**Research Department** **Bank of Israel**

# A Basic Structural VAR of Monetary Policy in Israel Using Monthly Frequency Data

**Eddy Azoulay and Sigal Ribon**[*]

Discussion Paper No. 2010.04
February 2010

---

[*] Bank of Israel, Research Department. E-mail: http://www.boi.org.il
Eddy Azoulay – E-mail: eddy.azoulay@boi.org.il; Phone: 972-2-655-2563
Sigal Ribon – E-mail: sigal.ribon@boi.org.il; Phone: 972-2-655-2610

The authors thank the participants at the Bank of Israel's Forum for Monetary Models and Yossi Yachin for their helpful comments.

חטיבת המחקר, בנק ישראל ת״ד 780 ירושלים 91007
Research Department, Bank of Israel, POB 780, 91007 Jerusalem, Israel

# A Basic Structural VAR of Monetary Policy in Israel Using Monthly Frequency Data

**Eddy Azoulay and Sigal Ribon**

### Abstract

Monetary policy in Israel and other developed countries is forward looking. The central banks in these countries are thus required to assess the effect of monetary policy (shocks) and accurately forecast the evolution of the economy for monetary decision-making purposes. Central bank monetary policy makers are guided by many models, ranging from purely statistical to theoretical models. This paper describes a basic structural VAR system for the Israeli economy, analyzes its characteristics and evaluates its forecasting performance.

In addition to the variables that usually appear in such models—activity, the exchange rate, the central bank interest rate and inflation—the model presented in this paper incorporates inflation expectations derived from the capital market, and it was found that this improves the model. It was further found that the exogenous variables included in the model contribute considerably to the explanation of the development of the endogenous variables in the past, and thus also enhance the ability to forecast them. The model shows that the central bank reacts more strongly to a shock in inflation expectations than it does to a shock in actual inflation. This result is consistent with monetary policy being forward looking.

# מודל VAR מבני בסיסי חודשי לצורכי המדיניות המוניטרית בישראל

**אדי אזולאי וסיגל ריבון**

### תקציר

המדיניות המוניטרית בישראל, ובמדינות מפותחות בכלל, מבוססת על הסתכלות לעתיד. לפיכך נדרשים הבנקים המרכזיים במדינות אלה להעריך את ההשפעה הצפויה של המדיניות המוניטרית ושל זעזועים בה, וכן לחזות את ההתפתחויות הכלכליות כדי לנהל את המדיניות. לשם כך הם נעזרים במודלים מסוגים שונים – ממודלים סטטיסטיים ועד למודלים תאורטיים מורכבים. מאמר זה מציג מודל VAR מבני בסיסי למשק הישראלי, מנתח את מאפייניו ומעריך את טיב התחזיות המתקבלות ממנו.

בנוסף למשתנים המקובלים במודלים מסוג זה – הפעילות, שער החליפין, ריבית הבנק המרכזי והאינפלציה – אנו כוללים במודל גם את הציפיות לאינפלציה הנגזרות משוק ההון ומוצאים שהכללתן משפרת את המודל. כמו כן נמצא שלמשתנים האקסוגניים הנכללים במודל חשיבות בהסבר תוואי התפתחותם של המשתנים האנדוגניים בעבר ולכן גם ביכולת לחזות אותם. מהמודל עולה כי הבנק המרכזי מגיב לזעזוע בציפיות לאינפלציה במידה רבה יותר מאשר הוא מגיב לזעזוע באינפלציה בפועל – תוצאה המתיישבת עם הסתכלות קדימה של המדיניות המוניטרית.

## *1. Introduction*

Monetary policy in Israel and other developed countries is forward looking. The central banks in these countries are thus required to assess the effect of monetary policy (shocks) and accurately forecast the evolution of the economy for monetary decision-making purposes. Central bank monetary policy makers are guided by many models, ranging from purely statistical to theoretical models. Regarding the statistical models, one common approach among central banks is to develop and use Vector Autoregressive (VAR) models that can be used to construct short-term forecasts for inflation and other variables such as key monetary policy forecast inputs.

The Bank of England (Kapetanios, Labhard and Price, 2007), for example, has constructed a suite of statistical models commonly used for forecasting. Such models include a basic multivariate VAR model; a univariate autoregression model for key economic series; a random walk model, which is used to forecast benchmarks; Markov switching models; and estimation of VAR using the Bayesian approach. The Norges Bank (Bjornland, 2005) and Sweden's (Jacobson et al, 2001) central bank use various types of statistical models to construct separate forecasts that are then combined to construct a non-judgmental benchmark that can be compared with projections generated by other theoretical models and independent forecasters.

VARs have become a key method for extracting macroeconomic information. Central banks in many developed economies currently apply VAR-based forecasting as an important statistical framework for analysis and projection of monetary policy. For example, New Zealand, (Buckle et al, 2002), Sweden, Norway, Spain (Camarero et al., 2002) and Australia (Dungey and Pagan, 2008) use VAR models for relatively small, open economies. Excluding New Zealand, these countries use a 13-equation model with a rather limited number of domestic endogenous variables, including inflation, output growth, nominal or real exchange rate and a measure of short-term interest rate. The models include a list of foreign exogenous variables that are generally the counterparts of the domestic endogenous variables and serve as an independent block that affects but is not affected by the endogenous variables. Most of the models mentioned above are estimated quarterly with a relatively short lag of up to four quarters. The Spanish model was estimated using monthly frequency data. Given that the confidence interval of a basic stand-alone-type VAR forecast appears to be wide, these forecasts contribute most when they are combined with forecasts constructed according to other statistical approaches.

The aim of this paper is to construct a basic structural VAR system that will allow short-run forecasting for the major nominal variables of the economy—CPI inflation, exchange rate and the BoI interest rate. In addition, such a model will also allow some analysis of the transmission mechanisms in the economy, using impulse response functions. In particular we will investigate two major issues. The first is the importance of including market-derived inflation expectations in the model for the description of the channels of transmission of the monetary policy. The second is investigating the importance of exogenous variables (shocks) to the course of the endogenous variables and the ability to forecast them.

We found that including market-based inflation expectations in the model improves the estimation results and it is the specification we adopt for further testing. Concerning the role of the exogenous variables in our model, we find that they play an important role in forecasting future developments. In particular, forecasting the movements of the exchange rate depends on estimates of future cross-rates, which are generally difficult if not impossible to predict. By contrast, the expected path of the policy instrument—the BoI interest rate—is affected more by the development of the endogenous variables in the system than by the exogenous variables.

### *2. Selecting a VAR Model for Forecasting*

The use of the VAR model for analysis and forecasting serves primarily to summarize the dynamic correlation patterns of observed data series. These patterns are then used to predict likely future values for each series. This section describes the basic VAR system used to analyze the effects of various shocks on key macro and monetary policy variables in Israel and to forecast the evolution of these series to enhance monetary policy implementation.

Any monetary VAR model treats mixed-frequency data. Some variables included in the VAR are measured monthly, whereas the others are measured only quarterly. In principle, the incorporation of data with varying frequencies into a single frequency model and the decision on the model's data frequency have important implications for the set of variables used in the model and the model's forecast performance. To exploit timely and more recent data, our VAR model is specified for data at a monthly frequency[1]. Focusing on a VAR model fitted to monthly data requires the use of procedures to convert some of the quarterly variables into monthly variables and to use monthly data on variables related to those that are measured quarterly and that can be considered a good substitution.

Our basic VAR has the following representation:

$$(1) \quad Y_t = C + A(L)Y_{t-1} + B(L)X_t + \mu_t \quad ,$$

where $Y_t$ is the vector of endogenous variables in Israel and $X_t$ is the vector of exogenous variables, including mainly foreign variables. In our basic VAR system, the vector of exogenous variables contains the fed fund rate (*ifed*, measured monthly), the rate of change in the dollar price of imported raw materials (*dlpmi*, converted to monthly frequency using linear interpolation), the rate of change in the dollar price of imported consumption goods (*dlpmc*, converted to monthly frequency using linear interpolation), US industrial production growth (*dlipus*, as a measure of business-sector output growth in the US), change in the dollar/euro cross rate (*dlcross*), the volume of net direct foreign investments (*net_direct*), a measure capturing changes in

---

[1] Fitting the VAR to monthly data rather than quarterly data increases the number of observations and allows the estimation to focus more on recent periods that may better represent the current set-up of the economy. Such an advantage is more pronounced in the case of Israel, whose economy has changed due to the many structural reforms implemented in the last decade.

the security and political environment in Israel (*security*), the inflation target set by the government (*target*), and seasonal dummies for April and September (*dum4* and *dum9*).

(2) $X'_t$ = [*ifed, dlpmi, dlpmc, dlipus, dlcross, net_direct, security, target, dum4, dum9*] .

The estimated specification of the model includes *ifed* and net direct investments as a moving average for a two-month period, *ipus* and the dollar price of imports as a three-month moving average of the dollar price of imported raw materials with weight of 0.8 and of the dollar price of imported consumption goods with weight of 0.2, according to their weight in the volume of imports. We also include *security* in the estimation as a four-month moving average. Although structurally each of the exogenous variables is expected to affect only some of the endogenous variables and not others, since we are estimating the system in its reduced form, we allow for all exogenous variables to appear in all the reduced-form equations and do not explicitly determine the structure of the exogenous effects.

We investigate two alternatives for the basic VAR comprising two versions of the endogenous vector $Y_t$. The first $Y_t$ consists of change in the monthly Composite Index calculated by the BoI, which is a variable related to business sector output growth (*dlci*); dollar exchange rate changes[2] (*dle*); CPI inflation (*dlcpi*); and the Bank of Israel (BoI, hereafter) monetary policy rate (*iboi*).

(3I) $Y'_t$ = [*dlci, dle, dlcpi, iboi*] .

The second $Y_t$ version adds the break-even inflation expectations as derived from the yield differential between nominal bonds and inflation indexed bonds (*infexp*) to the first four variables of (3I). We believe that developments in inflation expectations, though not consistent with a model that includes forward-looking expectations such as rational expectations, have played a key role in the design of monetary policy decisions in recent years and are a leading indicator of actual inflation affecting exchange rate changes as well.

(3E) $Y'_t$ = [*dlci, dle, infexp, dlcpi, iboi*] .

The inclusion of inflation expectations derived from capital market data is consistent with recent VAR literature suggesting that a system specification with forward-looking variables proves successful in dealing with expressions of misspecifications in monetary VARs for the United States, particularly the puzzling positive response of inflation to a monetary policy innovation[3].

---

[2] We use the dollar exchange rate, and not some other measure of foreign currency price because import prices are reported by the CBS in dollar terms. We include the cross rate between the dollar and the euro in order to take into account changes in the relative strength of these major currencies, which also affect the local currency price of imports.

[3] Brissimis and Magginas (2006), for example, augment a standard monetary VAR for the United States with two forward-looking variables: a money market forward rate reflecting monetary policy

The coefficients *C, A(L)* and *B(L)* in (1) and the covariance matrix Σ of its error vector $\mu_t$ are estimated once the lag order is specified. The lag length of each VAR version is chosen so as to eliminate the autocorrelation of the residuals, preserve as many degrees of freedom as possible and allow for the reaction of the endogenous variables in the lags to take into account the rigidities characterizing the economy. Table 1 evaluates the lag order of each VAR obtained on the basis of five different selection criteria. The lag length determined is the length selected by as many criteria as possible.

**Table 1: Lag-Length Selection for the two VAR versions**

**a. VAR (3I)**

Sample: 2000M01 2008M12
Included observations: 108

| Lag | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|
| 0 | NA | 1.89e-13 | -17.94724 | -16.95386 | -17.54446 |
| 1 | 482.3514 | 1.51e-15 | -22.78234 | -21.39161 | -22.21845 |
| 2 | 96.46193 | 6.99e-16 | -23.55784 | -21.76976* | -22.83284 |
| 3 | 42.00717 | 5.83e-16 | -23.75000 | -21.56456 | -22.86389 |
| 4 | 43.29046 | 4.70e-16 | -23.98164 | -21.39885 | -22.93441* |
| 5 | 34.05495 | 4.17e-16 | -24.12194 | -21.14180 | -22.91360 |
| 6 | 30.53751 | 3.82e-16 | -24.23832 | -20.86082 | -22.86886 |
| 7 | 27.34158* | 3.61e-16* | -24.33261 | -20.55776 | -22.80205 |
| 8 | 22.01742 | 3.64e-16 | -24.36992* | -20.19771 | -22.67824 |

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

**b. VAR (3E)**

Sample: 2000M01 2008M12
Included observations: 108

| Lag | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|
| 0 | NA | 6.01e-14 | -16.25614 | -15.01441 | -15.75267 |
| 1 | 576.5614 | 1.95e-16 | -21.99276 | -20.13017* | -21.23755 |
| 2 | 93.69004 | 1.08e-16 | -22.59446 | -20.11101 | -21.58751 |
| 3 | 59.49694 | 8.58e-17 | -22.84833 | -19.74401 | -21.58964* |
| 4 | 49.48080 | 7.46e-17 | -23.01973 | -19.29455 | -21.50931 |
| 5 | 42.50403 | 6.94e-17 | -23.13902 | -18.79297 | -21.37686 |
| 6 | 47.22972 | 5.86e-17 | -23.37061 | -18.40370 | -21.35671 |
| 7 | 49.66950* | 4.61e-17 | -23.69605 | -18.10828 | -21.43041 |
| 8 | 36.92012 | 4.33e-17* | -23.86964* | -17.66101 | -21.35227 |

---

expectations and a composite leading indicator of economic activity. They show that these variables appear to effectively control for the information set that the Fed may use in monetary-policy decision making, helping to obtain more pronounced, theory-consistent responses to monetary policy shocks.

Table 1 shows that tests for the length of lags seem inconclusive for different lag lengths, as each length was selected by some of the criteria. We believe that two lags (months) is too short given the need to capture economic rigidities and to allow for a slower reaction of prices and output to shocks for a period longer than three months. On the other hand, our short sample (January 2000 to December 2008) does not allow us to include eight lags, as suggested by some of the tests. We therefore deem six lags to be the appropriate length for running the estimation for the three VAR systems.

Each VAR system is estimated with data expressed in log differences, except for interest rates, inflation expectations, and the inflation target, which are expressed in levels. We run the estimation with the list of exogenous variables included in (2). As mentioned above, the sample comprises monthly data from January 2000 to December 2008 and includes 108 observations.

At this stage, it is important to address the issue of the differencing of the data series. Without question, the differencing of the nonstationary variables in an unrestricted VAR can result in misspecification errors, particularly if the variables are integrated and if the long-run equilibrium relationships among the variables contained in the levels are excluded. We chose to run the estimation with the series expressed in differences rather than in levels, because our sample period is relatively short, and it seems impossible to determine a stable long-term relationship among the endogenous variables properly, based on this short period. Moreover, the use of first differences when the variables may not be cointegrated eliminates such likely consequences as the tests' loss of power and coefficient bias.

In general, VAR estimation relies on the data generating process (DGP) being stationary. In Appendix A we present the results of the Augmented Dickey-Fuller (ADF) test and the KSPP test for the degree of integration of the series in our system. We check both the level and the rate of change (except for the interest rate and security which are only tested in levels). The levels of the composite index, exchange rate and CPI are found to be I(1), and their log difference is I(0), at least according to the ADF test. Inflation expectations are found to be I(0) based on the period Jan. 2000-Dec. 2008. We cannot reject the hypothesis that the Bank of Israel interest rate is I(1), except when a trend is added to the ADF test[4]. For the foreign variables, the picture is similar – most of the levels are found to be I(1) while the log difference is I(0) according to the ADF test, but the hypothesis of I(0) is usually rejected according to the KPSS test. The Fed interest rate is found to be I(1), except for the period Jan. 2000-Dec. 2008 according to the KPSS test which do not reject its I(0) hypothesis.

Although the results of the tests do not support the assumption that interest rates are stationary, we tend to believe that the nature of these series justifies their inclusion together with the log difference of industrial production, the log difference of the exchange rate, the inflation rate and the inflation expectations in our estimated system.

---

[4] This is another reason to include the inflation target, which is a trend variable, as an exogenous variable in the system.

The above-mentioned VAR systems are represented in a reduced form and are estimated by OLS, equation by equation.

Table 2 compares adjusted $R^2$ for each of the endogenous variables included in the two VAR versions. All equations in both VAR versions seem well specified, as evidenced by their relatively high adjusted $R^2$, which explains more that 50 percent of the variation in all the endogenous variables, excluding the rate of change in the shekel/dollar exchange rate. The equation for the rate of change in the shekel/dollar exchange rate in all three VAR versions has the lowest explanatory power among all the estimated equations, with adjusted $R^2$ equaling only about 0.4. The inclusion of market inflation expectations in (3E) yields a better in-sample fit than in the other model, which contains only four endogenous variables. This result is consistent with models used by other central banks, which usually incorporate market data and forward-looking series in their augmented VAR models. Also, the result is not surprising, because inflation expectations derived from capital markets respond instantaneously to news affecting the public perception of Israel's inflation environment, and are evidently an indicator in the information set on which the BoI bases its monthly monetary decisions. It is thus suitable for inclusion in a VAR system for the Israeli economy to augment the versions with four variables.

We chose the VAR version that includes the five endogenous variables (3E) as our benchmark model. Below, we present the estimation results of this VAR version, analyze the characteristics of this version and investigate its forecasting performance.

**Table 2: Comparison of Adjusted $R^2$ For Each of the Endogenous Variables Included in the Alternative VAR Versions**

| | VAR Version | dlci | dle | Dlcpi | iboi | infexp |
|---|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) | (5) |
| $R^2$ (adj.) | (3I) | 0.96 | 0.35 | 0.61 | 0.99 | - |
| | (3E) | 0.96 | 0.39 | 0.66 | 0.99 | 0.65 |

The estimation was conducted with six lags for 2000.M1 to 2008.M12 sample period.

### *3. Estimation Results of VAR 3E*

This section reports the estimation results of the VAR (3E) model, analyses the stability of the estimated VAR coefficients and evaluates the contribution of the exogenous variables to the goodness of fit of the endogenous variables. In addition, the use of short-run restrictions enables us to identify the structural shocks and thus to examine the impulse response functions. We examine each variable's contribution to total variability using variance decomposition analysis. We also report briefly the historical contribution of each structural shock to the evolution of the endogenous variables in our system.

**3a. Estimation results:** As in any other VAR model, the projection of each variable in our system is based on the historical relationship between a given endogenous variable and past developments exhibited in other exogenous series included in the system. Such relationships have been estimated for the period 2000.1-2008.12 and are summarized in the five regression equations appearing in Appendix B of this document.

Summing the coefficient estimates of the six lags for each endogenous variable can be a way to gauge the accumulated effect and direction of these six lag regressors on each of the five endogenous variables. In general, we find that accelerating inflation (*dlcpi*) and inflation expectations (*inf_exp*), exchange rate depreciation (*dle*), and real output growth lead to a monetary tightening as reflected in the BoI monetary rate equation; also, consumer price inflation, inflation expectations and exchange rate depreciation accelerate due to monetary expansion or exchange rate depreciation.

We find that most of the exogenous variables affect the endogenous variables in the expected direction: Industrial production in the US is positively correlated with Israel's real output growth, the increased dollar price of imports accelerates inflation in Israel, monetary tightening in the US increases the BoI's monetary rate, higher net direct investments and a globally weak US dollar strengthen Israel's currency.

Most of the nominal variables contained in the model do not seem to bear a significant relationship with real output. In particular, the effect of the short-term BoI interest rate on output (as measured by the BoI composite index) is not significantly different from zero. In fact, high short-term interest rates during the sample period were not necessarily followed by stagnation while low short-term rates did not stimulate the economy.

**3b. Stability of the regression coefficients:** The accuracy of VAR forecasts and the reliability of inference depend significantly on the particular specification of the system. Our estimated VAR model is linear and assumes that regression coefficients are constant over time. Instability of regression coefficients may point to some misspecification problems, indicating the need to realign the model by allowing, inter alia, for changes in coefficients over time. In the figures in Appendix C, we display the regressor coefficient values and standard errors band for each of the five equations investigated in our VAR system.

The evolution of coefficients over time was constructed by obtaining the coefficients and standard errors of the VAR estimated for the period 2000m1 to 2004m12+*i*, with *i* from 1 to 48, so that the longest period ends at 2008m12. The figures show that the estimated coefficients are generally stable, and those that are significant usually remain so as the sample is extended. In addition, the uncertainty of some of the coefficients of the exogenous variables (at the bottom of each figure) diminishes as the sample grows. Interestingly, the effect of past inflation on market-based inflation expectations declines as the sample advances, which is consistent with our empirical experience[5]. It is also worth noting that the coefficient of the cross-rate in the foreign exchange rate equation becomes somewhat larger (in absolute terms) as the sample progresses.

**3c. Explanatory power of exogenous variables:** Exogenous variables seem to play a key role in explaining past patterns of movement of the endogenous variables under investigation in our VAR system. Two different approaches are implemented to help us make inferences about the relative importance of the exogenous variables in our VAR specification. The first approach excludes the effect of the past values of endogenous variables from the estimated VAR system by excluding them from the estimated system, leaving the current values of the endogenous variables dependent on movements in the exogenous variables alone. In the second approach, the VAR system is estimated several times, with one of the exogenous variable excluded in each estimation. We then run dynamic in-sample simulations for these partially constructed VARs and compare them to a simulation run for a complete VAR estimation.

**Figure 1: The Effect of exogenous variables on the fit of dlci, dle, infexp, dlcpi and iboi – based on an alternative estimation (including only exogenous variables.)**

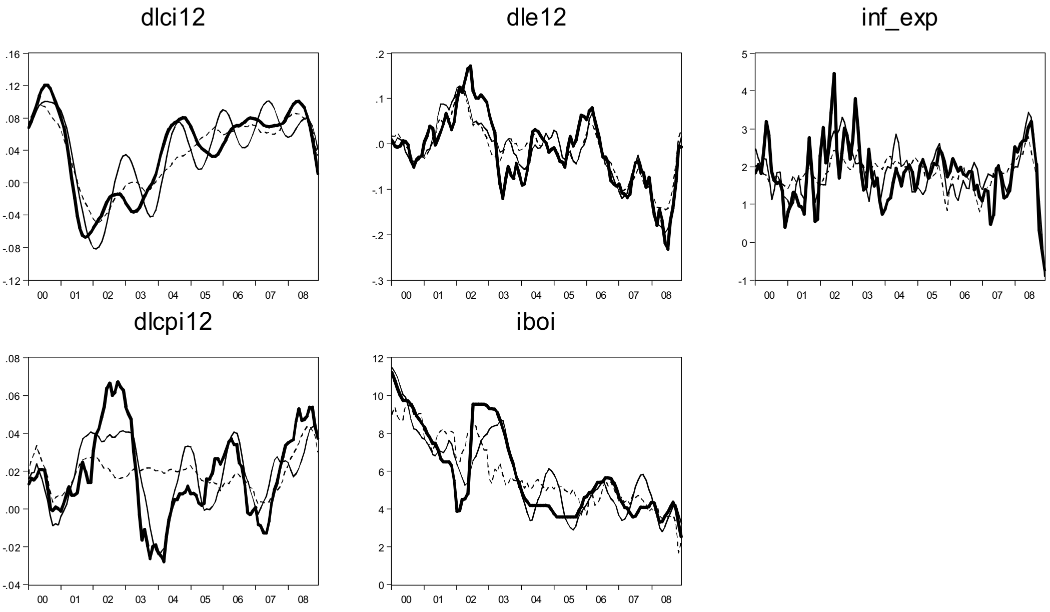


Figure 1 displays the actual data (thick line), in-sample dynamic simulations created for the complete VAR (thin line), and the VAR excluding past values of endogenous variables according to the above mentioned first approach (broken line). As can be seen, simulations constructed from the partial VAR tend to track the trends in the exchange rate and inflation expectations relatively well, making our specification of these two variables fairly sensitive to developments of the exogenous variables. The degree of this sensitivity, however, seems much smaller for the other variables in the VAR model – the real activity index, inflation and the BoI interest rate, which are less

---

[5] The correlation between inflation expectations and actual 12-month CPI inflation was very high (0.95) until 2001, and has diminished significantly later.

sensitive to exogenous changes. However, it should be noted, that the BoI's sensitivity to exogenous developments has, according to this analysis, increased in recent years.

The results of our second approach for analyzing the dependence of our VAR specification on the exogenous variables are presented in Table 3. This approach—which involves excluding in each estimation one of the exogenous variables—yields insight not only into the contribution of the whole group of exogenous variables to the goodness of fit, but also into the relative importance of each individual exogenous variable. Table 3 computes the RMSE of the in-sample simulations for six partial VARs and for our complete VAR system, and determines the importance of each exogenous variable based on the degree to which the exclusion of each exogenous variable resulted in an increase in the RMSE of the in-sample simulation. The results reveal that the level of the Fed fund interest rate and the security situation are the exogenous variables that contribute significantly to the evolution of the short-term interest rate. Cross rates are significant in explaining the developments in the exchange rate, and import prices contribute to the development of inflation expectations.

Generally, these results point to the importance of the exogenous variables in forecasting future periods. The ability to assess the future path of real activity relies heavily on our knowledge of the expected values of the exogenous variables. Forecasting the movements of the exchange rate depends on the future cross-rates, which are generally difficult if not impossible to predict. By contrast, the expected path of the policy instrument–the BoI interest rate–is less affected by the exogenous variables and more by the development of the endogenous variables in the system.

**Table 3: RMSE of In-Sample Simulations for the Complete VAR and VARs Excluding Individual Exogenous Variables**

| | | VAR excluding the following exogenous variables: | | | | | |
|---|---|---|---|---|---|---|---|
| Dependent Variables | Complete VAR | Cross rates | Fed interest rate | Import prices | Security | US industrial production | Net direct investment |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| dlci | 0.51 | 0.52 | 0.53 | 0.50 | 0.49 | 0.43 | 0.43 |
| dle | 1.65 | 1.85 | 1.68 | 1.64 | 1.63 | 1.61 | 1.74 |
| inf_exp | 0.60 | 0.60 | 0.63 | 0.75 | 0.59 | 0.57 | 0.59 |
| dlcpi | 0.42 | 0.43 | 0.42 | 0.43 | 0.40 | 0.40 | 0.43 |
| iboi | 1.01 | 1.05 | 1.16 | 1.04 | 1.40 | 0.95 | 0.99 |

**3d. Impulse response analysis:** Impulse response functions are not needed to construct forecasts of monetary policy decisions, as such forecasts can be calculated using the coefficients estimated from the reduced-form VAR. Nonetheless, impulse response analysis is an essential ingredient of VAR investigations, providing an efficient tool for determining how the variables interact in the structural form of our VAR model.

The effects of the various structural shocks on the time paths of the five endogenous variables included in our VAR (3E) model are identified through a non-recursive identification scheme following Sims and Zha (1998) and Kim and Roubini (2000). This approach allows us to explicitly establish short-run assumptions about contemporaneous relations among the variables in the system based mainly on economic theory and the transmission mechanism in the Israel economy, therefore, attributing some economic rationale to the impulse response analysis. In order to exactly identify the structural shocks in our 5-variable system, 15 restrictions must be imposed. Specifically, we use the following contemporaneous relation between the reduced-form errors $\mu_t$ and the structural disturbance $\varepsilon_t$:

$$(4)\qquad \begin{bmatrix} \varepsilon_t^{dlci} \\ \varepsilon_t^{dle} \\ \varepsilon_t^{\inf\exp} \\ \varepsilon_t^{dlcpi} \\ \varepsilon_t^{iboi} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ f_{2,1} & 1 & 0 & 0 & f_{2,5} \\ f_{3,1} & f_{3,2} & 1 & 0 & f_{3,5} \\ f_{4,1} & f_{4,2} & f_{4,3} & 1 & 0 \\ 0 & f_{5,2} & 0 & f_{5,4} & 1 \end{bmatrix} \begin{bmatrix} \mu_t^{dlci} \\ \mu_t^{dle} \\ \mu_t^{\inf\exp} \\ \mu_t^{dlcpi} \\ \mu_t^{iboi} \end{bmatrix}$$

This is an almost-Choleski decomposition with only two modifications. The first equation represents the sluggish response of real activity to the nominal variables, exchange rate changes, inflation expectations, inflation rate and short-term interest rates. In the second equation, exchange rate changes are allowed to respond contemporaneously to shocks in short-term interest rates, which are expected to affect financial markets instantaneously and are also allowed to respond contemporaneously to real activity growth. The third equation allows the shocks of real activity, exchange rate depreciation and a shock to the BoI interest rate to affect inflation expectations immediately, but assumes that shocks to consumer prices affect inflation expectations with a lag. The fourth equation assumes that shocks to the short-term interest rate affect inflation only with a lag. The last equation suggests that the monetary policy rate may respond immediately to the exchange rate and inflation but react only with a lag to real activity and inflation expectations. This specification is somewhat arbitrary; the BoI sets its interest rate for a month in advance, so actual values of all variables for that month are still unknown. We may assume that the BoI is responding to its best estimate of some of the variables. It should be noted that the characteristics of the impulse response function were found to be sensitive to the short-run restrictions imposed. Because the data is monthly, the significance of allowing a contemporaneous reaction or one-month-lagged reaction is less important. We chose this specific structure of short-run restrictions, which is similar to the Cholesky triangular decomposition, because it is reasonable from an economic point of view and provides sensible paths for the response functions of all variables in the system. Only three of the coefficients identified under the identification scheme specified in the above matrix are significantly different from zero.

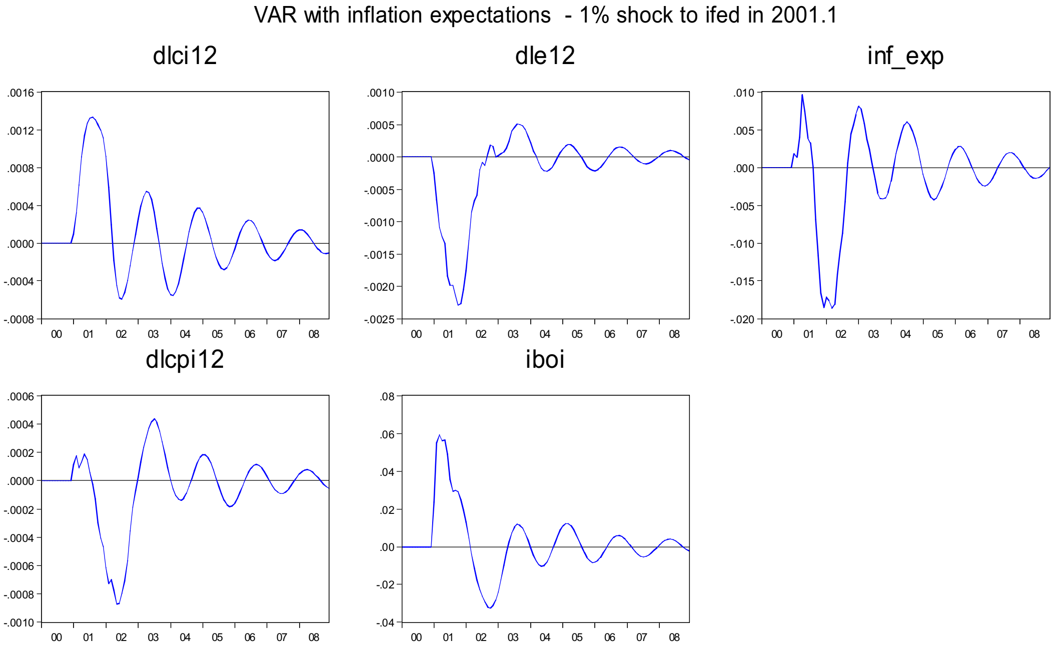
Using the results obtained from the estimation of the matrix in equation (4), we were able to construct the impulse response functions shown in Appendix D. The graphs display the impact (the impulse response) of a one-standard-deviation shock in output growth, exchange rate depreciation, inflation, and short-term interest rate. A one-standard-deviation shock is defined as an exogenous, unexpected, temporary rise in any of these five variables at t = 0 on the time path of these variables. In addition to the impulse response functions generated according to the structural decomposition described above, we also present the impulse responses produced using the Choleski decomposition. The results are qualitatively typically similar although some quantitative responses differ between the two sets of specifications.

The results can be summarized as follows:

- A one-time shock to the BoI interest rate tends to lower the exchange rate, i.e. to appreciate the local currency, as may be expected to happen in the short run, and to lower inflation and inflation expectations immediately, presumably due to the rapid effect of the exchange rate on prices. These effects are more pronounced in the structural identification relative than in the Choleski decomposition.
- The response of the BoI interest rate to other shocks, as read on the bottom line of the diagram, shows a significant increase in the interest rate in response to a depreciation of the exchange rate and a positive response of the rate to a rise in inflation expectations. The response of the interest rate to a rise in actual inflation is smaller and only marginally significant (according to the Cholesky decomposition). This is consistent with a forward-looking policy of the central bank.
- A shock to the exchange rate (second column) has a positive effect on inflation and inflation expectations, in both decompositions, as expected in a small open economy like Israel's.
- The effect of a real activity shock on the other variables and the response of real activity to other shocks is usually insignificant. It seems that the monthly frequency of the observations and model is more suitable to a description of the developments in the nominal variables and less appropriate for the dynamics of the real side of the economy.

**3e. A one-time shock to the Fed interest rate:** The estimated VAR system also allows us to analyze the effect of a shock to one of the exogenous variables in the system. Recall that we included in the estimated reduced-form system a number of exogenous variables we thought to be essential for the understanding of developments in the period investigated. Our exercise is carried out by allowing a one-time 1 percentage point shock to the Federal Reserve interest rate. We included all exogenous variables in all equations, disregarding the structural constraints on the effects of each of them on the endogenous variables. Nonetheless, the empirical results show that the effect of these exogenous variables was typically significant where it was expected to be so (see Appendix B for estimation results). Therefore, a one-time shock to *ifed* initially affects all endogenous variables but its effect on the BoI interest rate is the most sizeable effect, although still relatively small, and is evident in an increase in the BoI interest rate which subsequently results in a decline of the exchange rate (appreciation), inflation expectations and actual inflation. Due to the lag structure of the endogenous variables the convergence to the original state is volatile and lasts a substantial number of periods (Figure 2).

**Figure 2: The Effect of a 1 p.p. shock to the Federal Reserve interest rate**



**3f. Variance decompositions:** The relative importance of the different shocks for fluctuations in each variable can be gauged by the error variance decompositions. Table 4 presents the short-run and long-run variance decomposition according to the previously selected structural identification.

An important result is that short-term interest rate volatility, like the other variables, explains only a minor share of total volatility of output growth and some of the inflation forecast volatility, so that most of the variance in economic activity cannot be attributed to any one variable other than itself. Interest rate volatility stems in the short run mostly from the noise in the exchange rate and not directly from the *noise* in inflation or inflation expectations. This may be due partly to the relatively high volatility of the exchange rate and the effect thereof on inflation and inflation expectations. It is interesting to note that most of the volatility of the exchange rate forecast is due to volatility in the BoI interest rate (given the values of the exogenous variables).

## Table 4: Variance Decomposition in the short and long run

| Composite index for real activity | | | | | |
|---|---|---|---|---|---|
| Periods | Shock to the change in real activity | Shock to the change in exchange rate | Shock to inflation expectations | Shock to inflation | Shock to BoI interest rate |
| 0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1 | 96.4 | 0.8 | 1.9 | 0.0 | 0.9 |
| 3 | 93.6 | 1.6 | 2.6 | 0.1 | 2.1 |
| 25 | 83.7 | 6.0 | 4.0 | 3.5 | 2.9 |
| **Exchange rate** | | | | | |
| Periods | Shock to the change in real activity | Shock to the change in exchange rate | Shock to inflation expectations | Shock to inflation | Shock to BoI interest rate |
| 0 | 0.9 | 20.5 | 0.0 | 0.0 | 78.6 |
| 1 | 2.0 | 18.9 | 0.5 | 0.1 | 78.4 |
| 3 | 2.5 | 18.0 | 10.9 | 1.0 | 67.6 |
| 25 | 6.4 | 16.9 | 13.7 | 2.3 | 60.7 |
| **Inflation expectations** | | | | | |
| Periods | Shock to the change in real activity | Shock to the change in exchange rate | Shock to inflation expectations | Shock to inflation | Shock to BoI interest rate |
| 0 | 2.6 | 18.8 | 62.0 | 0.0 | 16.6 |
| 1 | 1.5 | 15.5 | 55.1 | 0.1 | 27.8 |
| 3 | 9.6 | 14.0 | 48.1 | 0.6 | 27.5 |
| 25 | 23.0 | 12.9 | 38.3 | 1.6 | 24.2 |
| **Inflation** | | | | | |
| Periods | Shock to the change in real activity | Shock to the change in exchange rate | Shock to inflation expectations | Shock to inflation | Shock to BoI interest rate |
| 0 | 0.3 | 8.7 | 0.0 | 57.9 | 33.0 |
| 1 | 6.4 | 14.1 | 4.9 | 36.8 | 37.7 |
| 3 | 7.1 | 13.7 | 10.6 | 33.1 | 35.5 |
| 25 | 18.5 | 17.0 | 11.0 | 21.0 | 32.6 |
| **BoI interest rate** | | | | | |
| Periods | Shock to the change in real activity | Shock to the change in exchange rate | Shock to inflation expectations | Shock to inflation | Shock to BoI interest rate |
| 0 | 3.1 | 67.7 | 0.0 | 0.0 | 29.2 |
| 1 | 3.3 | 78.5 | 6.6 | 0.2 | 11.4 |
| 3 | 1.4 | 68.3 | 16.8 | 2.0 | 11.4 |
| 25 | 20.3 | 38.2 | 12.7 | 2.7 | 26.0 |

### 3g. Historical decomposition of shocks[6]

The identification of the structural shocks makes it possible to determine each structural shock’s contribution to the estimated residuals of each equation based on the restrictions imposed. We assume that activity is affected contemporaneously only by its own shocks (equation 4). Therefore, the residuals of the *dlci* equation reflect only shocks to activity. Estimated residuals in the exchange rate equation may be

---

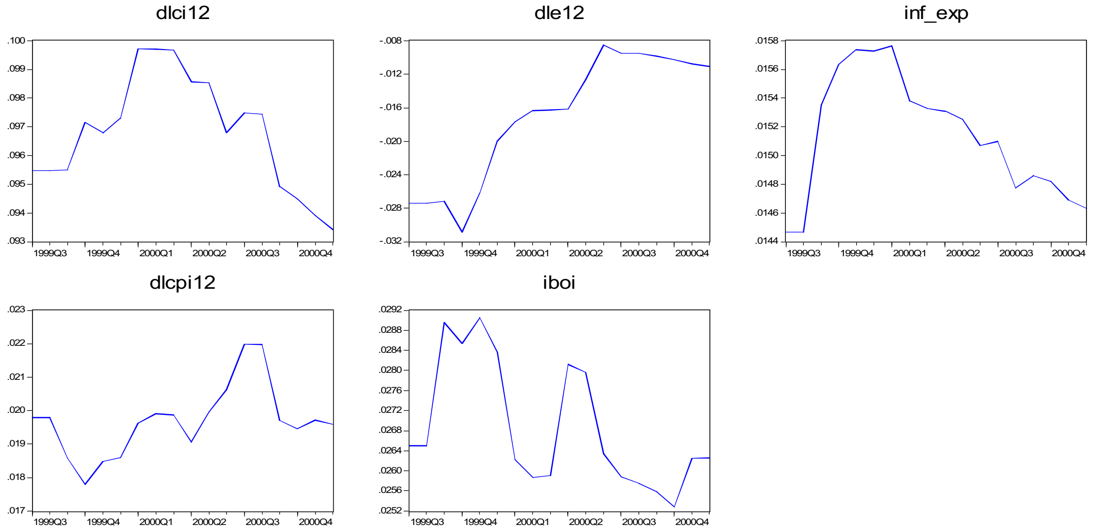
[6] We chose not to present graphs of the historical decomposition; the data is available upon request.

attributed, other to shocks to the exchange rate itself, mainly to structural shocks in the interest rate. This result is due to the restrictions we imposed setting to zero the contemporaneous effect on the exchange rate of a shock in inflation and inflation expctations. Deviations in the inflation equation result largely from shocks to the prices themselves and the exchange rate. Noises in the inflation expectations equation stem mainly from deviations in the short-run interest rate, and in the earlier period also from deviations to the exchange rate. The errors in the BoI interest rate equation stem from shocks to the exchange rate and to the interest rate itself. This decomposition concerns the contemporaneous direct effect of structural shocks. The assumption that other shocks do not have an immediate effect does not mean there is no direct or indirect effect after several periods.

### 3h. Stability of the long-run values

We test the plausibility of the long-run values of the system's endogenous variables. To check this, one must know or assume the long-run values of the exogenous variables and simulate the system assuming these values[7]. We checked the stability of these values over different estimation samples using a methodology similar to that employed and described in section 4b. In Figure 3, we show the long-run values for the annual rate of real activity, the change in the exchange rate and inflation and the rate of inflation expectations and BoI interest rate in the long run.

**Figure 3: Simulated long run values for samples from July 1997 through Dec. 2000**



The value at each point on the graphs is obtained by simulating a system that was estimated from that point in time until 2008.12. The fluctuations of these values are relatively small and are generally reasonable, although they may deviate from the expected values to some extent. Using shorter samples serves to reduce the growth rate of activity slightly, which is nonetheless still quite high, at about 7 percent. The depreciation rate is about 1 percent (annually), and inflation expectations are about 1.4 percent, somewhat lower than the long-run rate of inflation (2 percent) corresponding to the midpoint of the inflation target. The nominal interest rate, at

---

[7] The quantitative assumptions about the long-run values of the exogenous variables are presented in Appendix E.

about 1 percent, is lower than expected. Although we did not compute the standard deviation of these estimates, we may assume that taking the standard deviations into account would put most of the long-run values within a reasonable range.

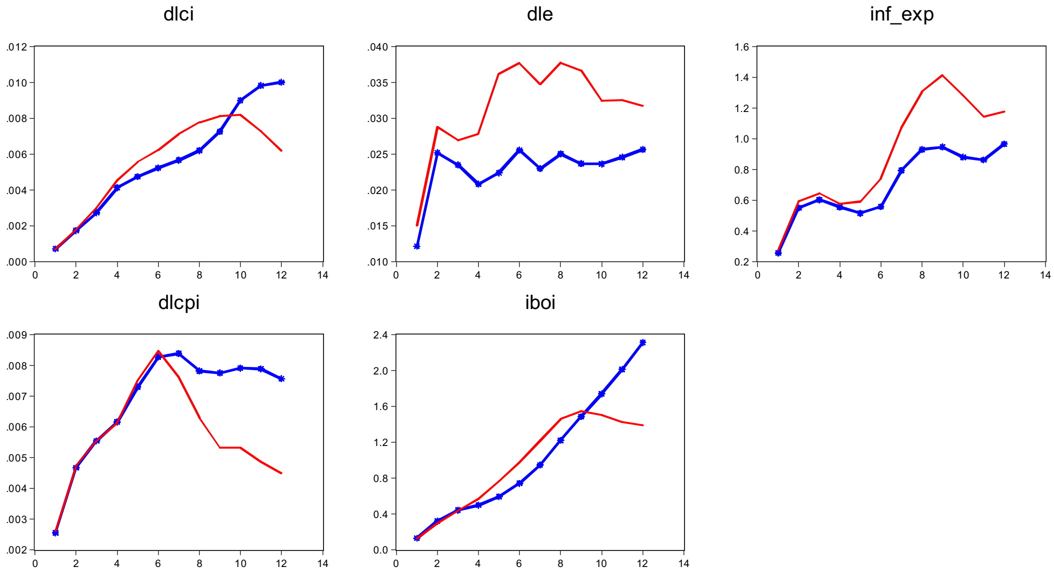
## *4. Forecasting and Measuring Forecast Accuracy*

VAR systems are frequently used for forecasting—usually short-run—and as a benchmark for other more structural models. To ascertain our model's forecasting ability and accuracy, we check the precision of the forecast for an out-of-sample period for which the real values of the endogenous variables are already known. This can be done using the actual values of the now known exogenous variables or estimated values for these variables constructed using a (different) VAR system. Another alternative, which we did not test at this point due to lack of data, is the performance of out-of-sample, ex-post forecasts using the information about the exogenous variables known at the time of the forecast.

### 4a. Out-of-sample forecast for historical data

We estimated the VAR system twelve times, starting from Jan. 2000 to 2007.3+*i*, with *i* going from 1 to 12. For each estimation we simulated an out-of-sample forecast up to twelve periods ahead. We did this in two ways. The first uses the known actual values of the exogenous variables, and the alternative uses a forecast for the exogenous variables based on a simple VAR model estimated for a period parallel to that of the main VAR system. Each method thus yields 12 one-period-ahead forecasts (each relating to a different date), 12 two-period-ahead forecasts, and so on, up to 12 forecasts for twelve-periods-ahead. For each horizon, the RMSE of the forecasts was computed based on 12 observations, as shown in Figure 4.

**Figure 4: RMSE of forecasts 1-12 periods ahead with actual exogenous variables (with squares) and VAR-based simulated exogenous variables**

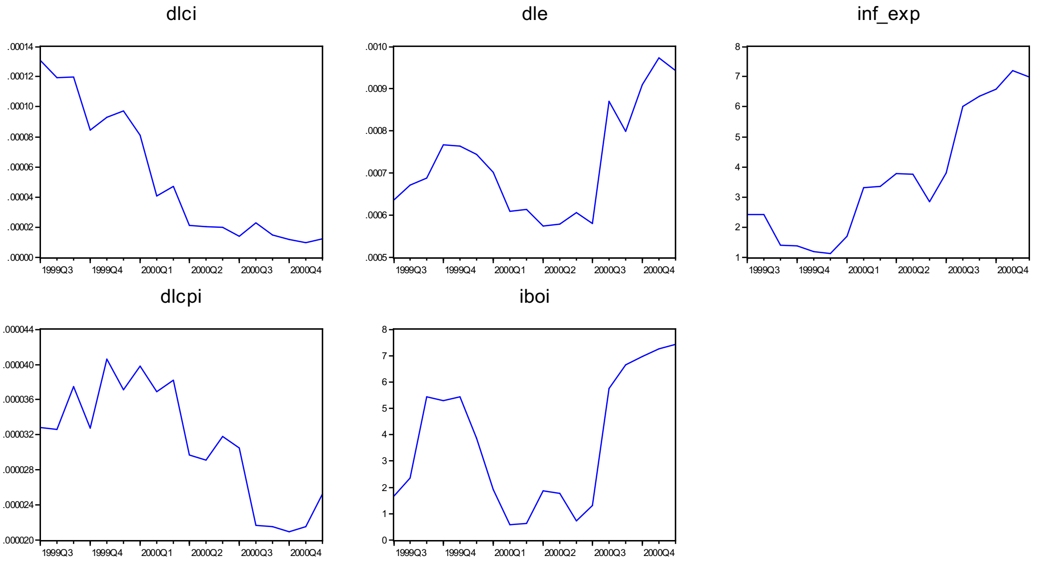


According to Figure 4, the error in forecasting later periods is usually larger than the forecast error for shorter horizons, except for the case of the exchange rate (*dle*). It is also apparent that knowing the actual ex-post values of the exogenous variables improves the accuracy of the forecast for the exchange rate, inflation expectations and, to some extent, inflation expectations, but does not contribute much to the forecast accuracy of the other variables. This is consistent with our findings that exogenous variables play an important role in explaining the path of the exchange rate and inflation expectations. (see Figure 1). In comparing the standard deviation of the actual values of the endogenous variables for the full sample period, we see that the magnitude of uncertainty in the forecast is similar to that of one standard error for inflation and inflation expectation horizons longer than one period,[8] a bit larger for the exchange rate, and significantly smaller for the BoI interest rate, indicating a relatively good ability to forecast the BoI future interest rate path.

### 4b. RMSE stability of forecasts

We also tested the out-of-sample RMSE of the forecasts for samples with different starting points. The system was estimated for samples starting at $t_0$ and always ending at 2007.12[9], where $t_0$ goes from 1999.7 to 2000.12. For each of these estimated VAR systems, we simulated a model for the periods 2008.1 through 2008.10 and computed the RMSE of the forecast for each of the five variables of the system, as shown in Figure 5.

**Figure 5: RMSE of forecast for 2008.4-2009.3 for samples starting at 1999.7 through 2000.12**



As the graphs show, the RMSE of the forecast fluctuates somewhat from one sample to the next. The forecast errors of real activity improve as the sample shortens, and to some extent, so do the inflation rate errors. A starting point of 2000.1, which we chose for our estimations, seems reasonable from this point of view. Except for the

---

[8] The standard deviations for 2000.1-2008.6 are 0.0055 for *dlci*, 0.0183 for *dle*, 0.0072 for *inf_exp*, 0.0051 for *dlcpi* and 2.3 for *iboi*.

[9] This sample was terminated at an earlier period than the sample we use in our base estimation (there we use data until 2008.12) in order to leave, for the out-of-sample forecast, a sufficient number of observations that have actual values for the endogenous variables estimated.

inflation rate, the RMSE of the forecast all other variables are at or close to their minimum, the RMSE of *dlcpi* is generally constant throughout the samples. The forecast error for the inflation rate improves only when the sample is shortened reasonably. A longer sample than the one chosen could improve some of the forecasts but harm others, and the same is true for shorter periods starting later than 2000.1.

## *5. Concluding Remarks*

The paper investigates the relationship between inflation rate, inflation expectations (as measured in the capital markets), the exchange rate, the central bank's interest rate and real activity using a monthly structural VAR. The statistical relationship between these variables, as revealed by the estimated system, allows us to construct short run forecasts for monetary policy and other purposes. Identifying the structural shocks, by imposing short-run restrictions, makes it possible to investigate the reaction of each of these variables, and in particular the central bank's interest rate reaction to different shocks.

We perform different tests both to assess the ability of the model to produce reasonable forecasts and to understand the transmission mechanism of structural shocks. We find that a specification that includes market-based inflation expectations improves the estimation results, and it is the specification we adopt for further testing.

We show that the estimated coefficients of the system are relatively stable and that the exogenous variables play an important role in forecasting future periods. Forecasting the movements of the exchange rate depends on knowing the future cross-rates, which are generally difficult if not impossible to predict. By contrast, the expected path of the policy instrument–the BoI interest rate–is affected less by the exogenous variables and more by the development of the endogenous variables in the system. In addition most of the variance in economic activity cannot be attributed to any one variable other than itself. Interest rate volatility stems in the short run mostly from the noise in the exchange rate and not directly from the noise in inflation or inflation expectations. This may be due partly to the relatively high volatility of the exchange rate and the effect thereof on inflation and inflation expectations.

Assuming an almost-Cholesky structural decomposition of the shocks, the model exhibits a significant reaction of the central bank to a shock in the exchange rate and inflation expectations and a much smaller response to a shock in actual inflation. This pattern fits the forward-looking feature of monetary policy. On the other hand, inflation and inflation expectations react as expected to a shock to the monetary policy and the exchange rate.

We found that most coefficients are relatively stable over changing samples and that long term values of the endogenous variables are around their expected values, in particular inflation was found to converge to the 2 percent inflation target.

## References

Bjorland H. (2005), "Monetary Policy and Exchange Rate Interactions in a Small Open Economy", Working paper 2005/16, December 2005, Norges Bank.

Brissimis, S. N., and N. S. Magginas, (2006), "Forward-looking information in VAR models and the price puzzle" *Journal of Monetary Economics*, 53, p.1225-34.

Buckle, R, K. Kim, H. Kirkham, N. McLellan and J Sharma (2002), " A Structural VAR Model of the New Zealand Business Cycle", Working paper 02/26, New Zealand Treasury.

Camarero, M., J. Ordonez and C.R. Tamarit (2002), " Monetary Transmission in Spain: A Structural Cointegrated VAR Approach", Applied Economics,34, 2201-12.

Dungey, M., and A. Pagan (2008), "Extending a SVAR Model of the Australian Economy", National Centre for Econometric Research, Working Paper 21.

Jacobson,T., P. Jansson, A. Vredin and A. Warne (2001), "Monetary Policy Analysis and Inflation Targeting in a Small Open Economy: A VAR Approach", Journal of Applied Econometrics, 16, 487-520.

Kapetanios, G., V. Labhard and S. Price (2007), "Forecast Combination and the Bank of England's Suite of Statistical Forecasting Models", *Bank of England,* Working Paper 323.

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(3), p. 561-586.

Sims C. and T. Zha (1998), "Does monetary policy generate recessions?", *Federal Reserve Bank of Atlanta, Working paper* 98-12.

## Appendix A

### Unit Root and Stationary Tests

| (1) | Period (2) | ADF Unit Root Test $H_0$: I(1) (3) | KPSS Stationarity Test $H_0$: I(0) (4) |
|---|---|---|---|
| **Endog. Vars.** | | | |
| CI | 1996-2008.12 | NR | R*** |
| E | 1996-2008.12 | NR | R** |
| CPI | 1996-2008.12 | NR | R*** |
| IBOI | 1996-2008.12 | NR | R*** |
| | 2000-2008.12 | NR | R*** |
| With trend | 1996-2008.12 | R** | NR |
| DLCI | 1996-2008.12 | R** | NR |
| DLE | 1996-2008.12 | R*** | R* |
| | 2000-2008.12 | R*** | NR |
| DLCPI | 1996-2008.12 | R*** | R** |
| | 2000-2008.12 | R*** | NR |
| INF_EXP | 1996-2008.12 | NR | R*** |
| | 2000-2008.12 | R** | NR |
| **Exog. Vars.** | | | |
| IPUS | 1996-2008.12 | NR | R*** |
| IFED | 1996-2008.12 | NR | R* |
| | 2000-2008.12 | NR | NR |
| With trend | 2000-2008.12 | NR | R** |
| CROSS | 1999-2008.12 | NR | R*** |
| PMI | 1996-2008.12 | R* | R*** |
| PMC | 1996-2008.12 | NR | R* |
| SECURITY | 1996-2008.12 | NR | R* |
| | 2000-2008.12 | R** | R** |
| NET_DIRECT | 1998-2008.12 | R*** | NR |
| DLIPUS | 1996-2008.12 | R*** | R** |
| DLCROSS | 1999-2008.12 | R*** | R* |
| DLPMI | 1996-2008.12 | NR | R*** |
| DLPMC | 1996-2008.12 | R*** | R*** |
| 0.8*DLPMI+0.2 *DLPMC | 1996-2008.12 | NR | R* |

R – the null is rejected. NR – the null is not rejected.
* significant at the 1% level. ** significant at the 5% level. *** significant at the 10% level.

Notes:
- Test results in columns (3) are based on the ADF test P-Values; the results in column (4) are based on the KPSS test LM-statistics.
- The tests were conducted without restricting lag length (in the ADF test) and bandwidth (in the KPSS test).

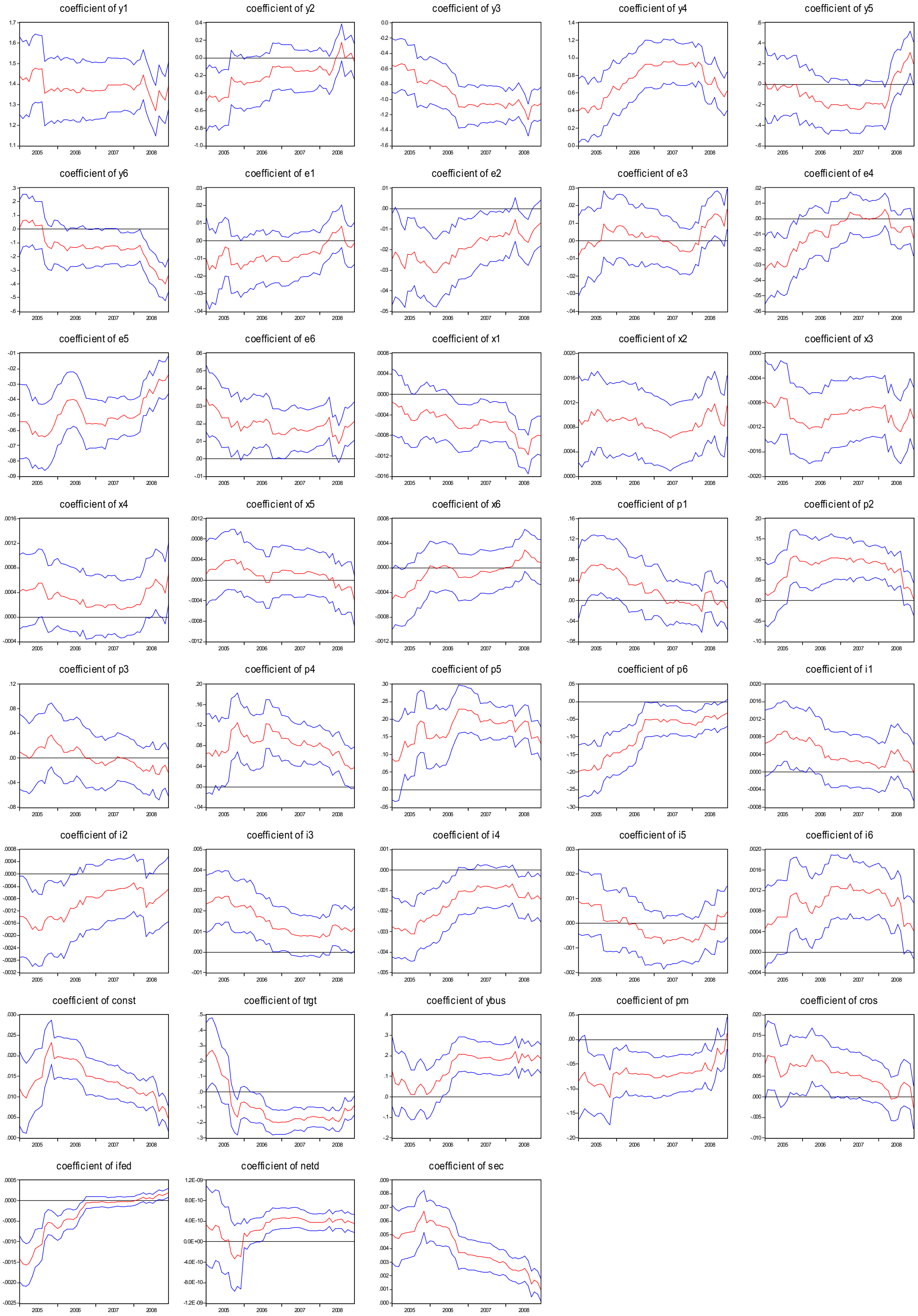
# Appendix B

## Estimation Results of VAR (3E) 2000M1 – 2008M12

| | **DLCI** | **DLE** | **INF_EXP** | **DLCPI** | **IBOI** |
|---|---|---|---|---|---|
| **DLCI(-1)** | **1.393** | 1.501 | 60.149 | **-0.540** | 10.637 |
| **DLCI(-2)** | -0.048 | -4.258 | -11.469 | 0.431 | -5.670 |
| **DLCI(-3)** | **-1.052** | 3.866 | -42.698 | 0.856 | -7.477 |
| **DLCI(-4)** | **0.617** | 1.036 | 8.992 | **-1.087** | -0.048 |
| **DLCI(-5)** | 0.203 | -3.158 | 37.557 | 0.787 | -15.133 |
| **DLCI(-6)** | **-0.336** | 1.307 | -37.293 | **-0.595** | 37.144 |
| **DLE(-1)** | -0.001 | 0.174 | 4.985 | **0.077** | 1.894 |
| **DLE(-2)** | -0.007 | 0.124 | 0.716 | -0.027 | -0.412 |
| **DLE(-3)** | **0.018** | -0.067 | -0.766 | -0.015 | 1.585 |
| **DLE(-4)** | -0.013 | -0.013 | -2.993 | -0.001 | 3.121 |
| **DLE(-5)** | **-0.024** | 0.101 | 3.479 | 0.013 | **4.583** |
| **DLE(-6)** | **0.022** | **-0.262** | -1.968 | -0.032 | 0.142 |
| **INF_EXP(-1)** | **-0.001** | 0.003 | **0.773** | **0.002** | **0.292** |
| **INF_EXP(-2)** | **0.001** | **-0.012** | **-0.410** | **-0.004** | -0.078 |
| **INF_EXP(-3)** | **-0.001** | 0.002 | 0.266 | 0.002 | 0.116 |
| **INF_EXP(-4)** | 0.001 | 0.008 | 0.255 | 0.000 | **-0.236** |
| **INF_EXP(-5)** | 0.000 | -0.010 | -0.168 | -0.001 | 0.145 |
| **INF_EXP(-6)** | 0.000 | **0.013** | 0.109 | **0.002** | 0.003 |
| **DLCPI(-1)** | -0.015 | -0.211 | 8.628 | 0.058 | 6.856 |
| **DLCPI(-2)** | 0.005 | -0.565 | -2.511 | 0.026 | **18.885** |
| **DLCPI(-3)** | -0.025 | 0.751 | -8.335 | **0.157** | 2.327 |
| **DLCPI(-4)** | 0.038 | 0.019 | 10.119 | -0.074 | -2.738 |
| **DLCPI(-5)** | **0.130** | -0.460 | -0.816 | 0.098 | 5.713 |
| **DLCPI(-6)** | -0.033 | 0.121 | 4.120 | -0.076 | 8.444 |
| **IBOI(-1)** | 0.000 | -0.010 | -0.306 | 0.000 | **1.240** |
| **IBOI(-2)** | 0.000 | 0.018 | 0.432 | 0.000 | **-0.543** |
| **IBOI(-3)** | 0.001 | -0.014 | -0.263 | 0.000 | **0.428** |
| **IBOI(-4)** | -0.001 | 0.000 | -0.007 | -0.001 | -0.144 |
| **IBOI(-5)** | 0.000 | 0.001 | 0.233 | -0.002 | -0.212 |
| **IBOI(-6)** | 0.000 | 0.001 | -0.179 | 0.002 | **0.192** |
| **C** | 0.004 | **-0.092** | **-2.240** | -0.011 | **-1.433** |
| **TARGET** | -0.087 | **1.527** | **43.569** | **0.376** | -7.868 |
| **@MOVAV(DLIPUS(-2),3)** | **0.186** | -1.314 | -39.064 | **-0.396** | -1.525 |
| **@MOVAV(0.8*DLPMI+0.2*DLPMC,3)** | 0.013 | 0.208 | **36.887** | **0.221** | 2.052 |
| **DLCROSS** | -0.003 | **-0.312** | 1.000 | 0.004 | **1.700** |
| **@MOVAV(IFED,2)** | **0.000** | -0.001 | 0.004 | 0.000 | **0.048** |
| **@MOVAV(NET_DIRECT,2)** | **0.000** | **0.000** | **0.000** | **0.000** | 0.000 |
| **@MOVAV(SECURITY,4)** | 0.001 | **-0.027** | **-0.655** | -0.003 | **-0.370** |
| **DUM4** | -0.001 | 0.001 | 0.135 | **0.009** | -0.014 |
| **DUM9** | **-0.002** | -0.004 | -0.066 | **-0.005** | -0.067 |
| | | | | | |
| **Adjusted $R^2$** | 0.96 | 0.39 | 0.66 | 0.65 | 0.99 |

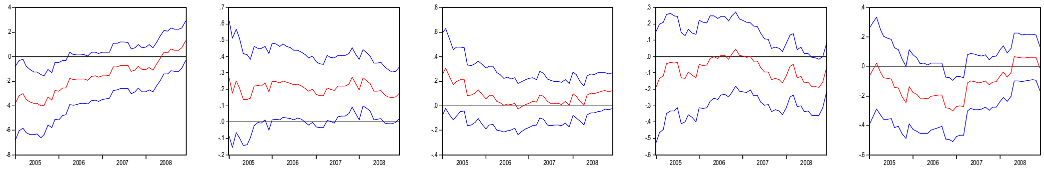
* Characters in bold indicate statistical significance at a level of at least 10 percent.

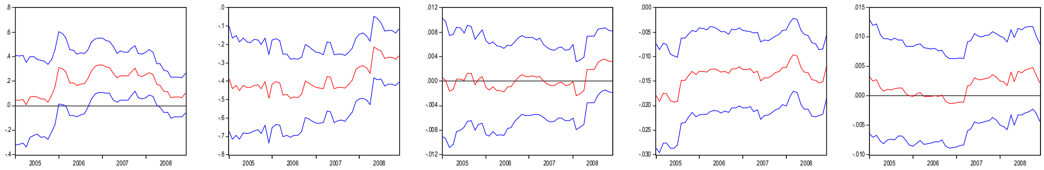
# Appendix C: Stability of Estimated Coefficients

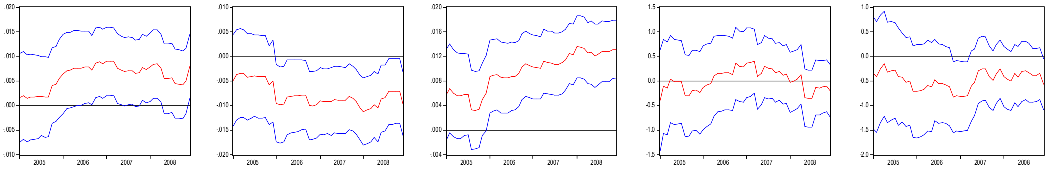

coefficients for dlci equation

coefficients for dle equation

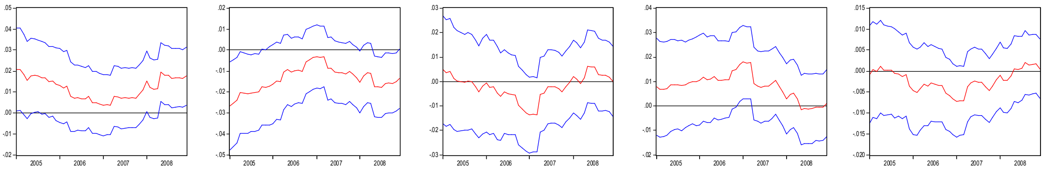

coefficient of y1 coefficient of y2 coefficient of y3 coefficient of y4 coefficient of y5

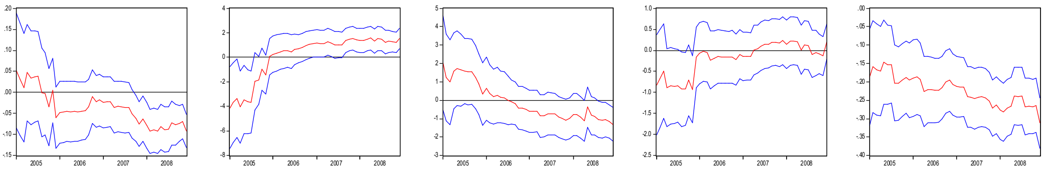

coefficient of y6 coefficient of e1 coefficient of e2 coefficient of e3 coefficient of e4

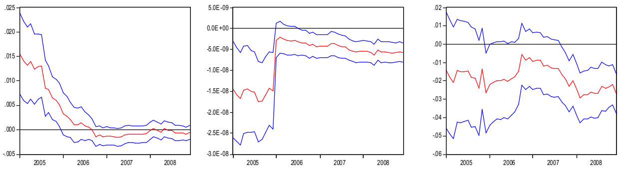

coefficient of e5 coefficient of e6 coefficient of x1 coefficient of x2 coefficient of x3

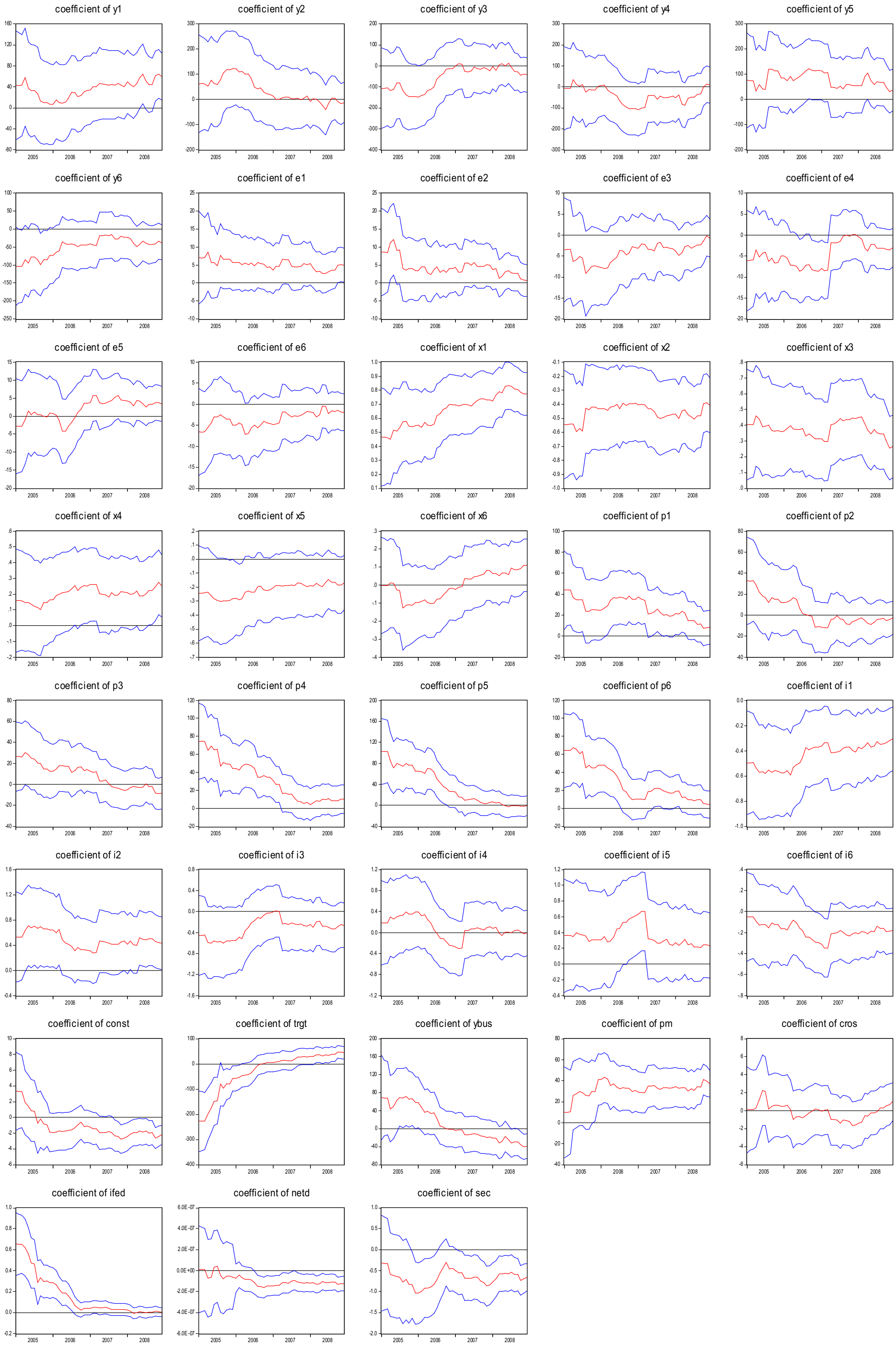

coefficient of x4 coefficient of x5 coefficient of x6 coefficient of p1 coefficient of p2


coefficient of p3 coefficient of p4 coefficient of p5 coefficient of p6 coefficient of i1


coefficient of i2 coefficient of i3 coefficient of i4 coefficient of i5 coefficient of i6


coefficient of const coefficient of trgt coefficient of ybus coefficient of pm coefficient of cros

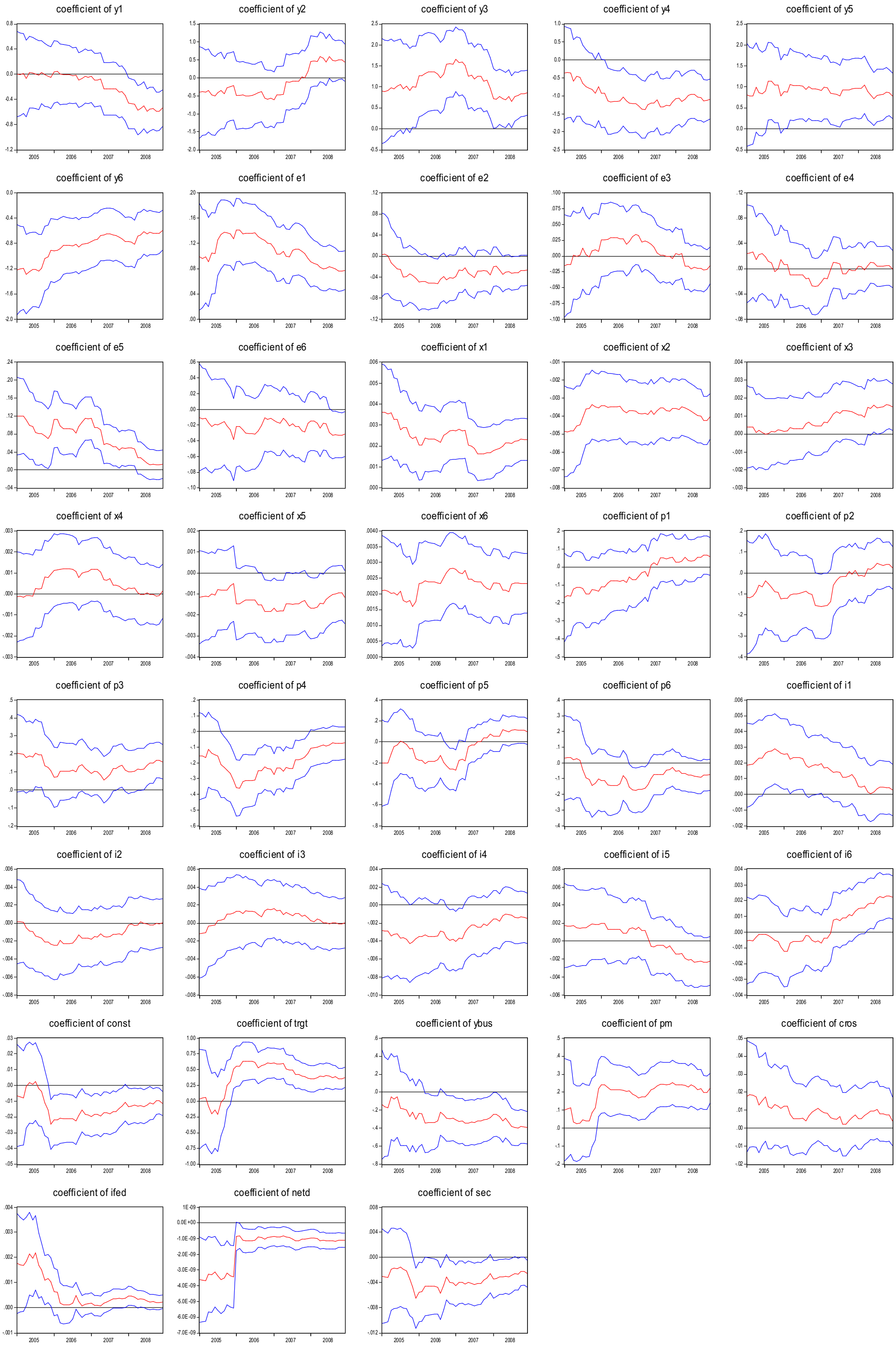

coefficient of ifed coefficient of netd coefficient of sec



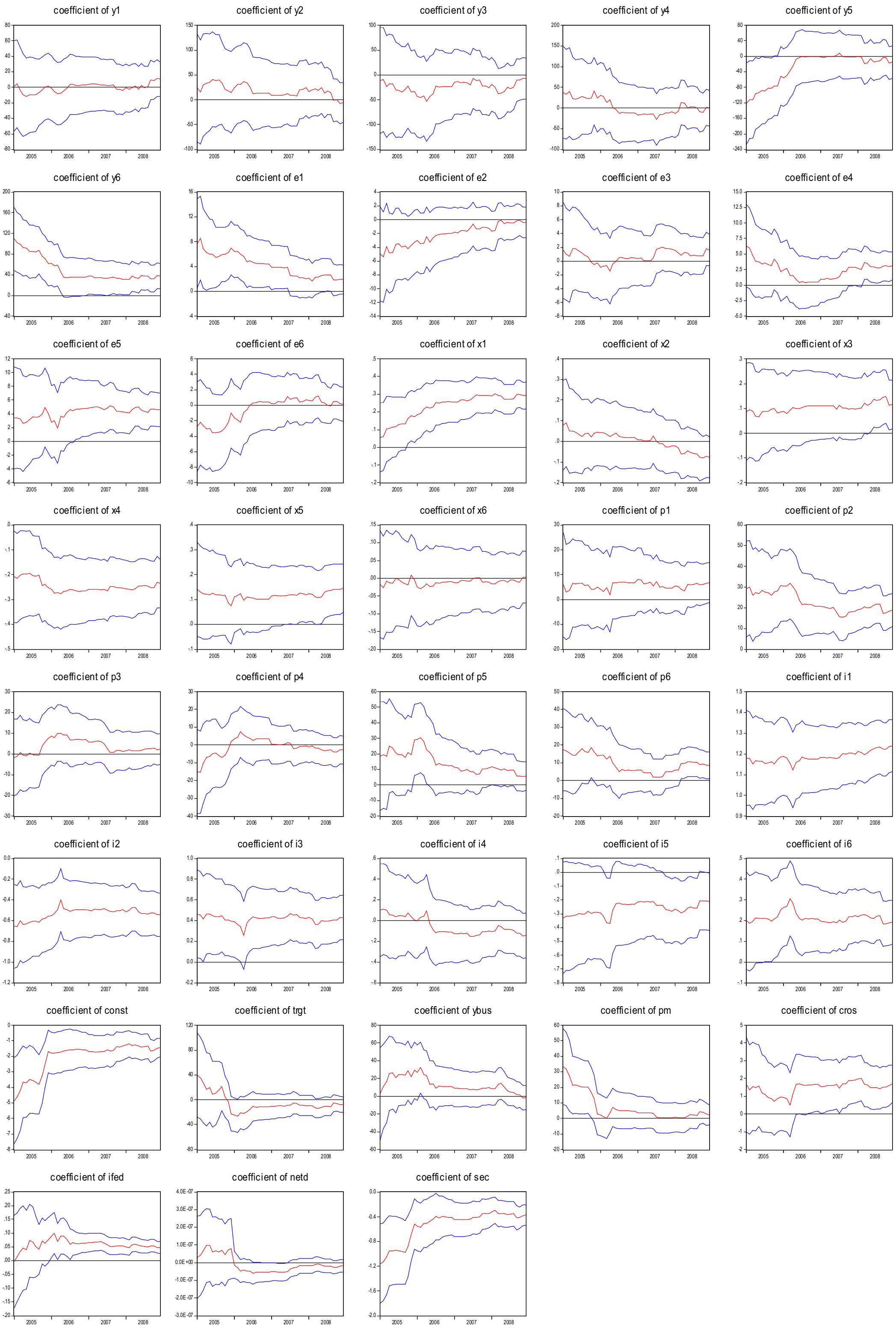
coefficients for inf_exp equation

coefficient of y1
coefficient of y2
coefficient of y3
coefficient of y4
coefficient of y5
coefficient of y6
coefficient of e1
coefficient of e2
coefficient of e3
coefficient of e4
coefficient of e5
coefficient of e6
coefficient of x1
coefficient of x2
coefficient of x3
coefficient of x4
coefficient of x5
coefficient of x6
coefficient of p1
coefficient of p2
coefficient of p3
coefficient of p4
coefficient of p5
coefficient of p6
coefficient of i1
coefficient of i2
coefficient of i3
coefficient of i4
coefficient of i5
coefficient of i6
coefficient of const
coefficient of trgt
coefficient of ybus
coefficient of pm
coefficient of cros
coefficient of ifed
coefficient of netd
coefficient of sec

coefficients for dlcpi equation



coefficients for iboi equation



coefficient of y1

coefficient of y2

coefficient of y3

coefficient of y4

coefficient of y5

coefficient of y6

coefficient of e1

coefficient of e2

coefficient of e3

coefficient of e4

coefficient of e5

coefficient of e6

coefficient of x1

coefficient of x2

coefficient of x3

coefficient of x4

coefficient of x5

coefficient of x6

coefficient of p1

coefficient of p2

coefficient of p3

coefficient of p4

coefficient of p5

coefficient of p6

coefficient of i1

coefficient of i2

coefficient of i3

coefficient of i4

coefficient of i5

coefficient of i6

coefficient of const

coefficient of trgt

coefficient of ybus

coefficient of pm

coefficient of cros

coefficient of ifed

coefficient of netd

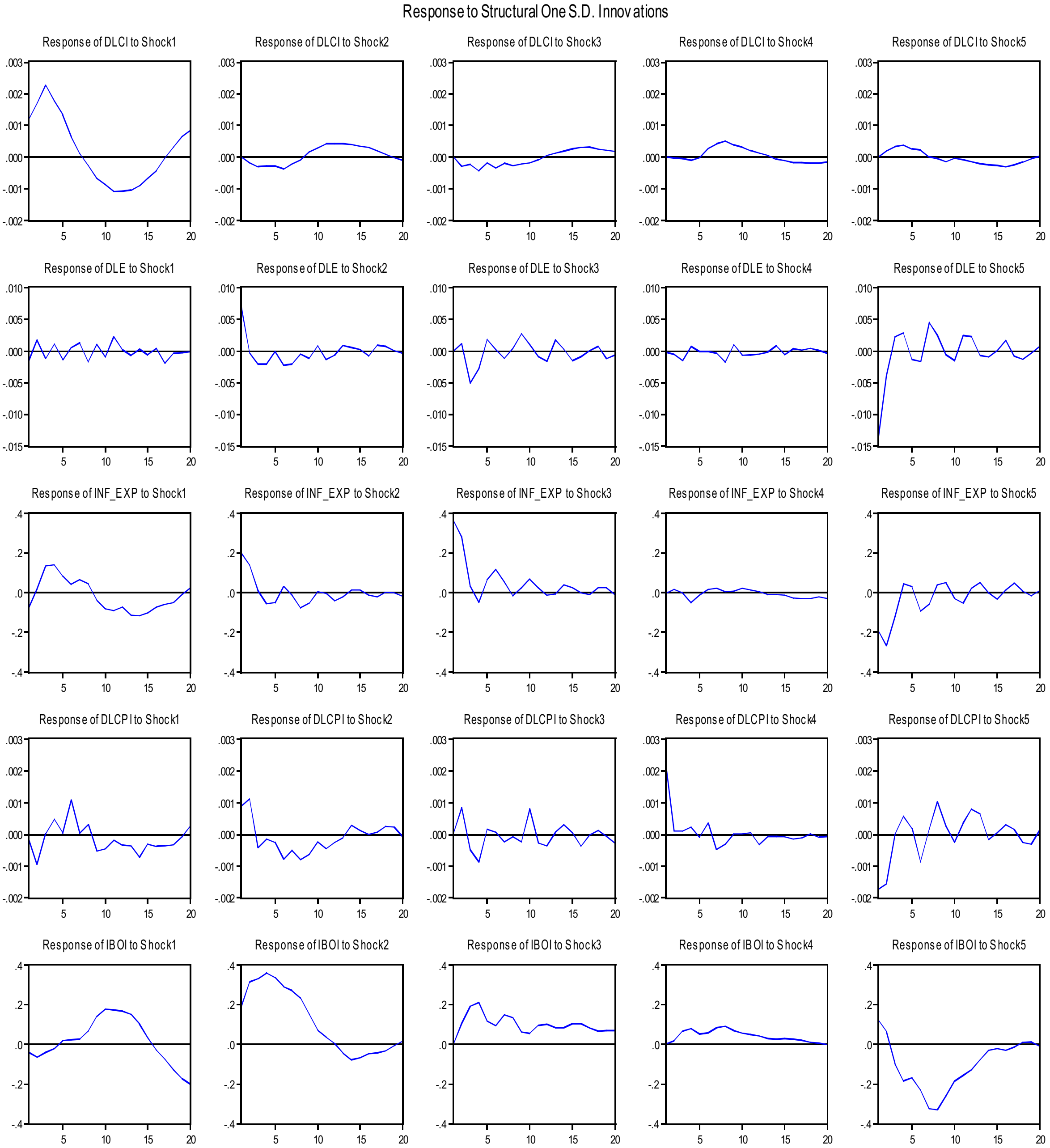
coefficient of sec

# Appendix D: Impulse Response Functions

## 1. Structural Decomposition

Shock to:

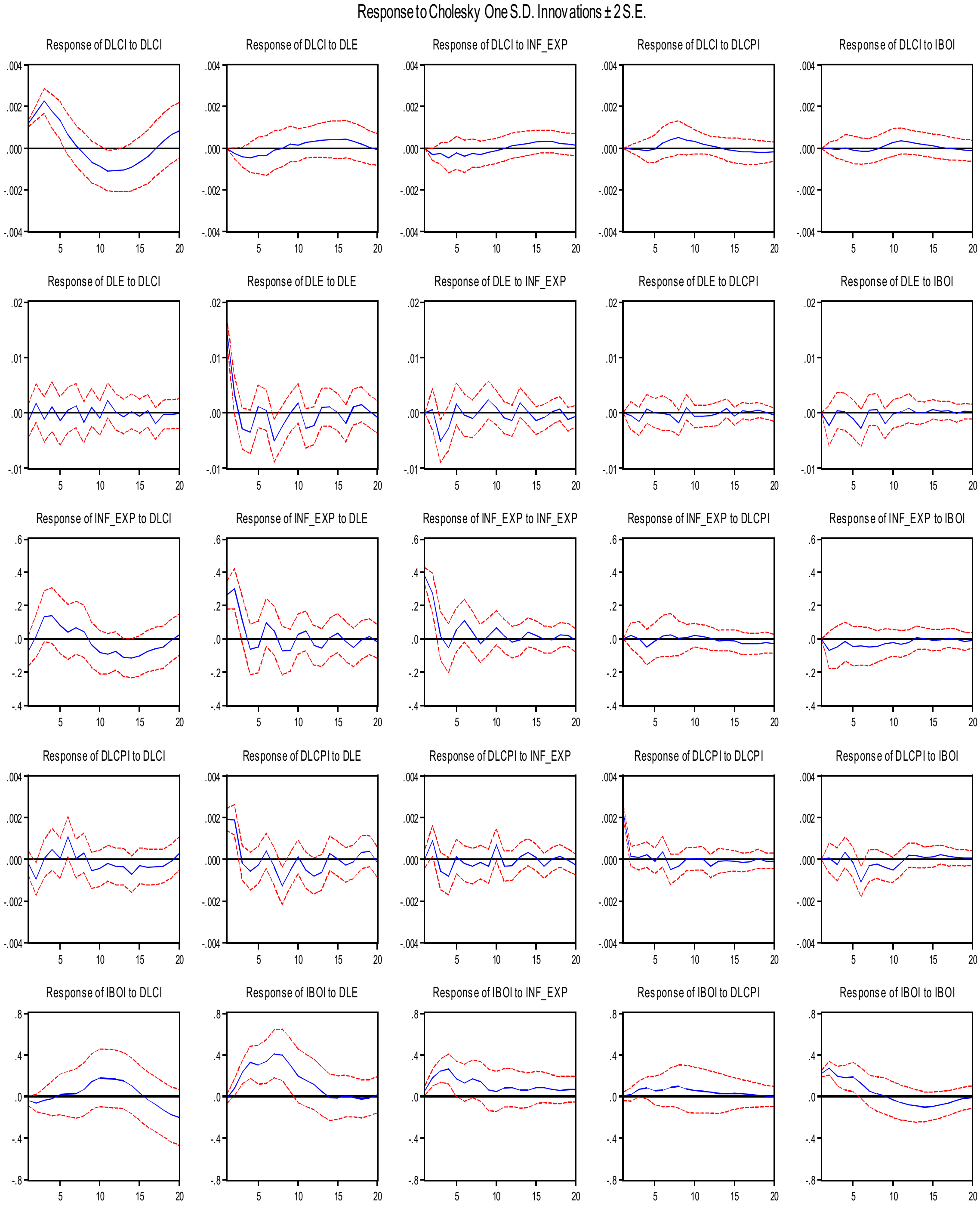
Real activity | Exchange rate | Inflation expectations | Inflation | BoI interest rate



## 2. Cholesky Decomposition

Shock to:

| Real activity | Exchange rate | Inflation expectations | Inflation | BoI interest rate |
|---|---|---|---|---|



Note: the dotted red lines show the 95 percent confidence band.

## Appendix E: The assumed values of the exogenous variables in the long run

| | | | |
|---|---|---|---|
| TARGET | Inflation target | 2% | Annual |
| DLIPUS | US industrial production | 3% | Annual growth |
| IFED | Fed interest rate | 4% | |
| DLCROSS | Dollar-euro crossrate | 0 | Rate of change |
| DLPMI | Intermediate goods import prices | 2% | $, Annual change |
| DLPMC | Final goods import prices | 2% | $, Annual change |
| SECURITY | Index for security situation | -2.5 | 2007-08 average |
| NET_DIRECT | Net direct foreign investment | $200,000 | 2007-08 average |