions taken in the money market to guide interest rate(s) in a particular way. A complete story of the monetary transmission mechanism should thus include a description of the central bank's reaction function showing how the central bank adjusts the short-term interest rate in response to various targets in the economy, including real output and inflation.

II.B. Central Bank Reaction Function

The macroeconomic policy aspect of many central banks' behavior reflects both their responsibility for controlling inflation as well as some other variables like net domestic assets, net foreign assets, foreign exchange rates and their attention to effects of monetary policy on overall economic activity. A central bank tries to achieve its objective subject to the constraints imposed by the private sector's activities and actions of fiscal authority. As a result, the central bank comes out with a strategy or plan by reviewing the state of the economy. This strategy is the central bank's *monetary policy* and the functional form which represents this behavior can be referred as the *policy reaction function*. This function has two components: the systematic reaction of the policy to economic conditions and unanticipated shifts in the policy (policy shocks).

In order to construct a functional form for monetary policy, we must know the objective of the central bank and its tools available to conduct this policy.

In a country where fiscal policy dominates monetary policy, objective function of the central bank is strictly constrained by that of the fiscal authority. In this case actions of the monetary authority may result in an unfavorable fashion. A main example is related to the response of price level to tight monetary policy. Normally, a tight monetary policy is expected to decrease general price level, but not to raise. However, when fiscal policy dominates monetary policy, the result is a higher inflation than it would be without a tight monetary policy.[5]

Next we explain some approaches describing central bank's behavior.[6]

Single variable approach:

One traditional approach is to use a single variable as an indicator of monetary policy. The common practice is to estimate the relation of the monetary aggregate to the other variables and then interpret the residuals calculated from such an estimation as policy shocks. The assumption underlying this practice is that the estimated relationship represents the central bank's behavior.

Multiple variables approach:

Inadequacy of a single-equation approach in identifying monetary policy led researchers to develop other ways of handling the complex relationships of multiple economic variables. One method is to include both policy instruments and other macroeconomic variables in the same framework, Sims (1992). This method seems superior to single equation approach, since it endogenizes the central bank's reaction and all other variables in the estimated system.

[5] Sargent and Wallace (1981) give a detailed discussion on the effects of tight monetary policy in case monetary authority is not independent.
[6] For a detailed discussion about these approaches, see Zha (1997).

In order to identify the effects of monetary shocks, the common assumption used in multiple variable approach is that different behaviors follow successive relationships. These successive relationships are called *ordering*. A variable in the ordering is contemporaneously affected by all variables proceeding it but contemporaneously affects only the variables succeeding it. For example one may assume that the money stock influences the interest rate contemporaneously but not vice versa, implying that the money supply is perfectly inelastic. This assumption would lead to results that may be inconsistent with the economic theory. Thus, in order to avoid inconsistent implications, successive assumptions should be made carefully, either using economic theory or empirical causality tests.

The importance of making successive assumptions for empirical methodology using multiple variables approach is explained in Appendix 1.

Country specific approaches

Understanding each country's relationship with the rest of the world and each central bank's systematic behavior is a necessary step when one makes identifying assumptions. The monetary policy reaction in any actual economy is complicated and the policy framework is a pragmatic one. In order to find out components of monetary policy in Turkey we must understand the main concerns of, and available instruments to, the Central Bank of Turkey (CBRT).

Monetary policy conducted in recent years in Turkey aimed at stabilizing the financial markets by reducing the variability of inflation rate, interbank interest rates and exchange rates. CBRT chose some target variables, mainly central bank money and reserve money to achive its aims.[7]

II.C. Anticipated-Unanticipated Money Model

In the thesis three different empirical models are estimated. First one is a two step procedure used by Mishkin (1982). This method involves simultaneous estimation of two equations; one is a money supply equation and the other is an output equation.

$$M_t = Z_t \gamma + u_t \tag{1}$$

$$Y_t = \sum_{i=0}^{N} \beta_i \left(M_{t-i} - M^e_{t-i}\right) + \sum_{i=0}^{N} \delta_i M^e_{t-i} + \varepsilon_t \tag{2}$$

where M_t is actual money growth, Y_t is deviation of output from its trend, M^e_t is expected money growth at time t, Z_t is a vector of variables known at time t-1, γ is a vector of coefficients, u_t is an error term assumed to be uncorrelated with any information available at t-1, β_i and δ_i are coefficients, ε_t is an error term and $M^e_t = Z_t \gamma + u_t$.

Money supply equation (1) has two components: anticipated money supply, $Z_t \gamma$, and unanticipated money supply, u_t. Then, equation (2) can be written as

[7] See the declaration of Gazi Erçel in a press meeting held on Jan. 8th, 1998. It can be obtained from the web site of the Central Bank of the Republic of Turkey.

$$Y_t = \sum_{i=0}^{N} \beta_i \left(M_{t-i} - Z_{t-i}\,\gamma\right) + \sum_{i=0}^{N} \delta_i\, Z_{t-i}\,\gamma + \varepsilon_t \qquad (3)$$

The second model is a near-VAR model used by YK following McGee and Stasiak (1985) (henceforth GS). GS estimate trivariate autoregressive model below:

$$\begin{bmatrix} Y_t \\ P_t \\ M_t \end{bmatrix} = \begin{bmatrix} a_{11}(L) & a_{12}(L) & a_{13}(L) \\ a_{21}(L) & a_{22}(L) & a_{23}(L) \\ a_{31}(L) & a_{32}(L) & a_{33}(L) \end{bmatrix} \begin{bmatrix} Y_t \\ P_t \\ M_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{1t} \\ \varepsilon_{1t} \end{bmatrix} \qquad (4)$$

where Y_t, P_t and M_t are the detrended natural logs of real GNP, the GNP deflator, and the money supply, respectively. $a_{ij}(L)$'s are polynomials in the lag operator L, where

$$a_{ij}(L)\,Y_t = \sum_{k=0}^{\alpha} a_{ij}^{k}\, Y_{t-k}\,.$$

In order to identify the autoregressive system in (4), GS make the following assumptions.

$a_{ij}^{0} = 0$ and $cov(\varepsilon_{it}, \varepsilon_{js}) = 0$ for all $t \neq s$, $i = 1,2,3$, and $j = 1,2,3$.

$a_{ij}^{0} = 0$ indicates that effects of all contamporaneous variables are constrained to be zero. In a vector autoregression system, coefficients of some contemporaneous variables must not be zero for the system to be idenfieble. In this sense GS methodology is a constrained version of VAR.

YK extends the structure of GS by including two more variables in the system, namely nominal government expenditures and Turkish lira value of U.S. dollar. Near-VAR model in this study is estimated with the same structure used by YK.

Now, in order to illustrate the connection between two step procedures and autoregressive representations, reconsider Mishkin (1982) model. Suppose, Z_t in equation (1) includes lagged values of M, Y and P. Then equation (1) becomes

$$M_t = \sum_{k=1}^{\alpha} \gamma_{mk} M_{t-k} + \sum_{k=1}^{\alpha} \gamma_{pk} P_{t-k} + \sum_{k=1}^{\alpha} \gamma_{yk} Y_{t-k} + u_t \tag{5}$$

Equations (5) and (2) together construct a restricted form of the system (4) by imposing the constraint $a_{11}(L)=a_{12}(L)=a_{21}(L)=a_{22}(L)=a_{23}(L)=0$.

As our third model, we follow Cochrane's (1998) anticipated/unanticipated model. He identifies affects of anticipated/unanticipated monetary policy using impulse-response functions obtained from a 6-variable VAR system. Now, we will show, in detail, how he identifies different effects of monetary policy.

First consider an empirical model which allows both for anticipated and unanticipated money to affect output.

$$y_t = a_a^*(L)\, m_t + a_u^*(L)\,(m_t - E_{t-1}\, m_t) + b^*(L)\, x_t \tag{6}$$

where y_t is the change in output, $a_a^*(L)$, $a_u^*(L)$ and $b^*(L)$ are coefficient polynomials in the lag operator, m_t is the actual monetary change and, $E_{t-1}\, m_t$ is the anticipated monetary change so that $(m_t - E_{t-1}\, m_t)$ is the unanticipated monetary change and x_t is the vector of other variables in the system.

Cochrane (1998) states that a_a^* and a_u^* are not separately identified and adds to this specification in (6) an ad-hoc assumption that shapes of a_a^* and a_u^* are the same, so that

$$a_a^*(L) = \left(\frac{\lambda}{(1-\lambda)}\right) a_u^*(L) \tag{7}$$

where 0<λ<1. Then, equation (6) can be rewritten as,

$$y_t = a^*(L)\left[\lambda\, m_t + (1-\lambda)\,(m_t - E_{t-1}\, m_t)\right] + b^*(L)\, x_t \tag{8}$$

When λ equals 0, only unanticipated monetary changes explain the changes in output. On the other hand, when λ equals 1, this model assumes no distinction between anticipated and unanticipated money, both are effective in the same way and magnitude.

Let us continue with two variables, y_t and m_t, for the sake of simplicity. We can denote the joint moving average representation of output and money recovered from a VAR as follows,

$$\begin{bmatrix} m_t \\ y_t \end{bmatrix} = \begin{bmatrix} c_{mm}(L) & c_{my}(L) \\ c_{ym}(L) & c_{yy}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{mt} \\ \varepsilon_{yt} \end{bmatrix}, \quad E\left[\begin{bmatrix} \varepsilon_{mt} \\ \varepsilon_{yt} \end{bmatrix} \begin{bmatrix} \varepsilon_{mt} & \varepsilon_{yt} \end{bmatrix}\right] = I \tag{9}$$

where y and m typically represent the detrended log of output and a monetary aggregate. c_{mm}, c_{my}, c_{ym} and c_{yy} represent coefficients of impulse response functions; i.e., $c_{mm,j}$ is the response of money at time t to a money shock occurred at time t-j or response of money at time t+j to a money shock occurred at time t, ε_{mt} and ε_{yt} are structural error terms, with zero covariances and constant variances and

$$c_{mm}(L) = \sum_{i=0}^{L} c_{mm,L-i}$$

We can represent (9) in equation form as

$$m_t = c_{mm}(L)\,\varepsilon_{mt} + c_{my}(L)\,\varepsilon_{yt},$$

$$y_t = c_{ym}(L)\,\varepsilon_{mt} + c_{yy}(L)\,\varepsilon_{yt}. \tag{10}$$

Now substitute (10) into (8) to obtain

$$\begin{aligned} &c_{ym}(L)\,\varepsilon_{mt} + c_{yy}(L)\,\varepsilon_{yt} = \\ &a^{*}(L)\left[\lambda(c_{mm}(L)\,\varepsilon_{mt} + c_{my}(L)\,\varepsilon_{yt}) + (1-\lambda)\,c_{mm,0}\varepsilon_{mt}\right] \end{aligned} \tag{11}$$

where $c_{mm,0}$ is the unanticipated monetary shock. Here, $b^{*}(L)\,x_t$ is not relevant for the moment. Since we aim to identify the effects of monetary shocks (anticipated or unanticipated), we consider only the behavior of ε_{mt}. Equating coefficients of ε_{mt} in (11) obtain yields

$$c_{ym}(L) = a^{*}(L)\left[\lambda\,c_{mm}(L) + (1-\lambda)\,c_{mm,0}\right] \tag{12}$$

where $c_{mm}(L)$ is the aggregate effect of monetary shocks on money; i.e., sum of the anticipated and unanticipated money. Thus, $c_{mm}(L)$ can be decomposed into anticipated and unanticipated money as follows:

$$c_{mm}(L) = c_{mm,0} + \sum_{i=0}^{L-1} c_{mm,L-i} \qquad (13)$$

Then we can separate the effects of anticipated and unanticipated monetary shocks. Substitute (13) into (12) to get

$$c_{ym}(L) = a^*(L)\left[\lambda\left(c_{mm,0} + \sum_{i=0}^{L-1} c_{mm,L-i}\right) + (1-\lambda)\, c_{mm,0}\right]$$

$$c_{ym}(L) = \lambda\, a^*(L) \sum_{i=0}^{L-1} c_{mm,L-1} + a^*(L)\, c_{mm,0}. \qquad (14)$$

An unanticipated money shock affects the output by $a^*(L)$ times shock and an anticipated money shock affects the output by $\lambda\, a^*(L)$ multiples of the shock. Once $a^*(L)$ is identified, we can obtain the effects of anticipated and unanticipated monetary shocks separately for various values of λ. In order to identify $a^*(L)$, we match powers of L in equation (12);

$$c_{ym,0} = a^*(0)\left[\lambda\, c_{mm,0} + (1-\lambda)\, c_{mm,0}\right] \text{ and then } a^*(0) = \frac{c_{ym,0}}{c_{mm,0}} \qquad (15)$$

and we identify $a^*(j)$ as follows:

$$c_{ym,j} = \sum_{k=0}^{j} \left(a^*(k)\,\lambda\, c_{mm,j-k} \right) + a^*(j)\,(1-\lambda)\, c_{mm,0}$$

$$c_{ym,j} = \sum_{k=0}^{j-1} \left(a^*(k)\,\lambda\, c_{mm,j-k} \right) + a^*(j)\,\lambda\, c_{mm,0} + a^*(j)\,(1-\lambda)\, c_{mm,0}$$

$$a^*(j) = \frac{\left[c_{ym,j} - \lambda \sum_{k=0}^{j-1} a^*(k)\, c_{mm,j-k} \right]}{c_{mm,0}} \tag{16}$$

A VAR system treats each variable symmetrically; i.e. each variable is affected by its own past realizations and current as well as the past realizations of other variables. Then, for each variable contained in x_t we can rewrite equation (8) by replacing y_t with this variable and solve for the effects of monetary shocks on the variables other than output.[8]

[8] Let Z_t a set of all variables in the system except m_t and z_t a variable in Z_t and $1 \geq \lambda \geq 0$. Then

$$z_t = a^*(L)\,[\lambda\, m_t + (1-\lambda)\,(m_t - E_{t-1} m_t)] + b^*(L)\,(Z_t \backslash z_t)$$

III. Data

III.A. Data Description

We use various data sets including different measures of variables in different frequencies covering the period 1987-1998, in order to see whether our estimation results are changing with different data specifications. Main difference between monthly and quarterly data sets is that monthly data sets include industrial production index to proxy aggregate economic activity whereas quarterly data sets include gross domestic product as a measure of output and aggregate consumption.

All data were obtained, via web-site, from the data delivery system of CBRT at www.tcmb.com.tr. Overnight interbank rates until 1990 were obtained from the Main Economic Indicators published by State Planning Organization.

As measures of monetary aggregates, Central Bank Money (M0), reserve money (RM), currency in circulation plus demand deposits (M1) and M1 plus demand deposits (M2) are used. Real gross national product (GNP), real gross domestic product (GDP) and industrial production index (IPI) are the measures of output. Nominal government expenditure (GOV) as indicator of fiscal policy in the estimation of near-VAR. Interbank overnight interest rates (ON) is used for short-term interest rate, consumer price index (CPI) for general price level and real private consumption (CNS) for consumption. A basket of exchange rates (EXC) is computed as 0.6 times USD/TRL plus 0.4 times DEM/TRL.

All data except percentages (ON and INF) are used in logarithmic form; so we added the prefix L to each relevant variable. Accordingly, for detrended series a prefix DT, and for seasonal adjusted series a prefix SA, were added to the name of each variable. For example, detrended and then seasonally adjusted log of GDP is SADTLGDP. Trends are removed by using Hodrick-Prescott (HP) filtering technique. All tests, data handling and estimation were conducted with the econometrics software package Econometric Views V. 3.1.

III.B. Data Characteristics

Levels, logarithmic levels, detrended forms and seasonally adjusted forms of all series used in the thesis are represented graphically in Appendix 3. Since modelling techniques for nonstationary series are different from stationary series, an important issue for identification of the series is the stationarity check. Stationarity is tested using Augmented Dickey-Fuller (ADF) unit root test[9] for the level, first difference and second difference of the series. Test results for logarithmic levels of data and for detrended data are reported at Table 1 and Table 2, respectively. If the level of a series is not stationary but the first difference is stationary, then it is integrated of order one, I(1). If the second difference of a series is stationary, then it is integrated of order two, I(2). All critical values are at 5% significance level. Number of lags in each test equation is determined according to correlogram of residuals and Q-statistics of the test equation in levels.

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[9] Appendix 3 describes ADF test procedure.

Table 1. ADF TEST RESULTS FOR LOGARITHMIC LEVELS OF DATA

Name of variable	Test specification*	Calculated test statistic	Critical value	Test specification	Calculated test statistic	Critical value	Test specification	Calculated test statistic	Critical value	Order of integration
LGNP	6, c&t	-2.3168	-3.5247	6, c	-4.9076	-2.9378				I(1)
LGDP	6, c&t	-2.9870	-3.5217	6, c	-5.1068	-2.9358				I(1)
LCNS	6, c&t	-3.1790	-3.5247	6, c	-5.0585	-2.9378				I(1)
LGOV	3, c&t	-1.3471	-3.5136	3, c	-3.5138	-2.9303				I(1)
LIPI	12, c&t	-2.3377	-3.4419	12, c	-4.1304	-2.8819				I(1)
LRM	12, c&t	-2.5218	-3.4557	12, c	-2.3504	-2.8912	12	-5.9158	-1.9434	I(2)
LM0	12, c&t	-2.8799	-3.4557	12, c	-3.4245	-2.8912				I(1)
LM1	12, c&t	-1.5422	-3.4417	12, c	-3.0817	-2.8818				I(1)
LM2	12, c&t	-1.1752	-3.4417	12, c	-2.4519	-2.8818	12	-5.3759	-1.9421	I(2)
ON	4, c	-3.6238	-2.8815							I(0)
LCPI	12, c&t	-2.0068	-3.4445	12, c	-2.5610	-2.8837	12	-5.7114	-1.9424	I(2)
INF	12, c	-2.5604	-2.8837	12, c	-5.6168	-2.8838				I(1)
LEXC	1, c&t	0.9209	-3.4415	1, c	-6.8142	-2.8815				I(1)

* Numbers in test specification column indicate number of lags, c&t means both intercept and trend are used, c means only intercept is used in test specification

Table 2. ADF TEST RESULTS FOR DETRENDED DATA

Name of variable	Test specification	Calculated Statistic	Critical value	Order of integration
DTLGNP	8	-2.7214	-1.9498	I(0)
DTLGDP	8	-2.8824	-1.9495	I(0)
DTLCNS	6	-2.9113	-1.9495	I(0)
DTLIPI	14	-4.0247	-1.9424	I(0)
DTLRM	12	-3.2220	-1.9434	I(0)
DTLM0	12	-3.1678	-1.9434	I(0)
DTLM1	10	-3.8401	-1.9423	I(0)
DTLM2	4	-3.6338	-1.9422	I(0)
DTON	2	-67189	-1.9421	I(0)
DTLCPI	6	-4.2181	-1.9422	I(0)
DTLEXC	2	-3.8581	-1.9421	I(0)

According to ADF test results all LGNP, LGDP, LIPI, LCNS, LEXC, LGOV, INF, LM0, and LM1 are I(1). LRM, LM2 and LCPI are I(2). Interest rate (ON) is stationary. All detrended data are stationary.

IV. Empirical Methodology

We first estimate a two step procedure following Mishkin (1982), and then we replicate the results of Yamak and Küçükkale (1998). Finally, we applied the VAR framework used by Cochrane (1998).

IV.A. Two-Step Framework

As an example of a two-step methodology, a system of two equations is estimated following the methodology used in Mishkin (1982).

$$DTLM1_t = Z_t\gamma + u_t$$

$$DTLIPI_t = \sum_{i=0}^{N} \beta_i \left(DTLM1_{t-i} - Z_{t-i}\gamma\right) + \sum_{i=0}^{N} \delta_i Z_{t-i}\gamma + \varepsilon_t$$

where Z_t includes lagged values of *DTON, DTLCPI, DTLEXC, DTLIPI* and *DTLM*1. $DTLM1_{t-i} - Z_{t-i}\gamma$ represents unanticipated monetary policy and $Z_{t-i}\gamma$ represents anticipated monetary policy.

Number of lags in the money supply equation (the first equation) is four as suggested in Mishkin (1982). However, the length of data period used in the thesis is not appropriate to use the lag length for the output equation that Mishkin (1982) proposed. Hence, we use four lags also for the output equation.

In order to test the effectiveness of monetary policy, both equations are first estimated simultaneously, using SUR technique, without imposing any restrictions on the equations. Here, the variance-covariance matrix of the unrestricted system is obtained. Then, to test the effectiveness of anticipated monetary policy, δ_i's are set to zero, i.e. the second part of the output equation is deleted, and this restricted system is estimated. Using variance-covariance matrices of the unrestricted and restricted systems, we calculate likelihood ratio statistic.[10] This statistic is higher than the 5% critical chi-square value, thus we conclude that anticipated monetary policy affects output in Turkey.

In order to test the effectiveness of unanticipated monetary policy, we repeat the same exercise by restricting the coefficients of unanticipated regressors to zero in the output equation. Likelihood ratio statistic computed for this restricted system again is higher than %5 critical chi-square value.

Using the two-step methodology, we conclude that both anticipated and unanticipated monetary policy effects output significantly in Turkey.

IV.B. Near-VAR Framework

Yamak and Küçükkale (1998) investigate the validity of the policy ineffectiveness hypothesis of Rational Expectations-Natural Rate models that only unanticipated policy changes affect real economic variables for Turkey. Their evidence rejects this hypothesis and concludes that anticipated policy is effective while unanticipated policy is not in determining real economic variables in Turkey. They use an extension of the model of McGee and Stasiak (1985). The autoregressive system constructed by YK is the following one:

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[10] Mishkin (1982) gives detailed information on the use of LR test.

$$\begin{bmatrix} LIPI_t \\ LM1_t \\ LGOV_t \\ LCPI_t \\ LUSD_t \end{bmatrix} = \begin{bmatrix} \alpha_{11}(L) & \alpha_{12}(L) & \alpha_{13}(L) & \alpha_{14}(L) & \alpha_{15}(L) \\ \alpha_{21}(L) & \alpha_{22}(L) & \alpha_{23}(L) & \alpha_{24}(L) & \alpha_{25}(L) \\ \alpha_{31}(L) & \alpha_{32}(L) & \alpha_{33}(L) & \alpha_{34}(L) & \alpha_{35}(L) \\ \alpha_{41}(L) & \alpha_{42}(L) & \alpha_{43}(L) & \alpha_{44}(L) & \alpha_{45}(L) \\ \alpha_{51}(L) & \alpha_{52}(L) & \alpha_{53}(L) & \alpha_{54}(L) & \alpha_{55}(L) \end{bmatrix} \begin{bmatrix} LIPI_t \\ LM1_t \\ LGOV_t \\ LCPI_t \\ LUSD_t \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \end{bmatrix}$$

where L is lag operator, $\alpha_{ij}(L)$'s are polynomials in the lag operator and e_{it} is the innovation of each equation at time t and $LUSD$ is log of USD/TL.

YK use different lag lengths for each equation; four for $LIPI$, two for $LM1$, four for $LCPI$ and six for $LUSD$. We also use the same lag structure to compare our results with theirs.

In order to test the effectiveness of unanticipated money, correlation coefficient between the innovations of the output equation and innovations of money equation is used. If this coefficient is significantly different from zero, then it is concluded that unanticipated money affects output. On the other hand, if the coefficients of the monetary variables in the output equation are jointly and statistically insignificant, it is concluded that anticipated monetary policy does not matter.

The autoregressive system is estimated by SUR technique since innovation terms are not necessarily orthogonal, i.e. they are probably correlated to each other. Estimation results of this near-VAR model obtained in the thesis are reported at Table 3. Our result conforms the YK's estimation by rejecting the null hypothesis that unanticipated money may determine the output. The test criteria is the correlation coefficient between the residuals of output and money equations which is found to be 0.130, not significantly[11] different from zero.

We test for the joint significance of money coefficients in output equation using likelihood ratio statistic and find that anticipated money is significant in determining output in Turkey.

Empirical results, obtained in the thesis -similar to YK's results- using a near-VAR framework, imply that only anticipated monetary policy matters. The fact that unanticipated money does not matter contradicts the results obtained by two step-methodology. In both methodologies, we use different restrictions. In the two step methodology, all variables determining money supply rule, except output, are assumed to be exogenous while in the near-VAR methodology they are assumed to have no contemporaneous relationship. These different restriction structures may cause contradicting results. Next, we apply a VAR framework with less restrictive assumptions than we imposed in the previous two methodologies.

[11] See Alper (1997) for how to decide on the significance of correlation coefficients.

Table 3.1. ESTIMATION RESULTS USING NEAR-VAR WITH QUARTERLY DATA BETWEEN 1987:I-1998:IV

	LIPI	LM1	LGOV	LCPI	LUSD
costant	2.449*	2.748*	0.471	0.891*	-9.171*
LIPI(-1)	0.060	-0.417*	-0.281	0.107*	-0.488*
LIPI(-2)	-0.343*		-0.558	0.099	1.300*
LIPI(-3)	-0.139		-0.490	0.092*	0.746*
LIPI(-4)	-0.485*		1.574*	0.092	1.049*
LIPI(-5)					1.764*
LIPI(-6)					0.158*
LM1(-1)	0.196*	0.674*	-0.162	0.080*	-1.243*
LM1(-2)	-0.291*		0.445	0.084*	1.413*
LM1(-3)	0.147		0.074	0.085	0.214*
LM1(-4)	0.171		0.383	0.089*	0.199*
LM1(-5)					-0.654*
LM1(-6)					-1.327*
LGOV(-1)	-0.019	0.112	0.440*	0.046*	0.176*
LGOV(-2)	-0.048		-0.082	0.037*	-0.365*
LGOV(-3)	0.017		0.333*	0.034*	-0.378*
LGOV(-4)	0.201*		-0.586*	0.042	-0.053*
LGOV(-5)					-0.128*
LGOV(-6)					0.165*
LCPI(-1)	-1.416*	0.163	1.673*	0.212*	1.121*
LCPI(-2)	0.283		1.145	0.170	1.648*
LCPI(-3)	0.387		-0.895	0.154*	0.264*
LCPI(-4)	0.237		-0.668	0.188	-0.859*
LCPI(-5)					0.471*
LCPI(-6)					-0.118
LUSD(-1)	0.222*	0.060	-0.698	0.082	0.673*
LUSD(-2)	-0.049		-0.334	0.061*	-0.069
LUSD(-3)	0.058		-0.228	0.069*	-1.056*
LUSD(-4)	0.016		0.336	0.071	0.170*
LUSD(-5)					0.610*
LUSD(-6)					-1.109*

Table 3.2. CORRELATION MATRIX OF RESIDUALS

Variables	LIPI	LGOV	LUSD	LCPI
LGOV	-0.467*			
LUSD	-0.610*	0.415*		
LCPI	-0.646*	0.671*	0.176	
LM1	-0.130	0.198	0.123	0.220*

Note: * significant at the %10 level.

IV.B. VAR Framework

The structural VAR model constructed for Turkey in the thesis is as follows:

$$\begin{bmatrix} 1 & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} & \beta_{16} \\ \beta_{21} & 1 & \beta_{23} & \beta_{24} & \beta_{25} & \beta_{26} \\ \beta_{31} & \beta_{32} & 1 & \beta_{34} & \beta_{35} & \beta_{36} \\ \beta_{41} & \beta_{42} & \beta_{43} & 1 & \beta_{45} & \beta_{46} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & 1 & \beta_{56} \\ \beta_{61} & \beta_{62} & \beta_{63} & \beta_{64} & \beta_{65} & 1 \end{bmatrix} \begin{bmatrix} M_t \\ ON_t \\ Y_t \\ CNS_t \\ CPI_t \\ EXC_t \end{bmatrix} = \begin{bmatrix} b_{11}(L) & b_{12}(L) & b_{13}(L) & b_{14}(L) & b_{15}(L) & b_{16}(L) \\ b_{21}(L) & b_{22}(L) & b_{23}(L) & b_{24}(L) & b_{25}(L) & b_{26}(L) \\ b_{31}(L) & b_{32}(L) & b_{33}(L) & b_{34}(L) & b_{35}(L) & b_{36}(L) \\ b_{41}(L) & b_{42}(L) & b_{43}(L) & b_{44}(L) & b_{45}(L) & b_{46}(L) \\ b_{51}(L) & b_{52}(L) & b_{53}(L) & b_{54}(L) & b_{55}(L) & b_{56}(L) \\ b_{61}(L) & b_{62}(L) & b_{63}(L) & b_{64}(L) & b_{65}(L) & b_{66}(L) \end{bmatrix} \begin{bmatrix} M_t \\ ON_t \\ Y_t \\ CNS_t \\ CPI_t \\ EXC_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix}$$

where M_t is one of the measures of money supply at time t, Y_t is one of the measures of real output at time t, β_{ij}'s are coefficients of contemporaneous variables, L is lag operator, $b_{ij}(L)$'s are polynomials in the lag operator. ε_{it}'s are white noise disturbances with constant variations, and are uncorrelated to each other. The VAR in standard form can be written as:

$$\begin{bmatrix} M_t \\ ON_t \\ Y_t \\ CNS_t \\ CPI_t \\ EXC_t \end{bmatrix} = \begin{bmatrix} a_{11}(L) & a_{12}(L) & a_{13}(L) & a_{14}(L) & a_{15}(L) & a_{16}(L) \\ a_{21}(L) & a_{22}(L) & a_{23}(L) & a_{24}(L) & a_{25}(L) & a_{26}(L) \\ a_{31}(L) & a_{32}(L) & a_{33}(L) & a_{34}(L) & a_{35}(L) & a_{36}(L) \\ a_{41}(L) & a_{42}(L) & a_{43}(L) & a_{44}(L) & a_{45}(L) & a_{46}(L) \\ a_{51}(L) & a_{52}(L) & a_{53}(L) & a_{54}(L) & a_{55}(L) & a_{56}(L) \\ a_{61}(L) & a_{62}(L) & a_{63}(L) & a_{64}(L) & a_{65}(L) & a_{66}(L) \end{bmatrix} \begin{bmatrix} M_t \\ ON_t \\ Y_t \\ CNS_t \\ CPI_t \\ EXC_t \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \\ e_{6t} \end{bmatrix}$$

where a_{ij}'s are polynomials in the lag operator for standard form VAR and e_{it}'s are innovations to each equation, and are functions of structural ε_{it}'s and β_{ij}'s.

In the third section, all measures of those variables used in the above VAR system are explained. In ADF tests some of those measures are found to be I(1), some I(2), while some I(0). If we could have found a set in which all variables are I(1), i.e. integrated of the same order, then we could use an error correction form of VAR (VEC). However, interbank overnight interest rate (ON) is I(0), and other variables are I(1) or I(2). Thus, detrended forms of all series are used in the VAR. All detrended series used in the thesis are found to be stationary at %5 significance level using ADF test.

Determination of Lag Lengths

Before estimating VAR model number of lags used must be determined. Lag length for both monthly and quarterly VAR are determined according to Schwarz Information Criterion (SC). SC values for monthly and quarterly VAR are reported in Table 4. Lag length which minimize SC has to be chosen. For both data frequencies, lag length suggested by SC information criterion is one.

Table 4. SC VALUES FOR MONTHLY AND QUARTERLY VAR MODELS USING DETRENDED DATA AND SEASONAL DUMMIES

Lag length / Data frequency	1	2	3	4	5	6	7	8	9	10	11	12
Monthly	-4.39	-4.28	-3.94	-3.40	-2.59	-1.87	-1.08	-0.43	0.16	0.63	1.22	1.64
Quarterly	-8.17	-7.23	-6.41	-6.72								

Exogeneity Tests

In order to determine whether some of the variables used are redundant or not, exogeneity tests are conducted. The test statistic used for exogeneity test is likelihood ratio statistic defined as:

$$LR = (T-C) * (\log|\Sigma_r| - \log|\Sigma_u|),$$

where T is the number of usable observations, C is the number of parameters estimated in each equation, $|\Sigma_r|$ is the determinant of residual variance-covariance matrix of the restricted VAR and $|\Sigma_u|$ is the determinant of residual variance-covariance matrix of the unrestricted VAR. LR statistic has a χ^2 distribution with degrees of freedom being equal to the number of restrictions. χ^2 statistics, reported at Table 4 for each variable is obtained by deleting this variable from the VAR and computing Σ_r. The 5% critical value for χ^2 statistic is $\chi^2_{0.95,1} = 3.84$. If computed statistics for a variable in Table 5 is less than this critical value, redundancy of the variable cannot be rejected. All computed statistics are greater than 3.84, ie. none of the variables is redundant.

Table 5. COMPUTED χ^2 STATISTICS FOR EXOGENEITY TEST

Deleted variable / Data frequency	DTLGNP	DTLCNS	DTLIPI	DTON	DTLM1	DTLCPI	DTLEXC
Monthly			796.42	-693.37	744.26	1074.56	926.52
Quarterly	243.01	245.38		-128.12	185.47	218.89	205.41

Ordering of Variables

Ordering of variables describes contemporaneous relationship among variables in a VAR system by imposing some restrictions on this relationship in order to identify effects of structural error terms. In the thesis two different orderings are applied in order to see whether the qualitative results are sensitive to different orderings or not.

The first ordering is M, ON, CNS, Y, CPI, EXC. This ordering, excluding EXC, is used by Cochrane (1998) measure the effects of changes in aggregate money supply. Exchange rate is not included in Cochrane (1998), however it is an important variable for the conduct of monetary policy in Turkey, so we include it. The ordering implies that changes in monetary aggregate is contemporaneously independent but only affected by the lagged values of other variables in the economy; i.e. monetary policy is autonomous.

The second ordering, again borrowed from Cochrane (1998), is CNS, Y, CPI, EXC, M, ON. This ordering implies that monetary authority uses interest rates as a policy tool (Cochrane uses federal funds rate) and can have information about economic variables instantly and react accordingly. It also implies that prices are sticky and do not respond instantaneously to changes in the interest rates, exchange rates and changes in the monetary aggregate but respond to lagged values of these variables.

Impulse-Response Functions

Impulse-response functions of monthly and quarterly VAR obtained using different measures of variables and different orderings are presented in Appendix 5.

Assuming different weights for anticipated and unanticipated effects of monetary variables, how other variables respond is presented in Appendix 6. As we explained in the "Anticipated/Unanticipated Money Model" part of the second section, effects of anticipated and unanticipated shocks are computed using λa^* and a^* respectively. λ presents the weight of the anticipated monetary policy. Computation of a^* is given in equations 15-16. Four different values are assumed for λ and four different graphs are obtained accordingly for each type of shock. Top panels of the figures in Appendix 6 represent responses of variables to an unanticipated monetary policy, and bottom panels represent responses of variables to an anticipated monetary policy.

Shocks on M1 and ON are used as monetary policy shocks and responses of each variable to these shocks are graphed in figures 14-21. These results are discussed in the following section.

V. VAR Results

Since the thesis focuses on the effects of monetary shocks, in this section only the responses to monetary shocks are discussed.

V.A. Impulse-Response Functions

In Appendix 5, impulse-response functions of various VAR implementations are reported. Effects of changes in various monetary aggregates are similar across four different monetary aggregates; reserve money (RM), central bank money (M0), M1 and M2. However, effects of RM and M0 on other variables are always insignificant except for the effect of RM on output. A positive shock to RM above its trend value affects output (IPI) negatively during two months, then positively during next five months. Responses of output to the shocks in M1 and M2 are similar to response of output to RM.

Positive shocks to M1 and M2 affect short term interest rates (ON) negatively, as anticipated. However, price (CPI) and exchange rate (EXC) responses contradict expectations. This negative response of price to a positive shock in money is called as 'price puzzle' by Sims (1992). If we use Sims (1992)'s explanation for this puzzle, we must say that CBRT has more accurate information than we can obtain from the available data. Thus CBRT knows that an inflationary pressure is arriving and takes necessary action, i.e. contracts money supply. Then, price level rises less than it would do in the absence of CBRT's action.

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Another puzzling result is the appreciation of Turkish lira in response to monetary expansion. This result may be explained with the existence of capital inflows. In case of a capital inflow, unless it is sterilized completely, money supply increases and Turkish lira appreciates. Thus, we may observe monetary expansion as well as currency appreciation. Exchange rate responses to all variables are similar to price responses. Since Turkey is a high inflation country, this observation may be explained by strong comovement of nominal variables..

Effects of interest rate also contain puzzles. When M2 is used as monetary aggregate there exists a 'liquidity puzzle', i.e. M2 raises above its trend value when ON jumps over its trend. If, M1 is used instead of M2, then liquidity puzzle disappears. However, in all cases 'price puzzle' remains. Positive ON shocks affect IPI negatively; whenever interest rate raises, output significantly decreases at least during six months.

In order to calculate these effects, values of impulse-response functions in Figure 7 are employed.

Responses to expansionary monetary policy defined by a positive shock on M1

In the top panel of Figure 14, in Appendix 6, response of ON to an unanticipated change in M1 is presented. $\lambda=1$ indicates that effects of anticipated and unanticipated money are the same, $\lambda=0$ indicates that only unanticipated money can have effects, and $0<\lambda<1$ indicates that both anticipated and unanticipated money can have effects. λ is the weight of the effect of anticipated money and $(1-\lambda)$ is the weight of the effect of unanticipated money.

When anticipated and unanticipated money are assumed to have the same effects, an unanticipated shock to M1 affects ON negatively during the first 3 months. Then response of ON becomes positive and reverts to zero at the end of tenth month. When it is assumed that only unanticipated money is effective, the negative response of ON becomes larger and longer. For intermediate assumptions ($0<\lambda<1$), the size and the length of the response are intermediate compared to $\lambda=1$ and $\lambda=0$ cases. Effect of an anticipated shock is smaller than unanticipated shock for intermediate cases while it is the same as unanticipated shock for $\lambda=1$ and zero for $\lambda=0$.

Responses of output are presented in Figure 15. Output response to an unanticipated M1 shock becomes longer as λ gets smaller; assuming only unanticipated money can affect output lengthens the response period of output.

Response period of prices and exchange rates have the same characteristic as output, i.e. assuming only unanticipated money can affect prices or exchange rates lengthens the response period of these variables. Figures 16 and 17 represent responses of prices and exchange rates to various M1 shocks respectively.

Responses to a contractionary monetary policy defined by a positive shock on ON

Effects of interest rates on other variables are presented in Figures 18-21. As in the responses of variables to M1 shocks, assuming both anticipated and unanticipated ON shocks can have effects shortens the response periods of all variables. As it is mentioned in the beginning of this section, price and exchange rate responses are puzzling. However, if interest payments have a large share in the cost of production then it may play a role in shifting aggregate supply curve upward so that total output decreases and prices increases with a rise in interest rates. Alternatively, foreign capital flow may cause interest rates to raise and at the same time monetary aggregates to grow.

VI. Conclusion

In the thesis, effects of anticipated and unanticipated monetary shocks on some macro variables (interest rates, real output, prices and exchange rates) are examined for Turkey in the period 1987-1998 using three different methodologies, various data descriptions, monthly and quarterly data frequencies.

Some results obtained from the VAR estimation are in line with economic theory while some are not. Main contradiction is in the response of prices to monetary shocks. As a result of an increase in money, price level is normally expected to rise. Surprisingly, for all measures of money used in the thesis, prices respond with a decrease to a positive shock in money and with an increase to a positive shock in interest rates. However, this contradictionary result has been obtained by Sims (1992) also. Sims (1992) has called this result as 'price puzzle' and pointed an excuse for this contradiction. According to Sims (1992) the information a monetary authority has about monetary pressures probably is better than what can be obtained from the variables in a model. Thus, authorities may know that inflationary pressure is arriving and take actions to dampen the effects of inflation. Then prices would rise by less than they would do without the policy action.

Another puzzle is in the response of interest rate to changes in money. Estimation results using M2 as monetary aggregate show that short term interest rate increases with a positive shock to money. However, using M1 as monetary aggregate corrects the result, so that M1 is used instead of M2 in analyzing separate effects of anticipated and unanticipated money in the thesis.

Response of exchange rate to monetary shocks is almost similar to the response of price. In high inflation countries, like Turkey, price level is an important determinant of exchange rates. Thus, almost comovements of price and exchange rate is a normal case.

Output response in some cases is found to be significant and positive for both anticipated and unanticipated positive monetary shocks. However, these output responses are very small and for some measures of money they are totally insignificant. On the other hand, output response to a positive interest rate shock has been always significantly negative in all cases, under different monetary and output measures and different orderings.

When it is assumed that not only unanticipated but also anticipated money affect other macro variables, responses of variables to monetary shocks get shorter and revert to zero quickly.

In order to conclude, some suggestions may be proposed for further research on the effects of monetary shocks. Recent studies by Weiss (1999) and Karras and Stokes (1999) inquiry asymmetric effects of monetary shocks; i.e. positive shocks may have different effects than negative ones, or responses of variables to monetary shocks may be different according to the size of the shock. A further investigation for Turkey in this area would probably be very fruitful.

Appendix 1. Vector Autoregressions and Impulse Response Functions

A system of vector autoregressions (VARs) is a multiequation system in which each variable in the system is endogenous and treated symmetrically. This system is developed by Christopher Sims at 1980. Sims's structural model takes the form:

$$B\,z_t - \sum_{j=1}^{p} \Gamma_j z_{t-j} = \varepsilon_t \qquad (1)$$

where z_t is an (Nx1) vector of all the current variables included in the model; the B's and Γ_j are (NxN) coefficient matrices, z_{t-j}'s are (Nx1) vectors of lagged variables of order j and ε_t is (Nx1) vector of white noise disturbances each element of which has a constant standard deviation and is uncorrelated with other elements. In the model there are no exogenous variables, but only predetermined variables. Further, it is assumed that no economic theory can be used to set elements of structural form matrices to zero. Thus this approach proceeds from the assumption that B and all the Γ_j are full matrices. This type of modeling does not assume any behavioral relationship among variables. It is in this sense that Sims's work has been labeled 'atheoretical'.

Suppose that z_t vector consists of two variables, m_t and y_t, and number of lags is one for simplicity. Then,

$$m_t = -B_{1y}y_t + \Gamma_{1m}\, m_{t-1} + \Gamma_{1y}\, y_{t-1} + \varepsilon_{mt}$$

$$y_t = -B_{2m}m_t + \Gamma_{2m}\, m_{t-1} + \Gamma_{2y}\, y_{t-1} + \varepsilon_{yt} \qquad (2)$$

In each equation of structural VARs one of the variables is explained as a function of lagged values of itself and current and lagged values of all other variables. The structure of the system incorporates feedback since m_t and y_t are allowed to affect each other. The terms ε_{mt} and ε_{yt} are pure innovations -with standard deviations σ_m and σ_y- in m_t and y_t respectively. If B_{2m} is not equal to zero, ε_{mt} has an indirect contemporaneous effect on y_t, and if B_{1y} is not equal to zero ε_{yt} has an indirect contemporaneous effect on m_t . By rearranging each equation it is possible to obtain reduced form equations

$$\begin{bmatrix} 1 & B_{1y} \\ B_{2m} & 1 \end{bmatrix} \begin{bmatrix} m_t \\ y_t \end{bmatrix} = \begin{bmatrix} \Gamma_{1m} & \Gamma_{1y} \\ \Gamma_{2m} & \Gamma_{2y} \end{bmatrix} \begin{bmatrix} m_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{mt} \\ \varepsilon_{yt} \end{bmatrix}$$

or $$Bz_t = \Gamma_1 z_{t-1} + \varepsilon_t \,. \qquad (3)$$

Then VAR model in standard reduced form for one lagged example can be written as:

$$z_t = A_1 z_{t-1} + e_t \qquad (4)$$

where $A_1 = B^{-1}\Gamma_1$ and $e_t = B^{-1}\varepsilon_t$.

The VARs reduced form in general is

$$z_t = \sum_{j=1}^{p} A_j z_{t-j} + e_t \,. \qquad (5)$$

To use VARs for policy analysis it should first be understood that policy is interpreted narrowly to mean the addition of a known innovation shock to the model. The VAR models are driven by stochastic shocks and the intention is to trace out the reaction of the system to a random shock. Thus, writing the moving average representation of the model

$$z_t = \sum_{j=0}^{\infty} D_j e_{t-j} \qquad D_0 = I \tag{6}$$

where the D_j's are (NxN) matrices, and recalling that $e_t = z_t - E_{t-1}(z_t)$, it is possible to trace out the likely effects of unanticipated shocks to the ith variable z_{it} on subsequent values of all the variables. However, e_t's are contemporaneously correlated. Remember that $e_t = B^{-1}\varepsilon_t$ and for two variable example we have

$$e_{yt} = (\varepsilon_{yt} - B_{2m}\,\varepsilon_{mt}) \,/\, (1-B_{1y}B_{2m}) \quad \text{and} \quad e_{mt} = (\varepsilon_{mt} - B_{1y}\,\varepsilon_{yt}) \,/\, (1-B_{1y}B_{2m}). \tag{7}$$

By substituting (7) into (6) we can obtain moving average representation of the system by means of structural error terms which have constant standard deviations and uncorrelated with each other:

$$z_t = \sum_{j=0}^{\infty} C_j \varepsilon_{t-j} \tag{8}$$

where C_j's are (NxN) matrices of coefficients. Again for two-variable example, (8) can be written as

$$\begin{bmatrix} m_t \\ y_t \end{bmatrix} = \Sigma \begin{bmatrix} C_{mm}(i) & C_{my}(i) \\ C_{ym}(i) & C_{yy}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{mt-i} \\ \varepsilon_{yt-i} \end{bmatrix}. \tag{9}$$

These coefficients can be used to generate the effects of and shocks on the entire time path of $\{ m_t \}$ and $\{ y_t \}$ sequences. The coefficient $C_{my}(0)$ is the instantaneous impact of a one-unit change in ε_{yt} on m_t. In the same way, the elements $C_{mm}(1)$ and $C_{my}(1)$

are the one period responses of unit changes in ε_{mt-1} and ε_{yt-1} on m_t respectively. Updating by one period indicates that $C_{mm}(1)$ and $C_{my}(1)$ also represent the effects of unit changes in on ε_{mt} and ε_{yt} on m_{t+1} . This set of coefficients, $C_{mm}(i)$, $C_{my}(i)$, $C_{ym}(i)$ and $C_{yy}(i)$ are called the *impulse response functions*.

In principle, it might be possible to know all the parameters of the structural system. However, an estimated VARs is underidentified; i.e. it is not possible to calculate all of the structural form parameters from reduced form estimation. Remember from (2) that structural two-variable VARs system contains eight parameters; B_{1y}, Γ_{1m} , Γ_{1y} , σ_m, B_{2m} , Γ_{2m} , Γ_{2y} , σ_y. Using reduced form two-variable VARs only seven parameters; four for coefficients of lagged variables, two for variance of error terms and one for covariance of error terms (in structural system error terms are uncorrelated so that covariance of error terms are zero). Hence, the econometrician must impose an additional restriction on the two-variable VARs and (n-1) restrictions for n-variable VARs system in order to identify the impulse-responses. If we continue with the two-variable system, it is possible to constrain the system such that the contemporaneous value of y_t does not have a contemporaneous effect on m_t. Formally, this restriction is represented by setting B_{1y}=0 in the structural system (2). The error terms can then be decomposed using (7) as follows:

$$e_{yt} = \varepsilon_{yt} - B_{2m}\,\varepsilon_{mt} \quad \text{and} \quad e_{mt} = \varepsilon_{mt} \tag{10}$$

The key point is that the decomposition forces a potentially important asymmetry on the system since an ε_{mt} shock has contemporaneous effects on both m_t and y_t. For this reason (10) is said to imply an ordering of the variables; m_t is prior to y_t. For more variables, the variables in the system are ordered so that an error term in any equation will only affect error terms below it in the ranking. Therefore, in general, each equation in a VARs system will include the current values of the dependent variable from each previous equation in the ordering, along with lagged values of all variables and current innovations in the dependent variable.

Each equation in the reduced form VARs can be estimated using ordinary least squares (OLS) technique. Since there are identical regressors in each equation, OLS estimates of parameters are consistent and asymptotically efficient. If some of the VARs equations have regressors not included in the others, seemingly unrelated regressions (SUR)[12] technique provide efficient estimates of the VARs coefficients. Hence, when there is a good reason to let lag lengths differ across equations, we can estimate the so-called *near VARs* using SUR.

If a VAR contains nonstationary variables of the same order then the existence of cointegration relationship(s) between variables should be investigated (see Johansen & Juselius (1990)) . If any cointegrating relationship is detected then a vector error correction model (VEC) should be applied.[13]

[12] The seemingly unrelated regression (SUR) method, also known as the multivariate regression, or Zellner's method, estimates the parameters of the system, accounting for heteroskedasticity, and contemporaneous correlation in the errors across equations.

[13] see Enders (1995), pp.355-421.

Appendix 2. Central Bank of Turkey - Analytical Balance Sheet

A. ASSET

A.1.- FOREIGN ASSETS

A.2- DOMESTIC ASSETS

A.2-a- Cash Operations

A.2-aa- Credits to the Public Sector

A.2-ab- Credits to the Banking Sector

A.2-ac- Other Items

P. LIABILITY

P.1- TOTAL FOREIGN LIABILITIES

P.2- CENTRAL BANK MONEY

P.2-A- RESERVE MONEY

P.2.Aa- Currency Issued

P.2-Ab- Deposit of Banking Sector

P.2-Aba- Required Reserves

P.2-Abb- Free Deposits

P.2-Ac- Extrabudgetary Funds

P.2-Ad- Deposits of Non-Bank Sector

P.2-B- OTHER CENTRAL BANK MONEY

P.2-Ba- Open Market Operations

P.2-Bb- Deposits of Public Sector

Appendix 3. The Augmented Dickey-Fuller (ADF) Test

To illustrate the use of Dickey-Fuller tests, consider first an AR(1) process:

$y_t = \mu + \rho y_{t-1} + \varepsilon_t,$

where μ and ρ are parameters and ε_t is assumed to be white noise. Here y is a stationary series if $-1<\rho<1$. If $\rho=1$, y is a nonstationary series (a random walk with drift); if the process starts at some point, the variance of y increases steadily with time and goes to infinity. If the absolute value of ρ is greater than one, the series is explosive. Therefore, the hypothesis of a stationary series can be evaluated by testing whether the absolute value of ρ is strictly less than one. DF test takes the unit root as the null hypothesis H_0: $\rho=1$. Since explosive series do not make much economic sense, this null hypothesis is tested against the one-sided alternative H_1: $\rho<1$.

The test is carried out by estimating an equation with y_{t-1} subtracted from both sides of the equation:

$\Delta y_t = \mu + \gamma y_{t-1} + \varepsilon_t,$

where $\gamma=\rho-1$ and the null and alternative hypotheses are

$H_0: \gamma = 0, \quad H_1: \gamma < 0$.

While it may appear that the test can be carried out by performing a t-test on the estimated γ, the t-statistic under the null hypothesis of a unit root does not have the conventional t-distribution. Dickey and Fuller (1979) showed that the distribution under the null hypothesis is nonstandard, and simulated the critical values for selected sample sizes. More recently, MacKinnon (1991) has implemented a much larger set of simulations than those tabulated by Dickey and Fuller. In addition, MacKinnon estimates the response surface using the simulation results, permitting the calculation of Dickey-Fuller critical values for any sample size and for any number of right-hand variables. Eviews, the econometric software package used in the thesis, reports these MacKinnon critical values for unit root tests.

The simple unit root test described above is valid only if the series is an AR(1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances is violated. The ADF test makes a parametric correction for higher-order correlation by assuming that the y series follows an AR(p) process and adjusting the test methodology.

The ADF approach controls for higher-order correlation by adding lagged difference terms of the dependent variable y to the right-hand side of the regression:

$$\Delta y_t = \mu + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \ldots + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t .$$

This augmented specification is then used to test

$H_0: \gamma = 0, \quad H_1: \gamma < 0$

in this regression.

Appendix 4. Data Graphs

Figure.1. Data in levels (RM, M0, M1, M2, GNP, GDP, CNS and GOV are in billions TL.)

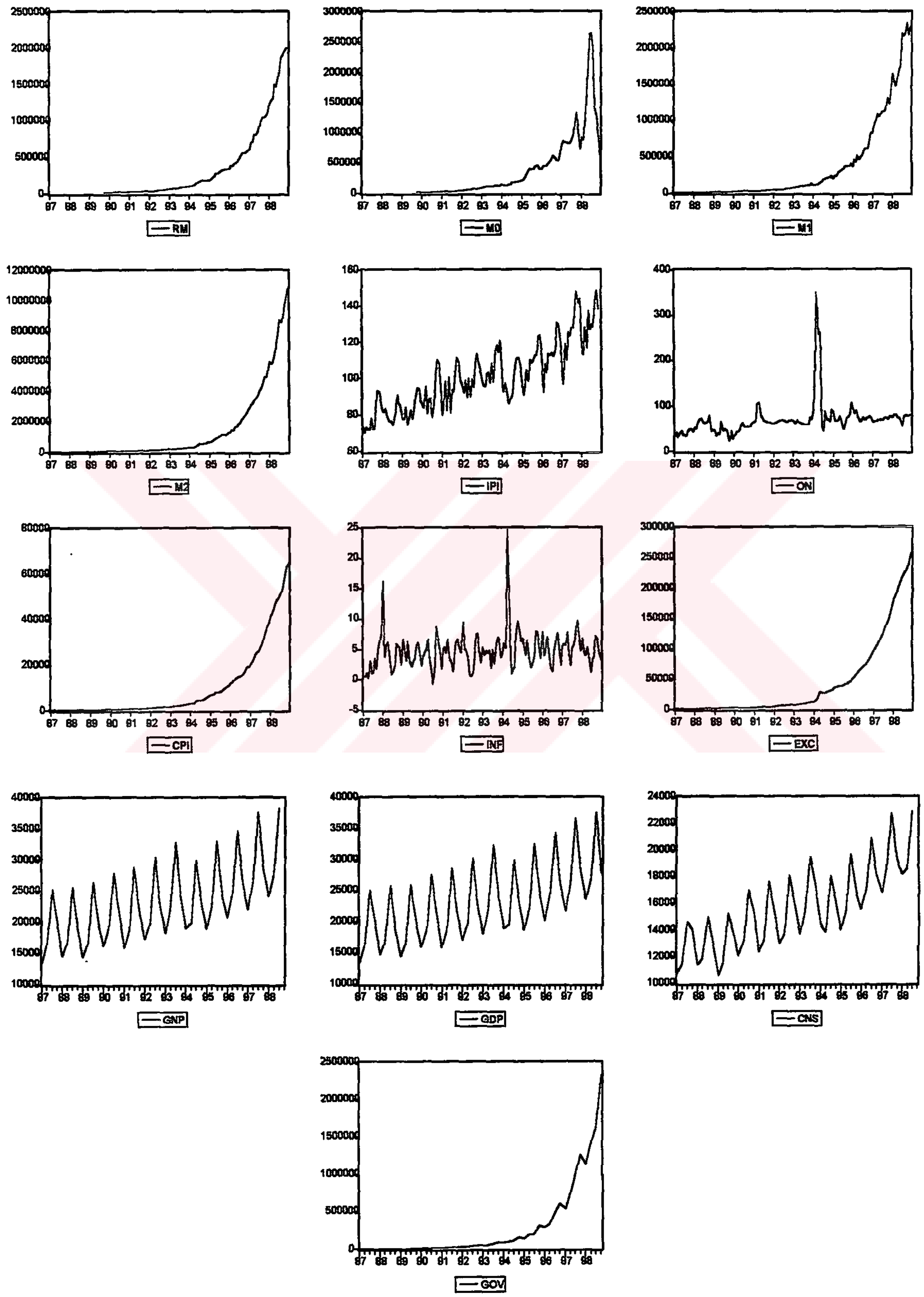


Figure 2. Data in logarithms

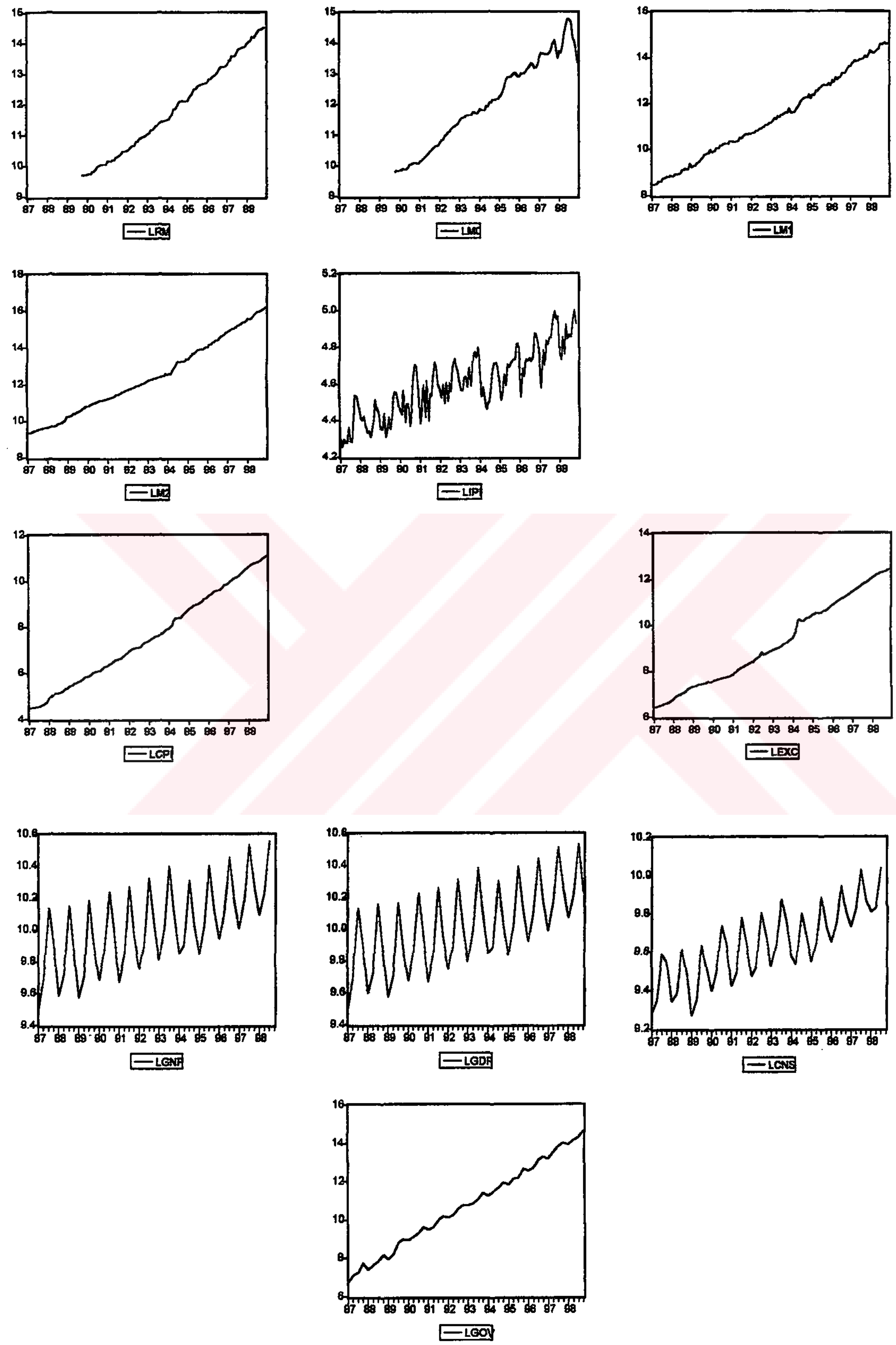


Figure 3. Detrended data

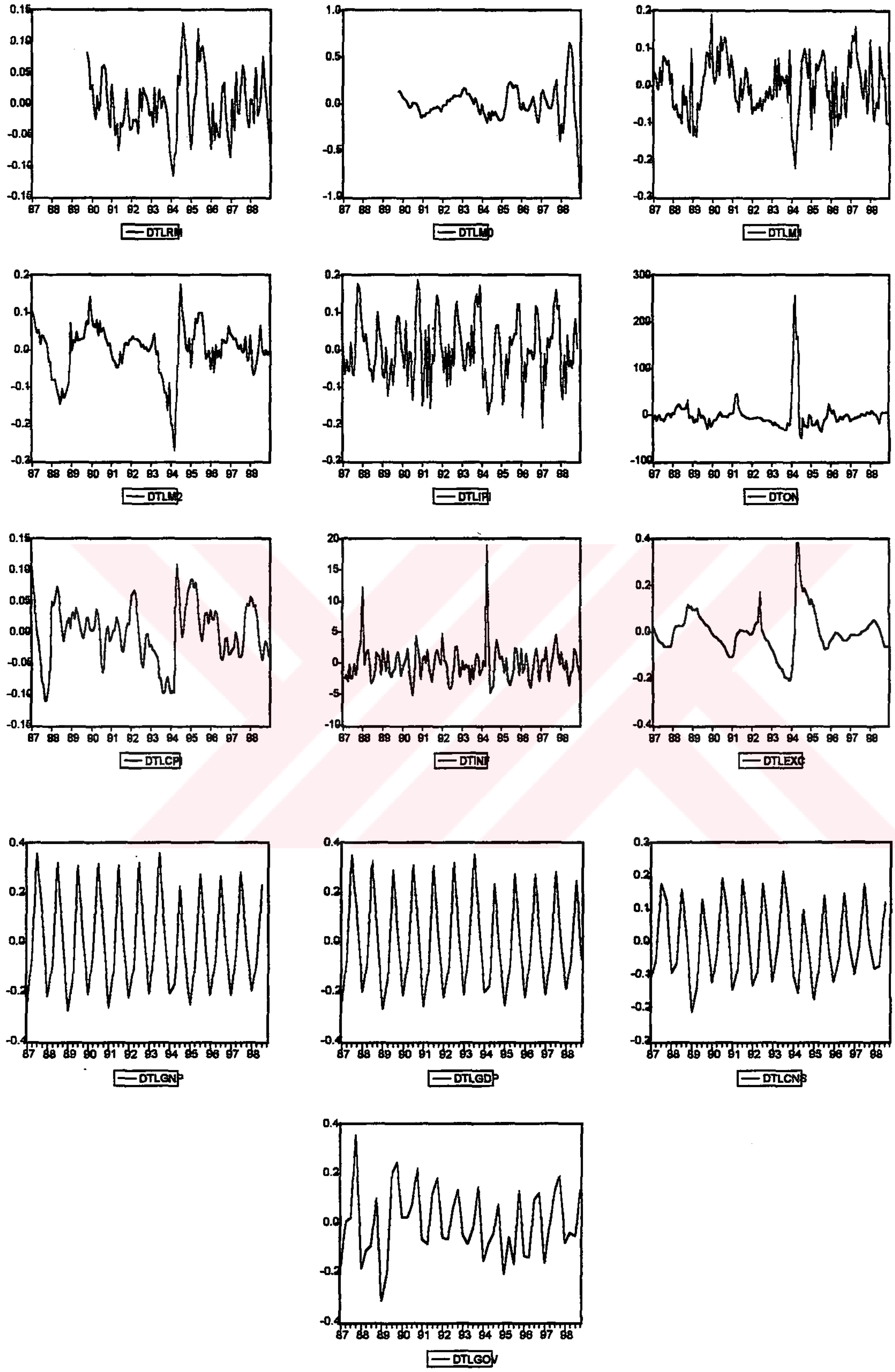
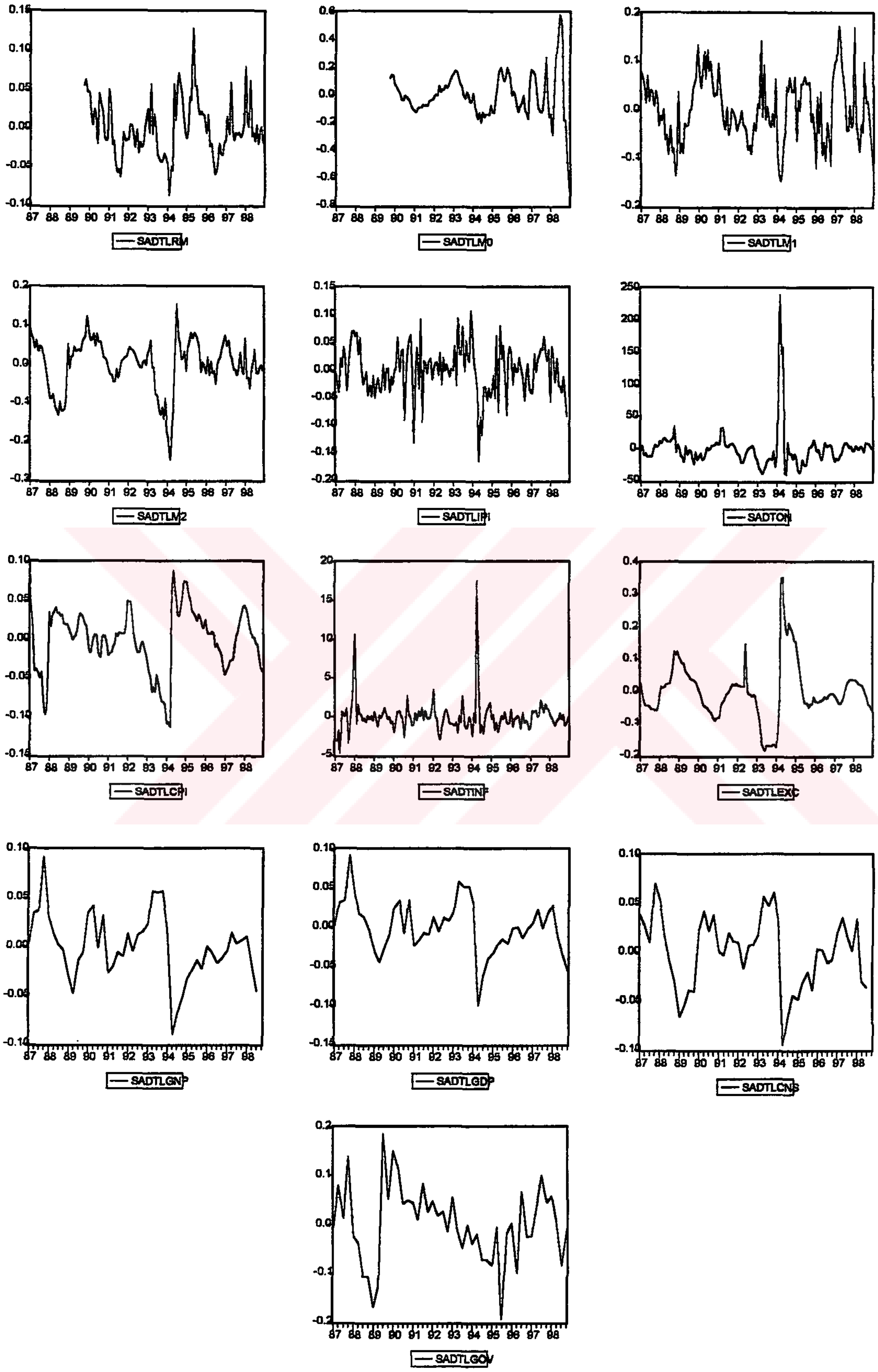


Figure 4. Seasonally adjusted and detrended data



Appendix 5. Graphs of Impulse Response Functions

Figure 5. Monthly VAR Impulse-Responses using reserve money as monetary aggregate and detrended log of all variables with seasonal dummies. Ordering is DTLRM, DTON, DTLIPI, DTLCPI,DTLEXC

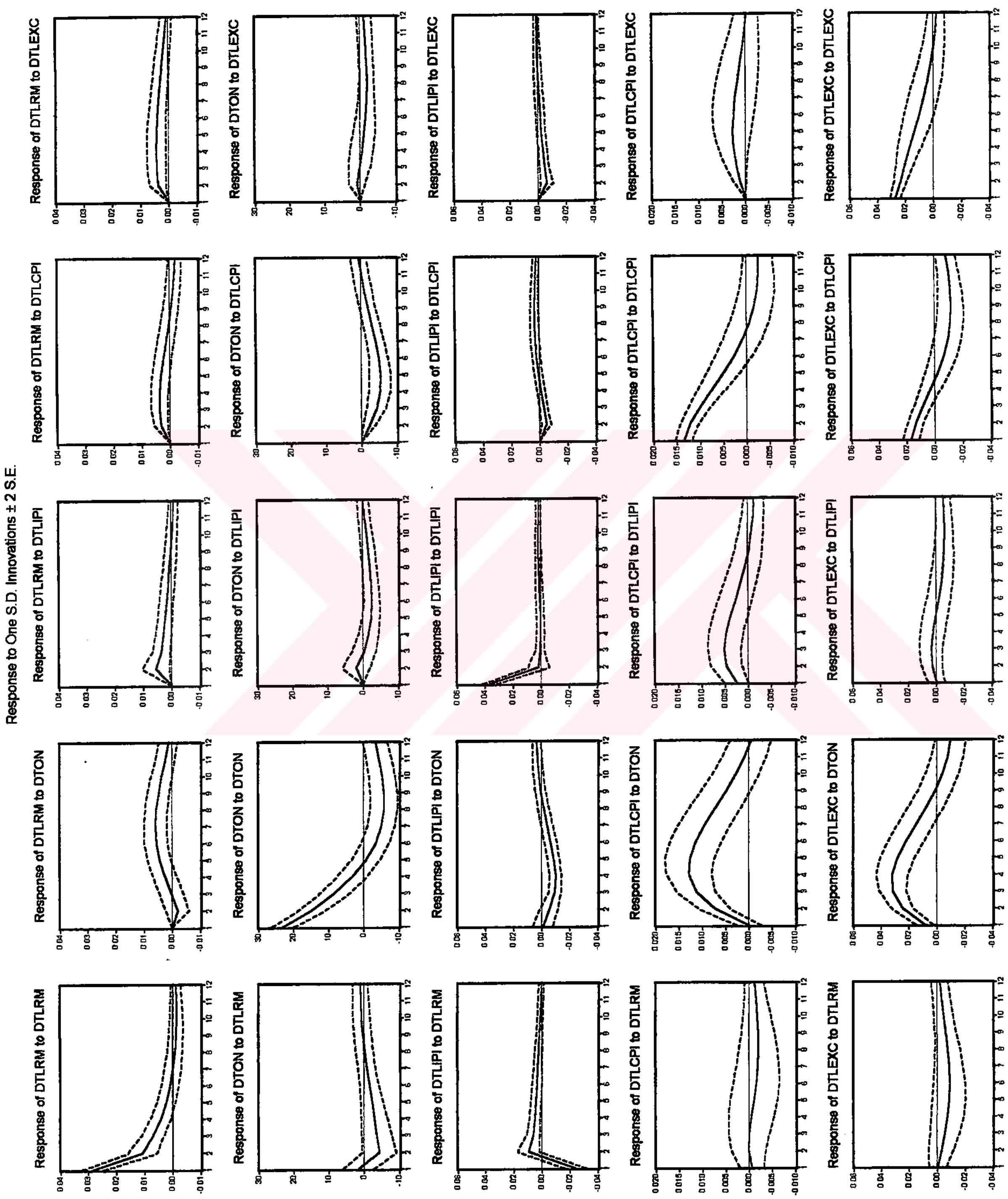


Figure 6. Monthly VAR Impulse-Responses using central bank money as monetary aggregate and detrended log of all variables with seasonal dummies. Ordering is DTLM0, DTON, DTLIPI, DTLCPI,DTLEXC

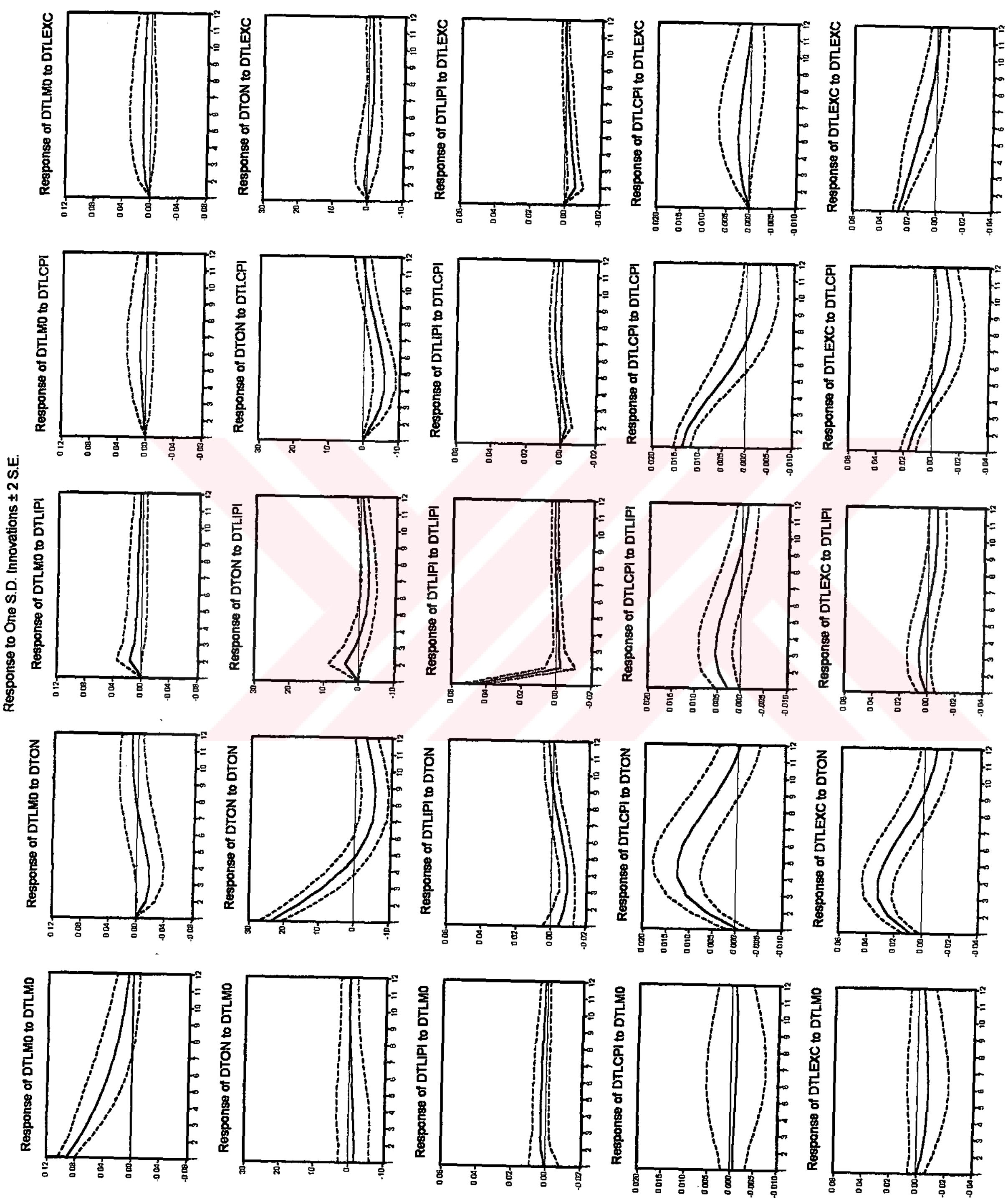


Figure 7. Monthly VAR Impulse-Responses using M1 as monetary aggregate and detrended log of all variables with seasonal dummies. Ordering is DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC

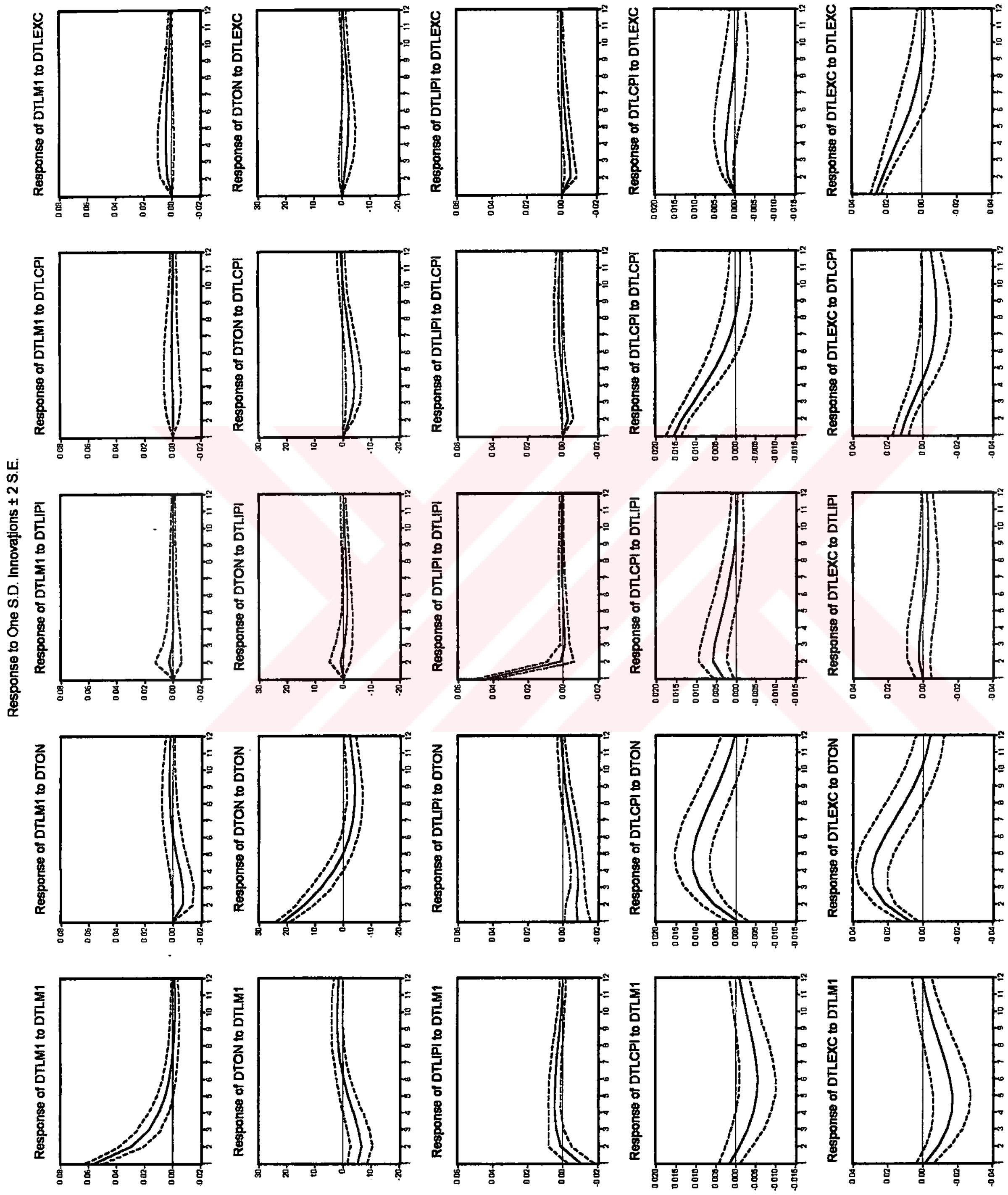


Figure 8. Monthly VAR Impulse-Responses using M2 as monetary aggregate and detrended log of all variables with seasonal dummies. Ordering is DTLM2, DTON, DTLIPI, DTLCPI, DTLEXC

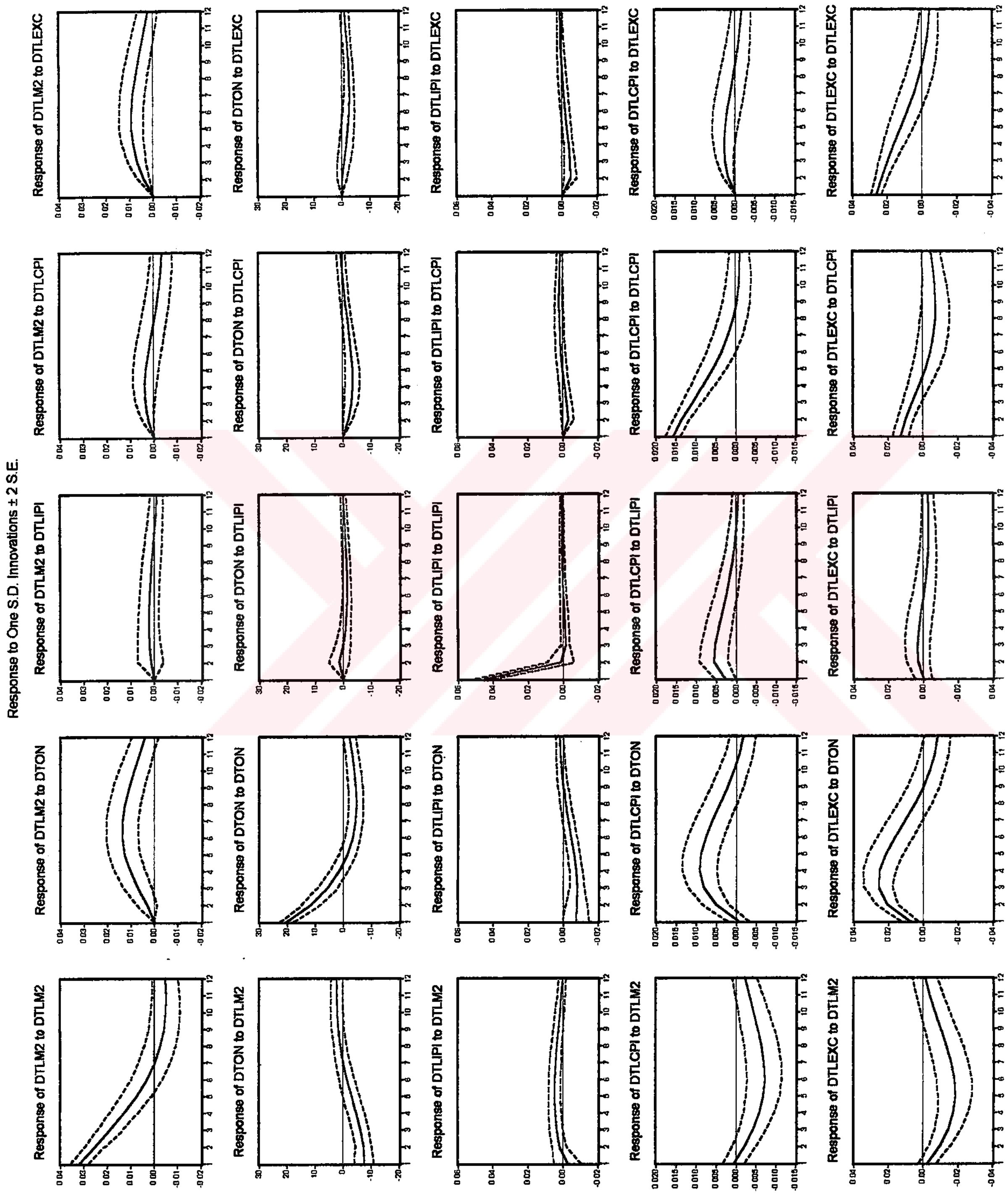


Figure 9. Monthly VAR Impulse-Responses using M2 as monetary aggregate and detrended log of all variables with seasonal dummies. Ordering is DTLIPI, DTLCPI, DTLEXC, DTLM2, DTON

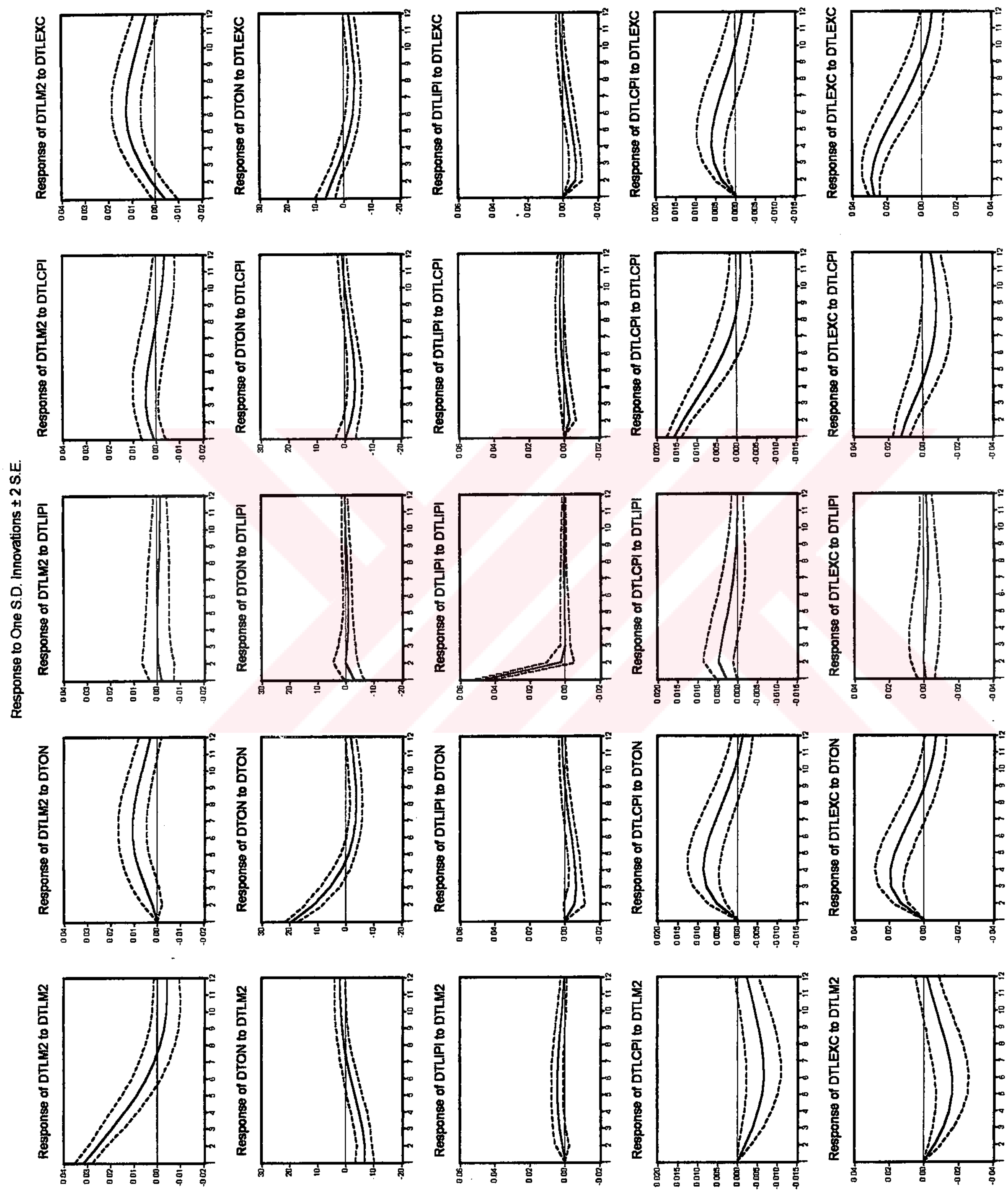


Figure 10. Monthly VAR Impulse-Responses using M2 as monetary aggregate and seasonally adjusted and detrended log of all variables. Ordering is SADTLM2, SADTON, SADTLIPI, SADTLCPI, SADTLEXC

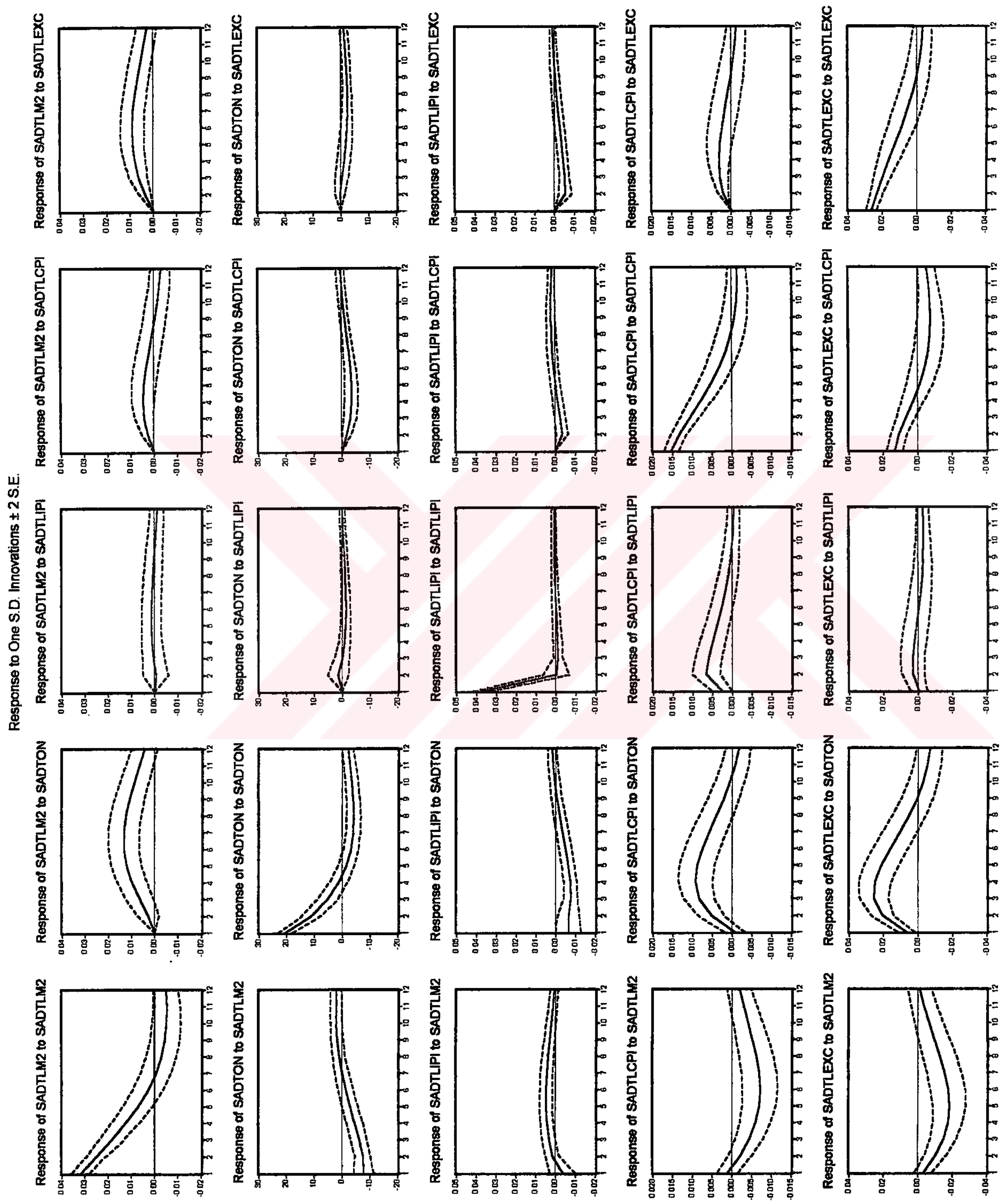


Figure 11. Quarterly VAR Impulse-Responses using M2 as monetary aggregate, real GNP as output and detrended log of all variables with seasonal dummies. Ordering is DTLM2, DTON, DTLCNS, DTLGNP, DTLCPI, DTLEXC

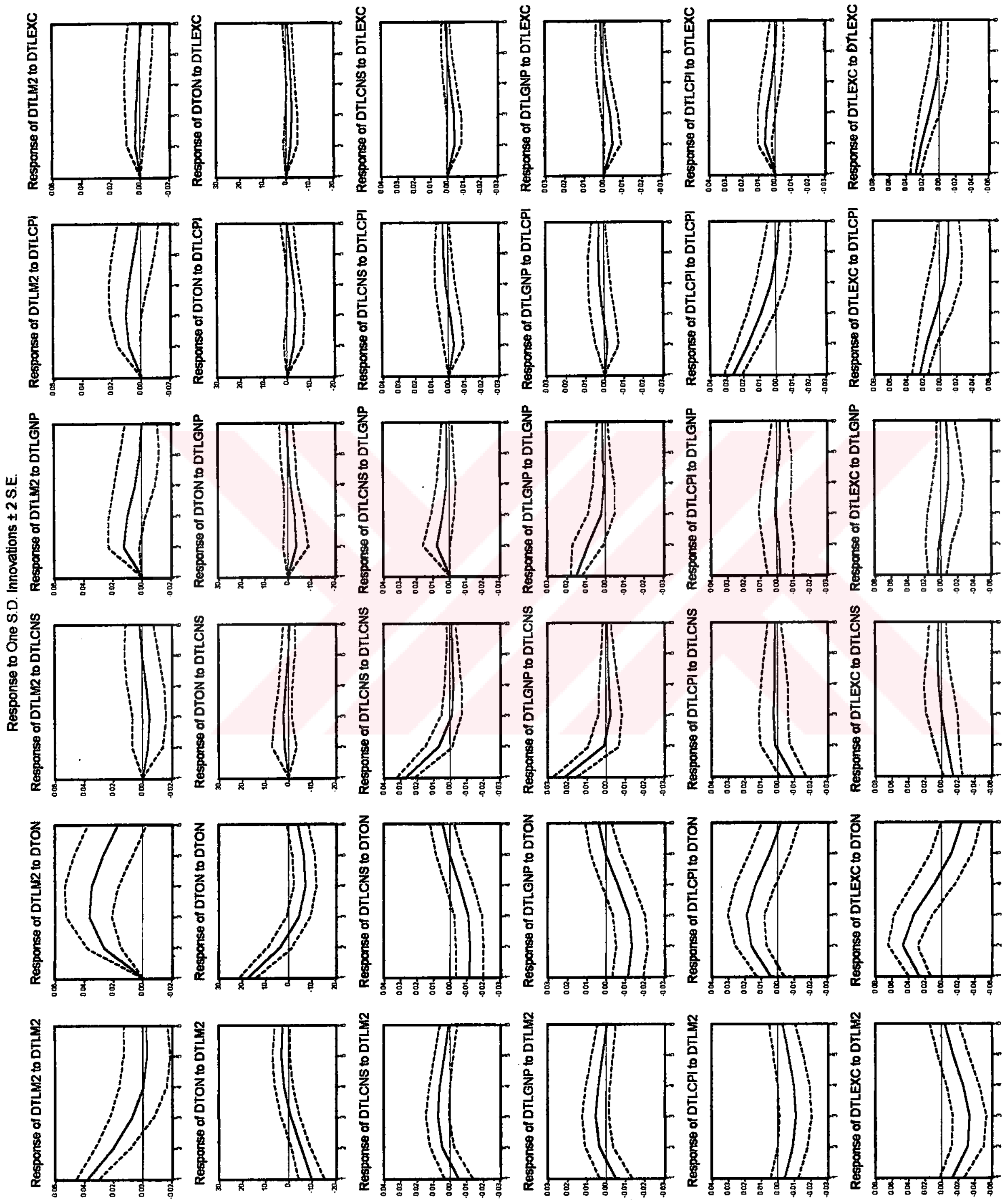


Figure 12. Quarterly VAR Impulse-Responses using M2 as monetary aggregate, real GDP as output and detrended log of all variables with seasonal dummies. Ordering is DTLM2, DTON, DTLCNS, DTLGDP, DTLCPI, DTLEXC

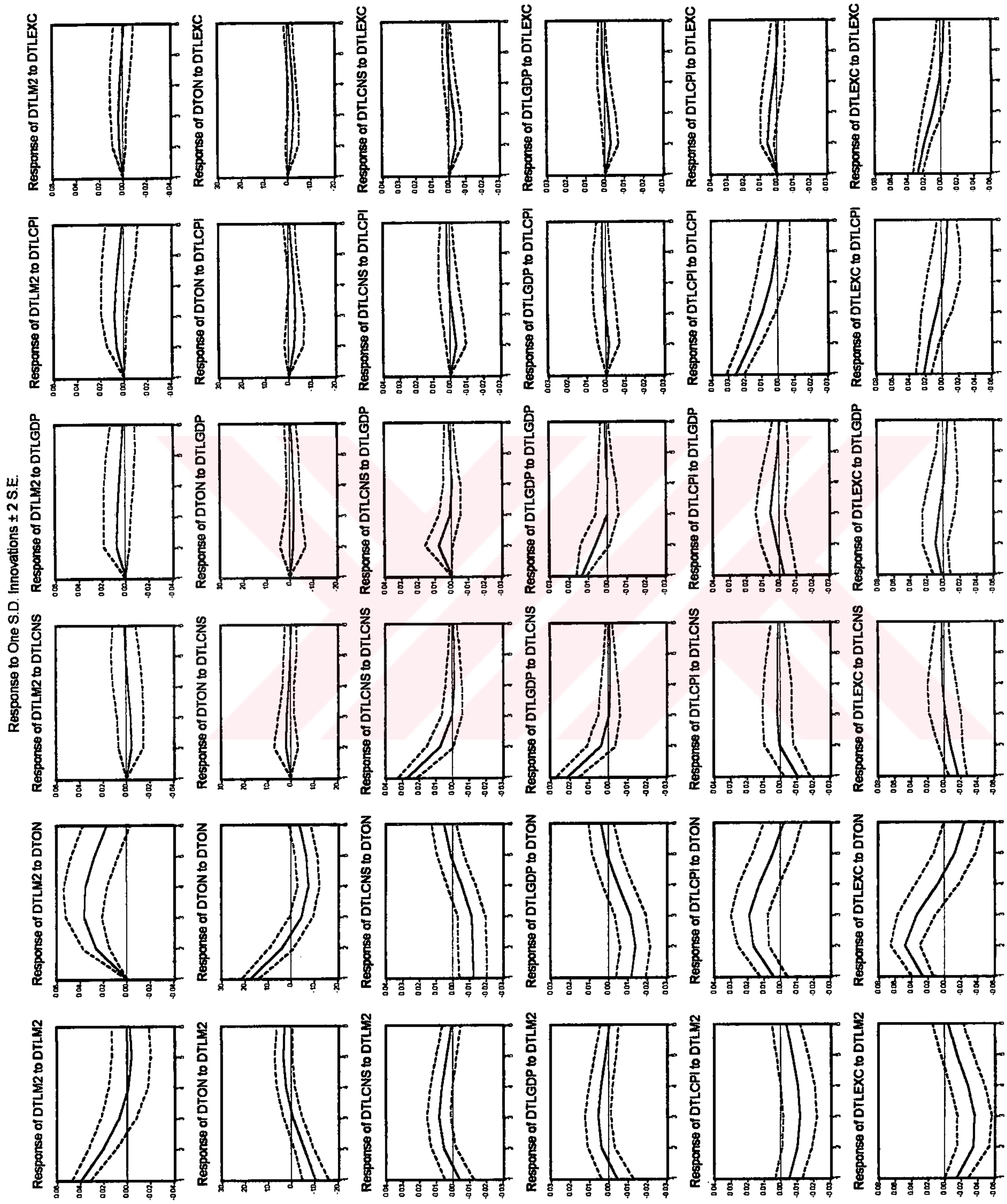
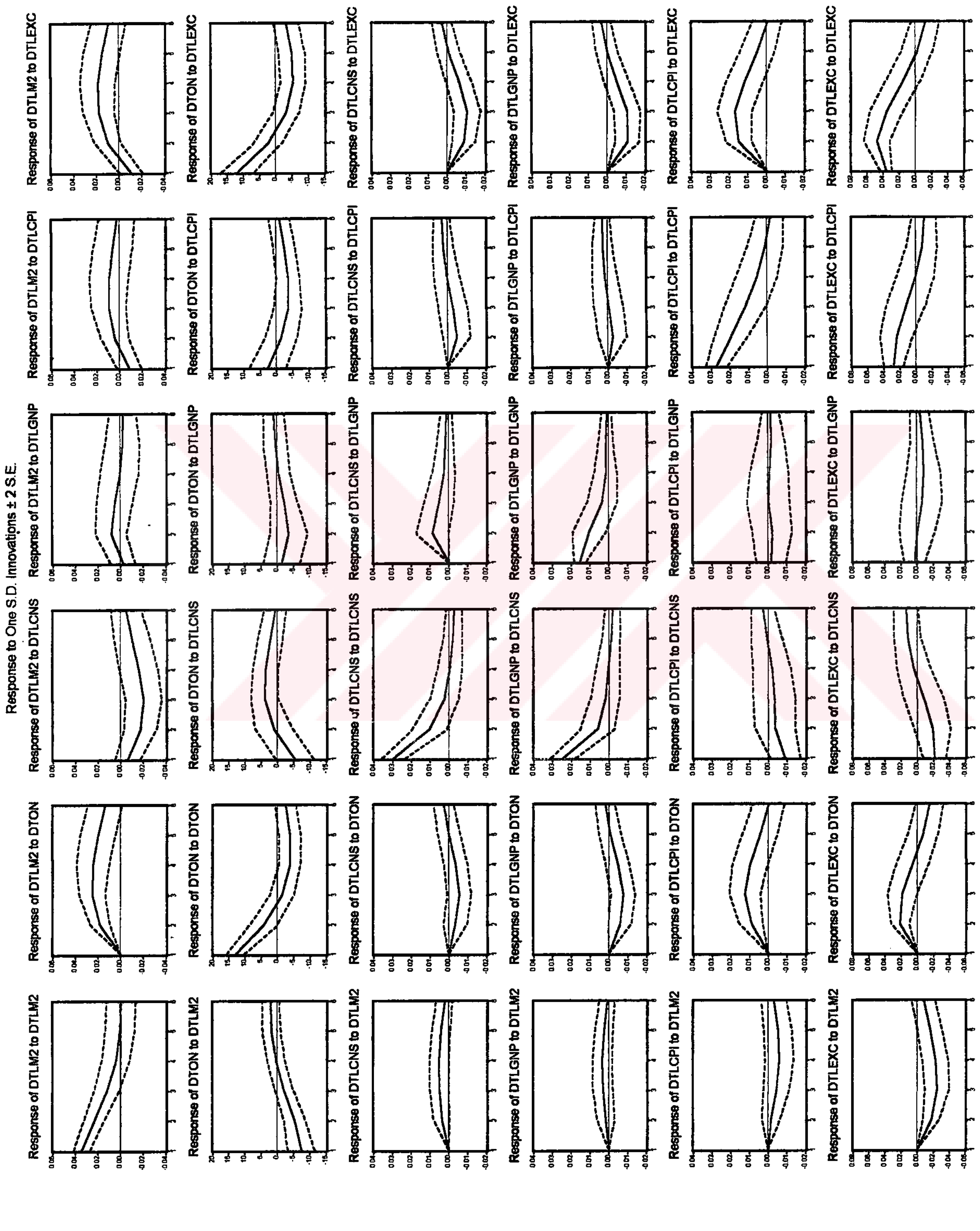
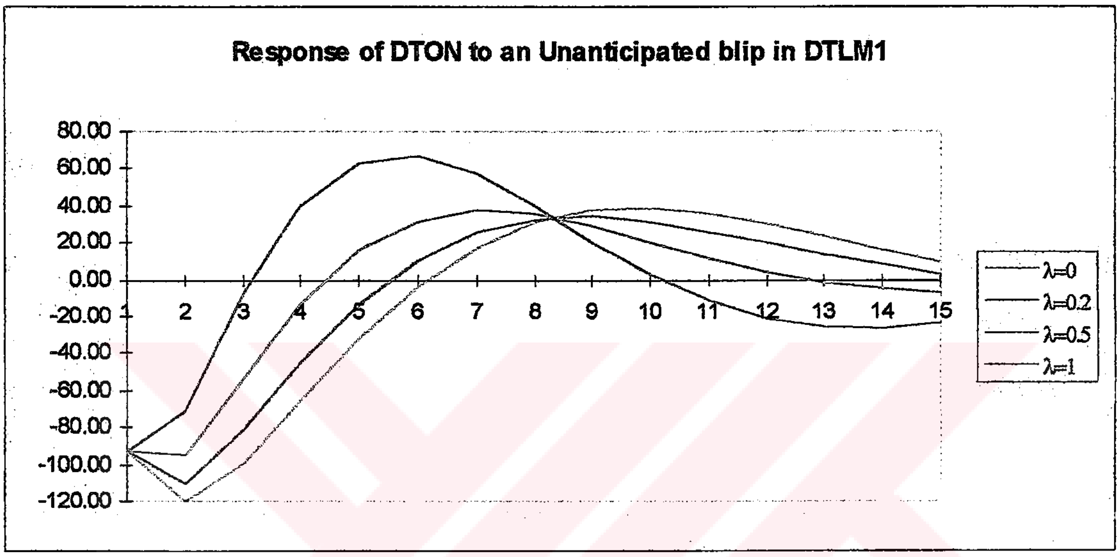


Figure 13. Quarterly VAR Impulse-Responses using M2 as monetary aggregate, real GNP as output and detrended log of all variables with seasonal dummies. Ordering is DTLCNS, DTLGNP, DTLCPI, DTLEXC, DTLM2, DTON



Appendix 6. Response Graphs of Macro Variables to Anticipated and Unanticipated Monetary Shocks

Figure 14. Interest rate effects of two monetary experiments, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.



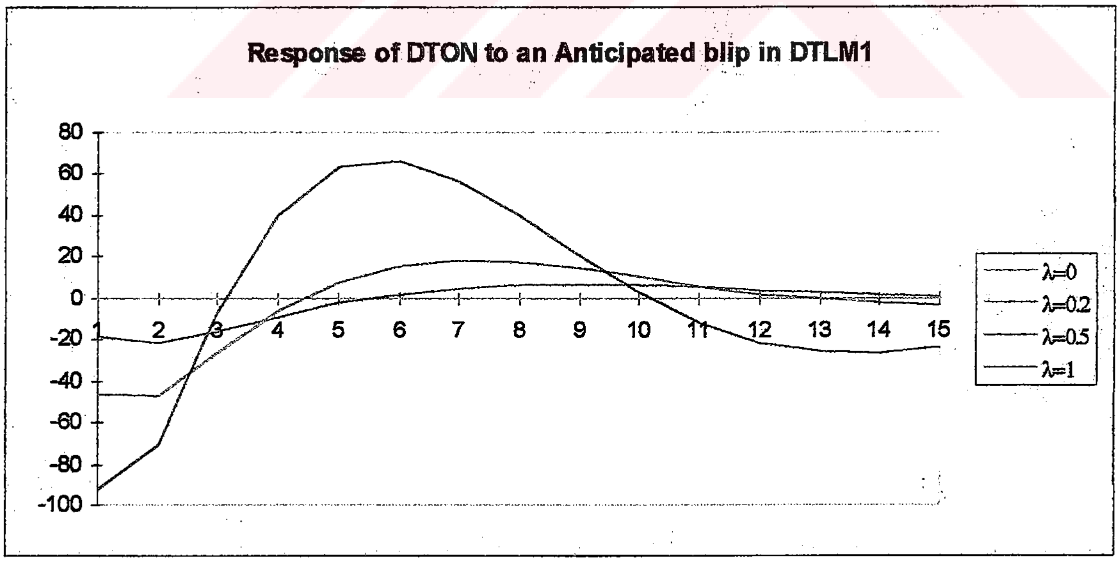
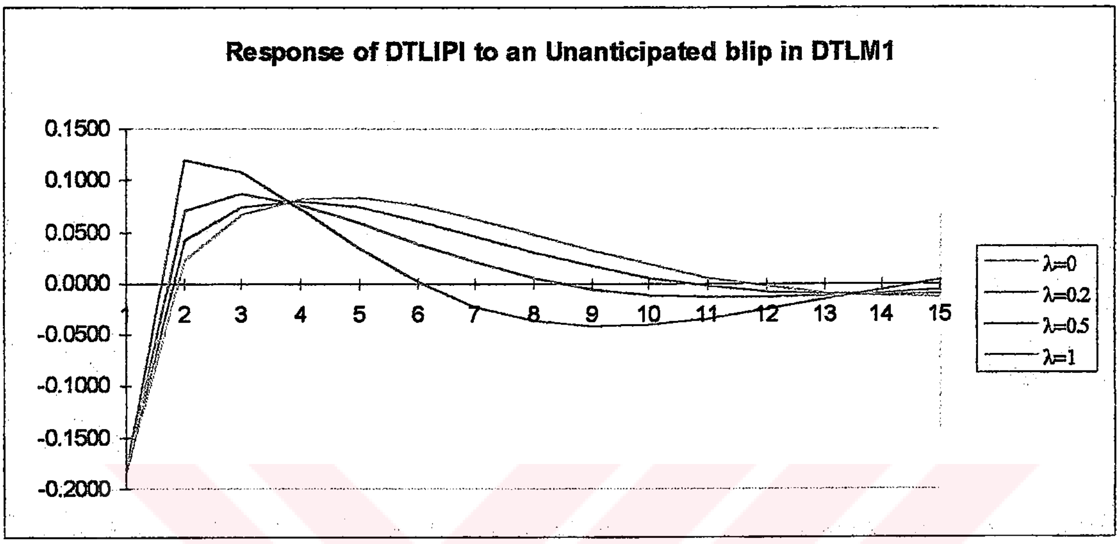


Figure 15. Output effects of two monetary experiments, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.



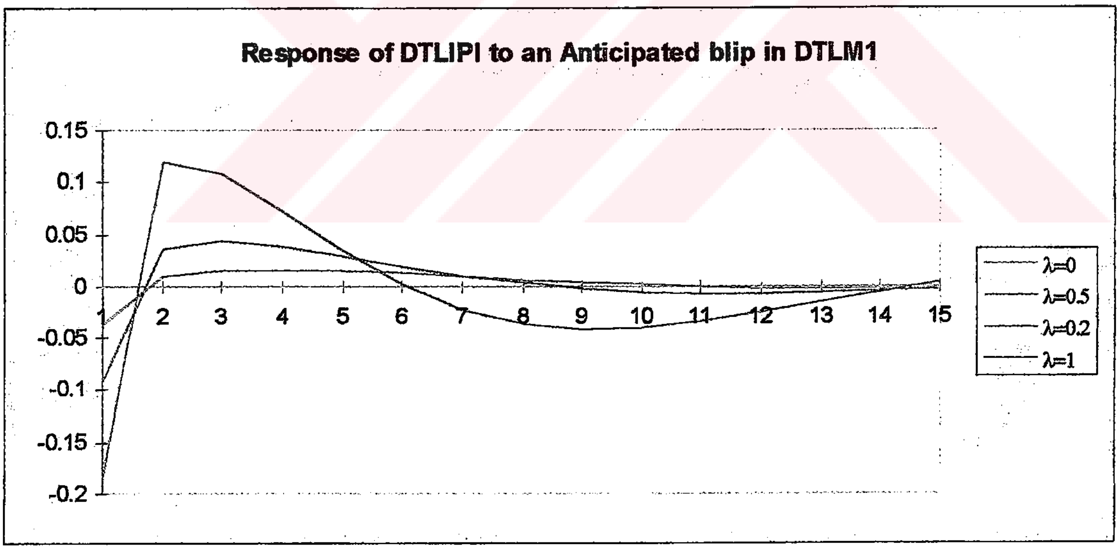
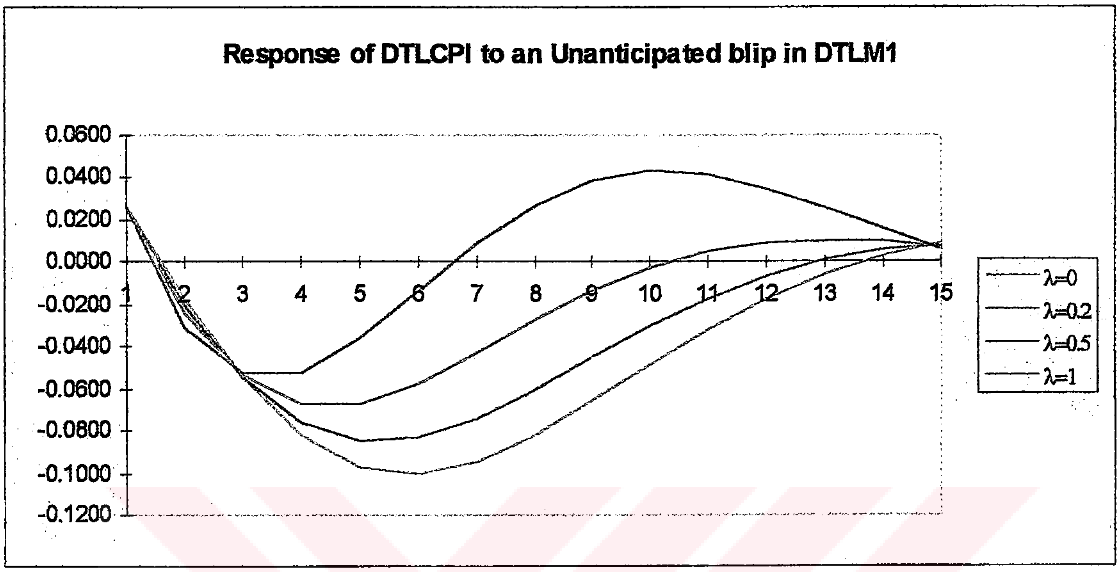


Figure 16. Price effects of two monetary experiments, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.



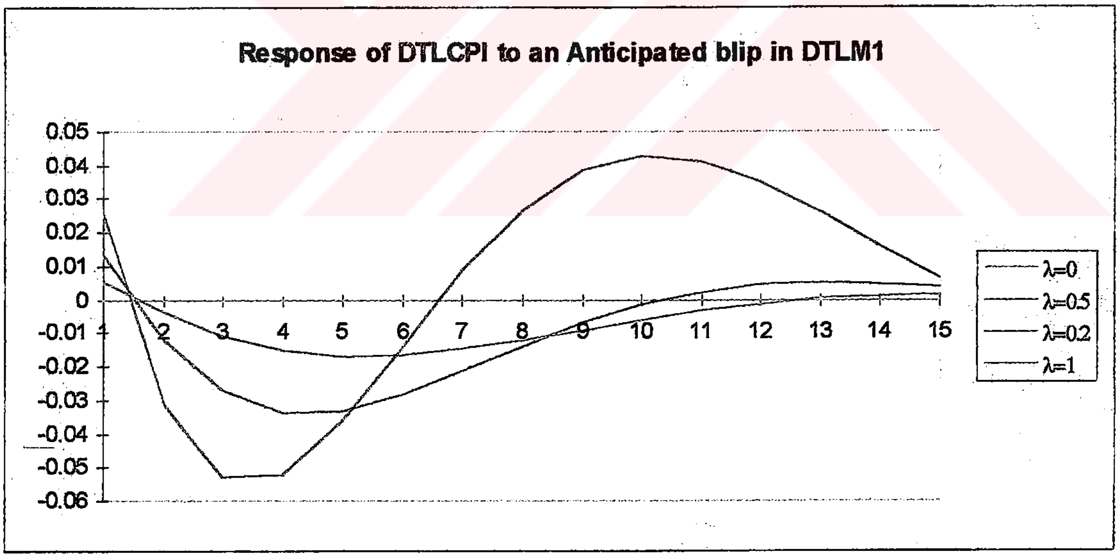
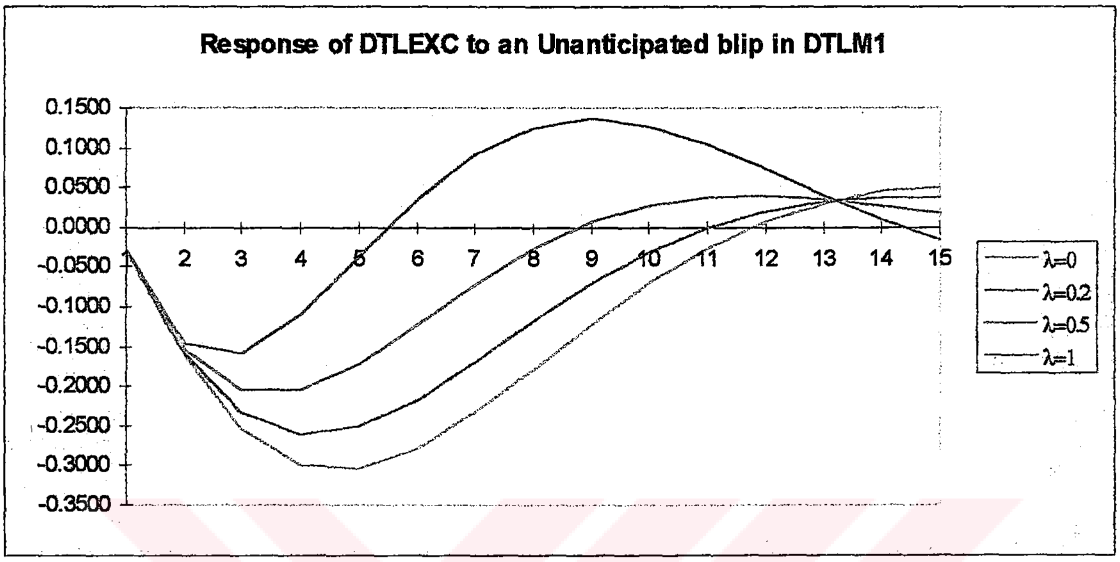


Figure 17. Exchange rate effects of two monetary experiments, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.



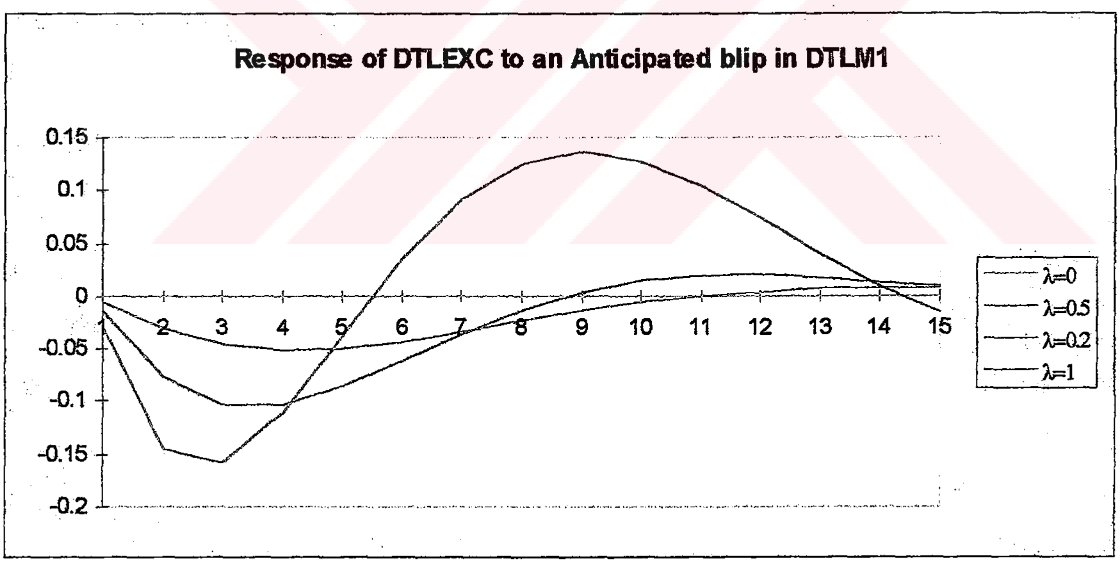
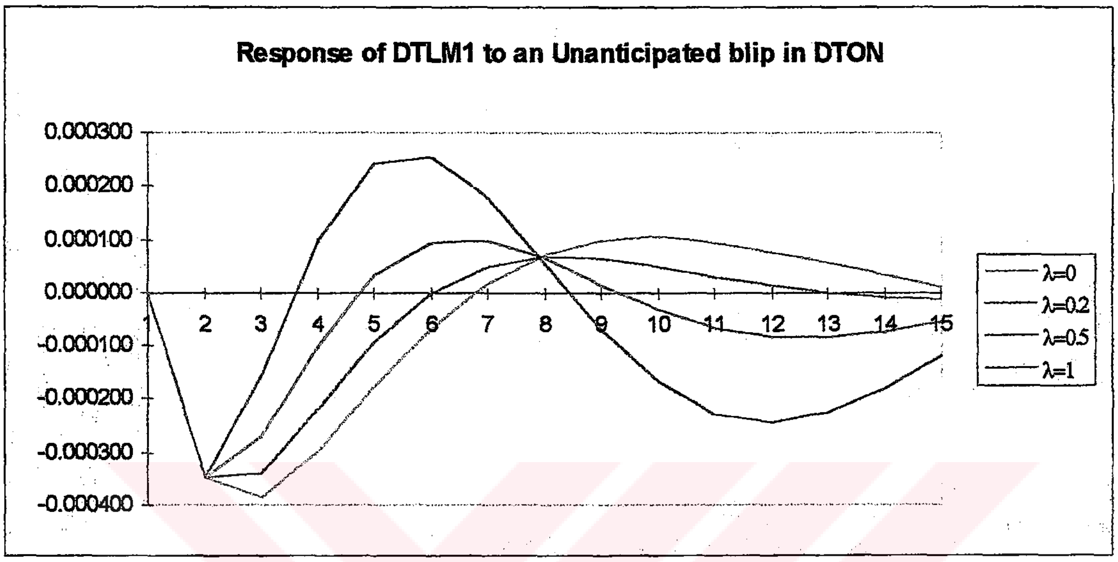


Figure 18. Money effects of two monetary experiments using ON shocks as monetary shocks, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.



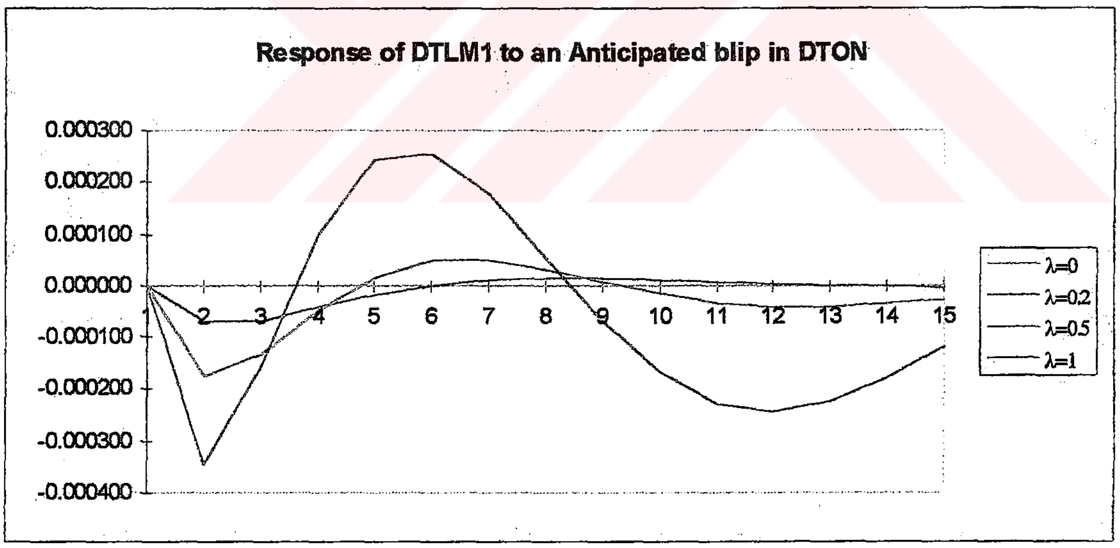
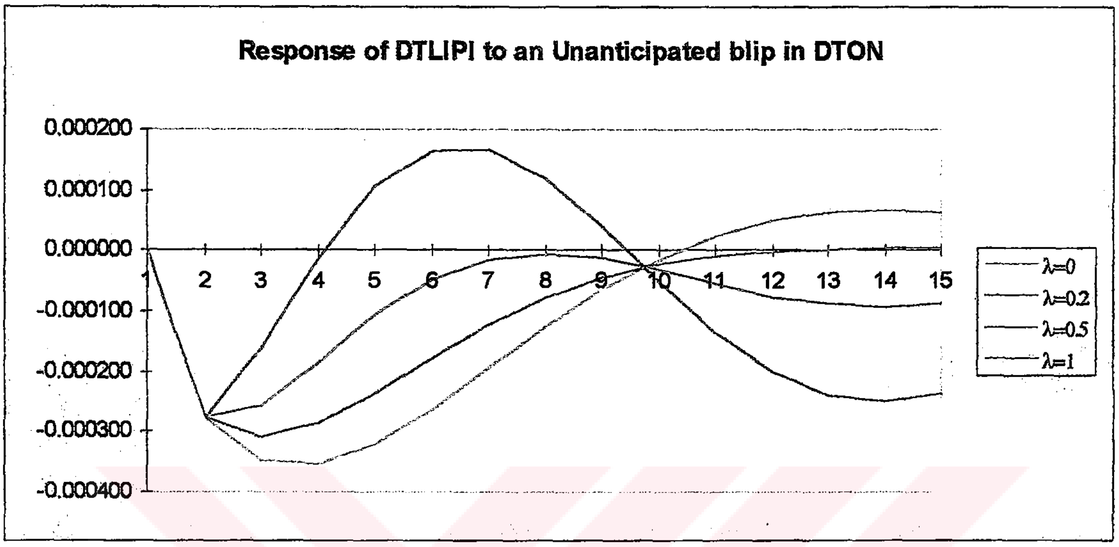


Figure 19. Output effects of two monetary experiments using ON shocks as monetary shocks, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.



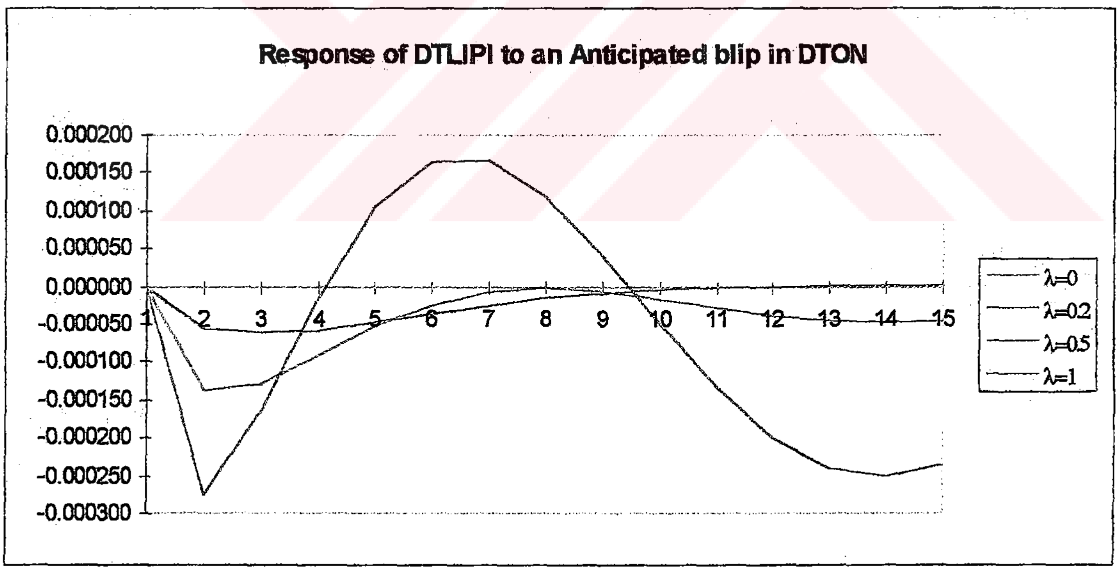
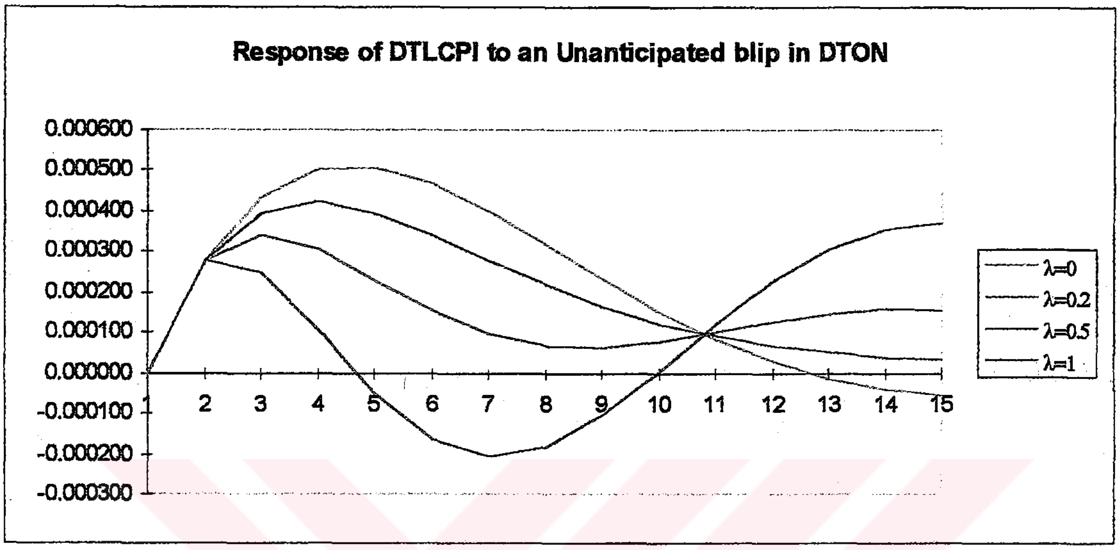


Figure 20. Price effects of two monetary experiments using ON shocks as monetary shocks, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.



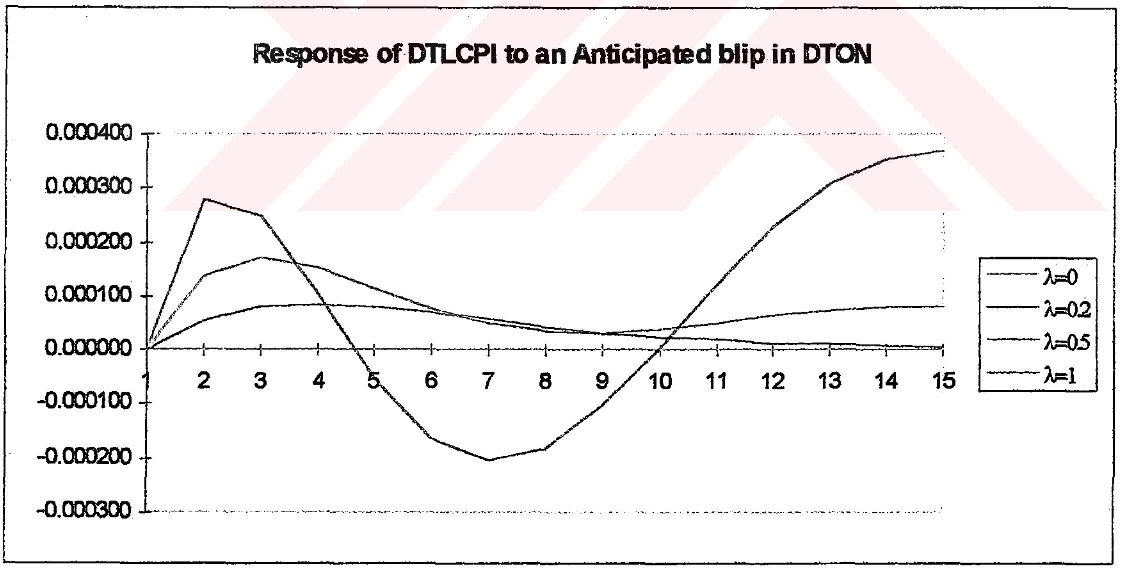
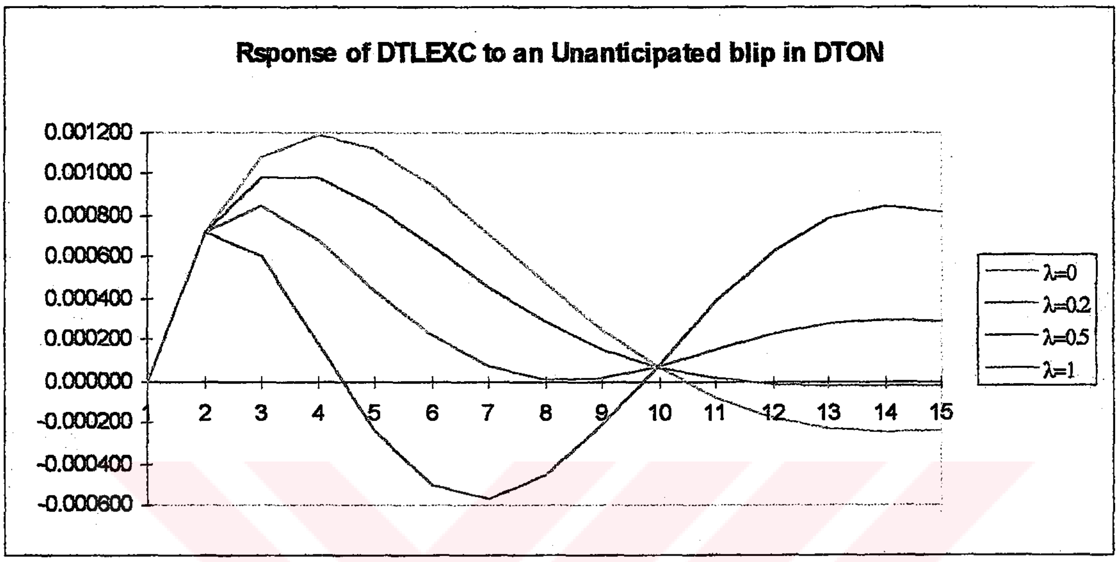
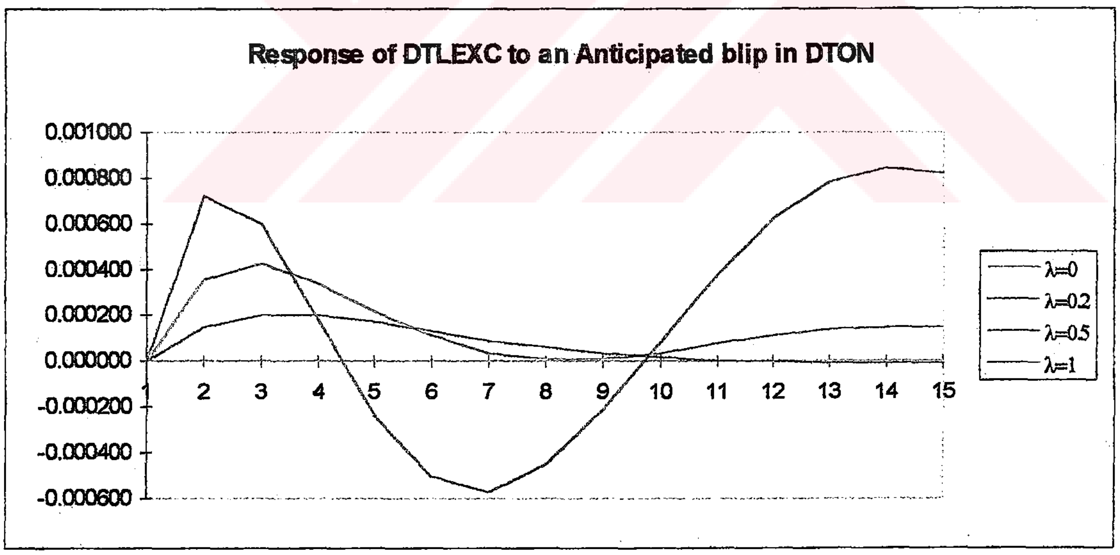


Figure 21. Exchange rate effects of two monetary experiments using ON shocks as monetary shocks, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from monthly VAR using ordering DTLM1, DTON, DTLIPI, DTLCPI, DTLEXC.





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