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The Effect of Monetary Policy on Inflation: A Factor Augmented VAR Approach using disaggregated data

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השפעת המדיניות המוניטרית על האינפלציה:
ניתוח נתונים באמצעות FAVAR

סיגל ריבון

תקציר

המחקר בוחן את ההשפעה של המדיניות המוניטרית על מדד המחירים לצרכן ועל רכיביו באמצעות שיטה המכונה Factor Augmented VAR. אנו בודקים את ההשפעה של זעזועים בשני משתנים נצפים – ריבית הבנק המרכזי ושער החליפין. נמצא כי רוב המחירים יורדים בתגובה על העלאת הריבית. לא נמצאה עדות לתופעה הנזכרת במחקרים על ארה"ב – עליית מחירים בתגובה על העלאת הריבית, תופעה המכונה "יחידת המחירים" (Price puzzle). זעזוע בריבית משפיע, לפחות לזמן מה, על המחירים היחסיים, עקב שוני בהשפעתו על רכיבים שונים של מדד המחירים. ככלל, מחירים המתואמים טוב עם התנאים המקרו-כלכליים, או שיש מיתאם סדרתי בזעזועים בהם נוטים להגיב יותר על זעזוע בריבית. מחירי הדיור ומחירי האנרגיה נוטים להגיב חזק יחסית על זעזוע בריבית. זעזוע חיובי בשער החליפין (פיחות) גורם לעלייה של כל סעיפי המדד, והשפעתו על מחירי המוצרים הסחירים, מחירי האנרגיה ומחירי הדיור חזקה יותר מאשר על מחירים אחרים. הממצאים שלנו תומכים בהערכה שמנגנון התמסורת העיקרי מהמדיניות המוניטרית למחירים פועל באמצעות שער החליפין.

The Effect of Monetary Policy on Inflation: A Factor Augmented VAR Approach using disaggregated data

Sigal Ribon

Abstract

This paper studies the effect of monetary policy on the Israeli consumer price index and its components using a Factor Augmented VAR approach. We identify shocks to two observable variables – the central bank's interest rate and the exchange rate. We find that most prices decline in response to an increase in the interest rate, so there is no "price puzzle". A shock to the interest rate has, at least for some time, an effect on relative prices due to a distinct effect on partial price aggregates of the CPI. Generally, price aggregates that are better correlated with macro factors, or that are characterized by serial correlation in the specific shocks tend to react more to a monetary shock. Housing and energy prices tend to react stronger to a shock in the interest rate. A shock to the exchange rate (depreciation) has a positive effect on all prices with prices of traded goods, energy and housing increasing more than other prices. Our findings suggest that the main transmission channel of monetary policy to prices is through the exchange rate.

1. Introduction

Standard VAR models usually include a small number of variables, among them customarily are an indicator for real activity, inflation, a short-term interest rate, and in open economies, a measure of the exchange rate. The Factor Augmented VAR (FAVAR) which was introduced by Bernanke, Boivin and Eliasz (2005, BBE hereafter), allows to analyze a broader set of variables in the framework of a VAR system and therefore, to learn more about the dynamic relationship between main variables in the economy and the effect of shocks on them. This paper uses the FAVAR method in order to analyze the effect of monetary policy (a change in the interest rate) on the array of prices that compose the aggregate CPI and for investigating the characteristics that affect the magnitude of the response of different prices to monetary policy. Because we include a large array of variables in our system, as a byproduct, we get a more detailed picture of the response of many other variables like real activity indicators, monetary aggregates and long term interest rates, to a shock to monetary policy.

The basic idea of the factor-augmented VAR (FAVAR) is to condense the information embedded in a large number of economic indicators into a small number of factors, construct a "regular" VAR for these factors and then "reverse-engineer" the responses of the original variables to shocks, relying on the relationship between the factors and the original series. This approach is supported by the view that when the central bank decides on the course of its interest rate, it examines a wide array of indicators, much larger than the very small number of variables that usually appear in a standard VAR system. Therefore, trying to describe the monetary policy using only a few general indicators may lead to biased results concerning its effect on the economy.

A possible empirical weakness of the standard VAR, some papers point to, is the "price puzzle" – a hike in prices in response to a positive shock to the interest rate that exists in some of the small "ordinary" VAR systems, but is resolved when the FAVAR approach is implemented. (See Blaes, 2009 and Boivin, Giannoni and Mihov 2009). Using a small number of factors to describe the economy is based on the perception that macroeconomic fluctuations can be described by a compact number of factors, and that the difference between movements in these factors and in the individual variables can be attributed to sector specific conditions. We will employ this approach in the empirical analysis.

The FAVAR modification of the very widely used VAR analysis was introduced by Bernanke, Boivin and Eliasz (2005), based on the work of Stock and Watson (2002) which shows that under some assumptions the principal components are a consistent estimator for

the underlying factors. It has been used for the analysis of various issues, usually linked to monetary policy[1]. Following BBE, Blaes (2009) uses a similar method, with some modifications, to learn about the transmission mechanism of monetary policy in the Euro area. The FAVAR method allows McCallum and Smets (2007) to learn about the transmission mechanism from monetary policy to real wages in the Euro area; Lagana and Mountford (2005) apply the FAVAR to UK data and find that the price puzzle which exists in the basic VAR is solved in the augmented system; Masahiko (2005) implements the method to Japanese data; Chow and Choy (2009) implement the FAVAR for the analysis of the effect of monetary policy on asset prices in Singapore and Vargas-Silva (2008) uses the method to learn about the housing market in various regions of the US. Among the papers written in recent years some use international data and look for a common trend using the FAVAR (for example: Bagliano and Morana, 2009; Boivin and Giannoni, 2008; Mumtaz and Surico, 2009). In BBE's analysis a small number of factors was extracted, according to the procedure they introduced, from the entire set of variables; some other researchers choose to extract separate factors for distinct groups of variables that describe different sectors – such as, "real activity", "prices" and "asset prices". This modification allows to assign economic interpretation to the factors, and to identify the shocks associated with them. Among those that adopt this methodology are Belviso and Milani (2006), Mumtaz and Surico (2009) and Mumtaz, Zabczyk and Colin (2009). This issue will be addressed later in this paper when the factors are constructed.

Two papers analyze the effect of monetary policy on disaggregated prices, as is the main subject of this paper. Boivin, Giannoni and Mihov (2009) look for the sources of volatility in aggregate inflation and in the price changes of different sectors. They find that macroeconomic shocks explain only 15 percent of sectoral inflation fluctuations and that the persistence of sectoral inflation is driven by macroeconomic factors. Using information about profitability and concentration of the different sectors they find that prices fall more in sectors that are less concentrated in reaction to a shock to monetary policy. Mumtaz, Zabczyk and Colin (2009) follow the above mentioned paper using UK data, and also find that prices in specific sectors are less affected by the macro conditions than are aggregate prices. They also find that the persistence of the aggregate inflation series is much higher than the underlying persistence in a range of disaggregated price series.

[1] A FAVAR system for forecasting inflation is part of the suite of models in use in the Bank of England. See Kapetanios, Labhard and Price (2008).

As far as we are aware, there does not exist any previous study for Israeli data that examines the effect of monetary policy on disaggregated consumer price data. There are several studies that look into the dynamics of price adjustments using microdata on prices (for example: Lach and Tziddon 1992, Eden, 2001 and Lach, 2002) but they do not focus on the effect of monetary policy. Ribon (2007) studies the effect of a shock to monetary policy on disaggregated producer prices and quantities in the manufacturing sector in Israel using separate small VAR systems for each one of the industries.

A detailed examination of the effect of monetary policy on different groups of prices is important in order to understand the transmission mechanism from policy to inflation and the ability of policy to affect changes in different prices and therefore affect the evolution of relative prices.

The paper includes five parts. The second part, after this introduction, describes the FAVAR framework and its empirical implementation. The third part describes the data and in the fourth part impulse response results are reported and analyzed. The fifth and last part concludes.

2. The FAVAR Framework

2.1 The model

The approach taken here follows the one presented in Bernanke, Boivin and Eliasz (2005) and many others who follow their steps. The basic idea is to use the information contained in a large number, N, of economic series by representing them in a much smaller number, K, of unobservable factors. We assume a (N×1) vector of macroeconomic series, X_t, that may be represented as a linear combination of K unobservable factors, F_t, and S_t observable factors, Z_t, such that:

$$(1) \qquad X_t = \Lambda^f F_t + \Lambda^r Z_t + u_t$$

where Λ^f and Λ^r are the (N×K) and (N×S) matrices of factor loadings, respectively, and u_t is the (N×1) vector of error terms with mean zero and it is assumed to be serially and mutually weakly correlated.

We assume that the joint dynamics of F_t and Z_t are given by:

$$(2) \qquad \begin{pmatrix} F_t \\ Z_t \end{pmatrix} = \Phi(L) \begin{pmatrix} F_{t-1} \\ Z_{t-1} \end{pmatrix} + \upsilon_t$$

where $\Phi(L)$ a lag polynomial and υ_t an error term with mean zero and covariance matrix $\sum_{\upsilon}$. Equation (2) is the VAR representation of the system including the factors F_t and the observable variables, Z_t.

The estimation is carried out in two steps. In the first step the factors are estimated using the principal components method. In the second step we replace the unobservable factors in (2) with the estimated factors from the first step. The observable variables, which are two in this model[2] (S=2), and are the last variables in the VAR system are the interest rate (i) and the rate of change in the Dollar-Shekel exchange rate (e)[3]. By implementing the Cholesky decomposition, we assume that the interest rate is affected simultaneously by all other variables, except for the exchange rate and affects them only with a lag, and that the exchange rate, which appears last, is affected simultaneously by all the preceding variables and affects them only with a lag. This assumption seems very reasonable for monthly data due to the fact that the next month's interest rate is announced and known a few days ahead of the month for which it was set, and may therefore affect simultaneously the exchange rate.

We are then able to identify structural shocks to the interest rate and to the exchange rate and analyze their effect on the factors and therefore on all original variables X. The paper's main interest is analyzing the effect of shocks to the interest rate on various price aggregates, but by specifying the model with the exchange rate as an additional observable variable we will be able to verify the contribution of shocks to the exchange rate and as a result their contribution to the transmission of interest rates to prices.

2.2 Empirical Implementation

As presented above, the first step is to estimate the factors by principal components. In doing so we have to choose which group or groups of variables we want to represent by common factors. One possibility is to find a small number of factors based on all the variables in our dataset (as is done in BBE, 2005). Another possibility is to partition our dataset into sub-groups by sectors of the economy such as real activity, labor market, nominal data or prices and represent each of these groups by a separate set of common factors. (As is done in Mumtaz, Zabczyk and Ellis, 2009). After experimenting with some options we decided to construct the factors according to two alternatives. The first is to

[2] Most papers specify the model with only one observable variable which is the interest rate. Bernanke, Boivin and Eliasz (2005) present an alternative model with 3 observables (the interest rate, industrial production and the CPI). Soares (2011) also suggests an alternative specification with the price index, GDP and interest rate as observables.

[3] For the sake of brevity we will omit "the rate of change in" when referring henceforth to the exchange rate.

generate aggregate principal components for the whole dataset, as shown in equation (1). We will notate this alternative as **ALL**. The second alternative, notated **RN**, is to partition the data into two sets: real variables and nominal variables[4]. In that case equation (1) may be written specifically as:

$$(3) \qquad \begin{aligned} X_t^Y &= \Lambda^Y F_t^Y + u_t^Y \\ X_t^N &= \Lambda^N F_t^N + u_t^N \end{aligned}$$

Where X^Y is the group of real variables, X^N the group of nominal variables, Λ^Y and Λ^N are the corresponding factor loadings, F^Y and F^N are the factors and the u's are the errors. The real variables are assumed to react only with some lag to the interest rate and exchange rate, and are called "slow" variables[5], but within the set of nominal variables, some may react contemporaneously to e and i ("fast" variables), and therefore it may be that the factors extracted from this group include the effect of these two variables, which appear separately in the VAR system. Therefore this effect should be removed from the factors. We do so by estimating their effect together with the effect of the slow factors on the principal components of the nominal group. Corrected factors are then constructed by subtracting the effect of the interest rate and exchange rate on the original factors.[6]

For each of the two alternatives for producing the factors, (RN and ALL), we proceed and estimate the VAR system presented in equation (2). In order to do so we have to choose the number of factors to include in the system, in addition to the central bank's interest rate and the exchange rate. According to Stock and Watson (2002) the number of factors is determined on the basis of the model's goodness of fit characteristics (information criteria).[7]

For each of the two alternatives we chose a suitable specification of the VAR. For the ALL version we chose 6 factors plus the BoI interest rate and the exchange rate. For the RN version the VAR system also includes 6 factors - 3 for each of the real and nominal sectors, and the BoI's interest rate and exchange rate. Based on lag order tests, and taking into account the constraints on the degrees of freedom, the estimated VAR according to both versions, includes 2 lags.

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[4] Because our sample is relatively short, more groups with a smaller number of variables each, which we experimented with, led to unsatisfactory results.

[5] See BBE (2005) for the use of this term.

[6] See a detailed description of this procedure in Blaes (2009).

[7] Bau and Ng (2002) developed criteria to determine the optimal number of factors, but they only work well when N and T go to infinity. Moreover, Bernanke, Boivin and Eliasz (2005) say that this suggested criteria does not necessarily relate to the number of factors in a VAR model. Other studies, such as Blaes(2009) and Mcallum and Smets (2007) determine the number of factors in an ad hoc manner.

3. The Data

We use 112 monthly series, starting from January 1997[8] to August 2010 (164 observations). A detailed description of the series is presented in Appendix 1. The factors are extracted from 106 monthly indicators for real activity, labor market data - employment and nominal and real wages, CPI data including 38 sub-categories of total CPI and other partial aggregates of this index, market-based inflation expectations, monetary aggregates and different yields. The two observable variables in the VAR system are the NIS/US exchange rate and the BoI declared interest rate. In addition we use 4 global variables as separate exogenous variables in the VAR estimation. These include the US production index, a commodity price index, oil prices and the Fed's interest rate. All local variables are seasonally adjusted, transformed to be of order I(0) and are normalized to have zero mean and unit variance. This is because different scales of the time series could impair factor extraction. (See Lagana(2004), Belviso and Milani (2005) Blaes (2009)).

4. Results

4.1 The principal components

Using principal components to describe a set of series allows us to compress the data without the loss of a large amount information. This is done by finding the eigenvectors of the covariance matrix of the data and sorting them by their contribution to the explanation of total variance - the most important being the first principal component.[9]

When evaluating the principal components separately for the real variables and the nominal variables (RN option) it was found that the cumulative proportion of variance of each of the groups that is explained by a small number of components is reasonable. The first three principal components for the real group of variables, which includes 37 variables, explain about 32 percent of their variance. The first 7 components explain about 55 percent. The first three principal components for the nominal group (71 variables, including the exchange rate and the interest rate) account for about 35 percent of the variance. The first 7 components explain 50 percent. In the ALL version, the first 6 principal components account for 37 percent of total variance.

Table A.1 in the Appendix presents the correlation between the principal components and some of the variables in the dataset for the RN and the ALL option. As expected, in

[8] January 1997 was chosen as the starting date of the sample, based on the conventional analysis that sets 1997 as the time of a structural break in monetary policy, on the background of the full adoption of the inflation target framework. (See Barnea and Djivre, 2004).

[9] For *n* series of data, *n* principle components may be extracted and cumulatively explain total variance.

general, the correlation between the principal components generated in the RN version, and the original variables is higher than that of the principal components from the ALL version and the original variables. In the ALL version, the first component tends to describe better the nominal variables, and in particular the prices, while the third and fifth relate better to the real variables. Generally, there is no clear mapping between variables or groups of variables and a factor that replicates them closely.

The principal components can be referred to as the "common factors" while the variance which is not explained by the principal components may be referred to as the sector-specific component. Therefore each original data series x may be written as a combination of the common factors F and a specific factor u. More specifically, for the nominal group, from equation (3) we see that $\Lambda^N F^N$ represents the effect of the common factors while the u^N are the "sector-specific" components, and accordingly $\Lambda^R F^R$ and u^R for the real group. The relative importance of the common factors in the evolution of the specific variable is captured by the R^2 of the estimated equation (3) and may serve as an indicator to the variable's sensitivity to changes in the economic environment, and in particular in the interest rate. Another characteristic of the series is the persistence of the actual value, of the estimated value and of the residual, which are measured by the coefficient of an AR(1) process. The value of the AR(1) coefficient for the fitted value and the residual depends on the specification chosen – ALL or RN. In Table 1 we present the average R^2 and AR(1) coefficient for fitted value and the residual, based on both specifications, for total CPI and for each of the 10 CPI groups, computed on the basis of the 38 sub-groups of the index.

Table 1: R^2 and AR(1) coefficient, by groups* and total

			RN			ALL		
	Group name	**Weight in 1/2009 (%)**	**R^2**	**AR(1) in fitted**	**AR(1) in resid.**	**R^2**	**AR(1) in fitted**	**AR(1) in resid.**
0	Fruits and vegetables	**14.8**	0.18	0.18	0.03	0.14	0.24	0.01
1	Food	**3.6**	0.33	0.45	0.09	0.26	0.50	0.15
2	Housing	**20.7**	0.23	0.40	0.40	0.24	0.37	0.38
3	Dwellings maintenance	**10.7**	0.33	0.42	0.05	0.24	0.56	0.07
4	Furniture and household equipment	**3.8**	0.26	0.59	0.03	0.24	0.56	0.06
5	Clothing and footwear	**3.2**	0.18	0.05	0.07	0.08	0.27	0.14
6	Education, culture and entertainment	**12.5**	0.32	0.52	-0.04	0.26	0.44	-0.04
7	Health	**5.2**	0.27	0.59	-0.04	0.17	0.60	0.07
8	Transport and communication	**21.1**	0.42	0.43	0.07	0.40	0.45	0.05
9	Other	**4.5**	0.29	0.41	-0.12	0.26	0.45	-0.09
	Total CPI	**100**	0.66	0.62	0.30	0.67	0.60	0.17

* Computation based on 38 groups.

Table 1 shows that the share of variance (over time) in price changes that is explained by the common factors is similar for both the RN and the ALL versions. Autocorrelation is usually higher in the ALL version for the fitted value and similar in both specifications for the residuals. There is considerable variability in the values of R^2 among the groups of prices. The evolution of the fruit and vegetable prices, clothing and footwear and health prices in the ALL version is poorly explained by the common factors. On the other hand, prices of transport and communications, education and food are significantly affected by the common factors. The common factors explain about two thirds of the variability of total CPI and it is much higher than that of its components. This result is reasonable, as the total CPI expresses the macroeconomic conditions, while separate price groups are also affected by changes in relative prices. A similar result is presented in Boivin, Giannoni and Mihov (2007).

Autocorrletion exists, particularly in the ALL version, in the fitted values, but it is much weaker in the residuals, except for the housing prices. This suggests that shocks to common factors tend to be prolonged, while idiosyncratic shocks are short-lived

4.2 The response to a monetary shock[10]

As was described above, two versions of principal components were implemented. Generally they produce similar results, but not for all variables and tests. We present and analyze the results for both the RN version and the ALL version, although we tend to prefer the RN option, due to preferable results in some aspects, which will be referred to in the next sections.

The main analysis concerning the CPI components is preceded by a short analysis of the effect of a monetary policy shock on main macro-economic variables which generally produces reasonable results.

a. Impulse responses for macroeconomic variables

Responses to an interest rate shock: Most of the impulse responses generated by the system seem reasonable, and with the expected sign.[11] (See diagrams A.1-A.4 in the Appendix) The weakest results are for the real indicators which typically exhibit a positive, although

[10] In order to get a real sense of the magnitude of effect of a shock to the monetary policy, all impulses were transformed to show the effect of a 1 pp shock to the (original measure of) the BoI interest rate on the original measurement units (for example, percentage points change of the original CPI) of the effected variables.

[11] Standard errors for the impulse response functions were generated in the same manner as their mean by implying the coefficients of equation 1 to the standard errors of the principle components' VAR. We disregard, at this stage the uncertainty in the estimation of the factors in the VAR. (See footnote 13 in BBE (2005)).

for some of them close to zero, or a non-significant response to a shock in the interest rate (i.e. a rise in the interest rate). This could be explained by the forward looking nature of monetary policy. If expected higher real activity in the future drives monetary policy makers to raise interest rates now, we may mistakenly interpret the positive correlation between present monetary policy and future real activity.

Concerning the nominal variables (Diagrams A.2 and A.3): inflation expectations decline in response to the shock. The nominal exchange rate of the shekel to the dollar appreciates (lower Shekel to Dollar rate) and operates as an important transmission mechanism of the interest rate to prices, as will be discussed henceforth. Monetary aggregates react in general as expected - M1 and over-night deposits shrink, while short term interest bearing deposits expand. Local currency bank credit contracts in reaction to a positive shock to the interest rate. Yields on long term indexed government bonds rise in the RN version, but nominal short term yields in the RN version and all yields in the ALL version decline, contrary to the expected response. (Diagram A.4). Construction input prices, house prices and wholesale prices, which are not part of the CPI, decline in response to a positive shock in the interest rate. (Diagram A.4).

Responses to an exchange rate shock: (Diagram A.6). Real activity declines in a response to a positive shock to the exchange rate (depreciation). Imports react in the expected direction and decline in response to a positive shock to the exchange rate, but further analysis, not presented in the diagram, shows that exports decline in response to an exchange rate shock – a result which cannot be accepted as reasonable. It may be that imports react immediately while exports react with a longer lag that cannot be captured in this setting. Market based inflation expectations rise in reaction to an unexpected depreciaition (Diagram A.7) and so does the BoI interest rate and local currency bank credit. Short run nominal yields and long run real yields generally rise. House prices (in the RN version) and wholesale prices rise, as expected, as a result of a shock to the exchange rate. (Diagram A.9).

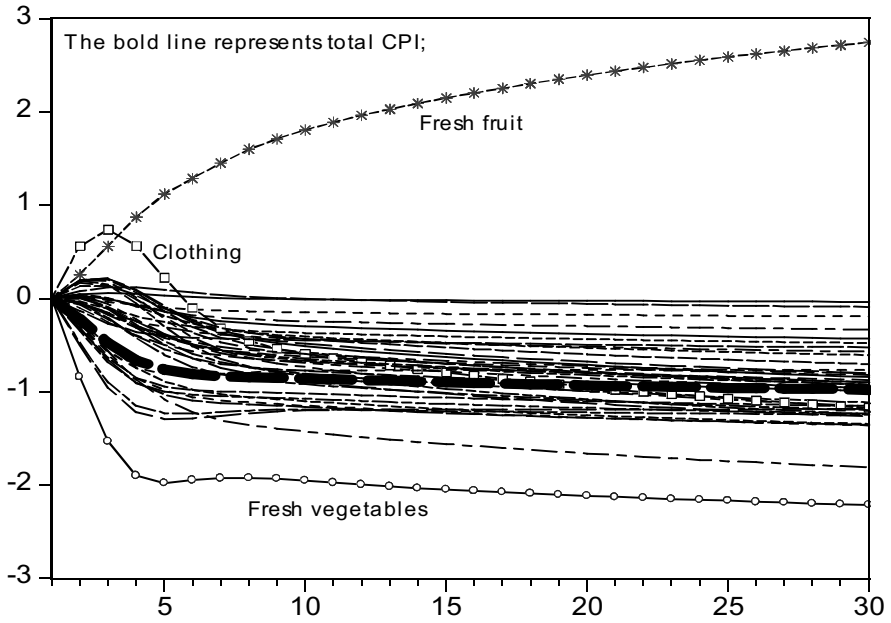
The generally reasonable responses of major macroecomic indicators to a shock to the BoI interest rate and to the exchange rate gives us confidence that the estimated system, are valid. The RN version seems to generate more reasonable results and therefore we will tend to adopt it as the preferred version for the analysis of the main issue of this paper - the reaction of different prices to a monetary shock and an exchange rate shock and the factors that affect it.

b. Impulse responses of disaggregated prices

The main interest of this paper is to present the response of different groups of prices to a shock to the central bank's interest rate and examine the factors that affect the variation in these responses. We also examine the response of disaggregated prices to a shock in the exchange rate.

Diagram 1 shows the response of each of the 38 price groups and the aggregated CPI (in bold) to a 1 pp shock to the interest rate. Almost all prices decline in response to the shock (except for fresh fruits) but there is heterogeneity in the magnitude of the response. Some prices increase very slightly in the first few periods before declining.

Diagram 1: Responses of disaggregated prices to the interest rate (RN version)



In order to get a first idea of how prices are affected by a shock to the interest rate we present the weighted average of the response of each of the ten main groups of the CPI in Table 2a and 2b [12]. Some facts emerge from the table: prices in all 10 categories decline in reaction to a positive shock to the interest rate and the cumulative effect grows up to 6 months and then remains stable for most categories. The housing component, measured by rental contracts rates exhibits the largest reaction in the short run, but a much milder reaction than in previous versions of the paper with earlier samples of data. Historically, the housing component was indexed to the dollar exchange rate, and therefore reacted

[12] As noted before, the analysis was done at a 38-group level. The table presents the weighted average of the responses of these 38 items, by their main group.

immediately to a shock in interest rate which was expressed immediately in the exchange rate and therefore had an immediate effect on housing prices. This link between rent prices and the exchange rate no longer exists, and the relatively strong reaction of rent prices, probably represents this affect on the earlier part of the sample.

The effect on total CPI as measured directly, by using the aggregate CPI data, is almost identical to that of the weighted average of the response of individual price groups. According to our results, a 1 percentage point shock to the interest rate will bring about a reduction of almost 1 percent in the CPI inflation after a year according to the RN version, which we tend to prefer, and a reduction of only 0.4 percent according to the ALL version.

Table 2a: Accumulated response of prices to an interest rate shock, different horizons, by groups and total CPI, RN version

	Group name	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
0	Fruits and vegetables	-0.52	-0.48	-0.40	-0.37	-0.96
1	Food	-0.31	-0.56	-0.67	-0.74	-0.35
2	Housing	-1.09	-1.17	-1.17	-1.20	-0.79
3	Dwellings maintenance	-0.64	-0.96	-1.11	-1.20	-1.22
4	Furniture and household equipment	-0.28	-0.61	-0.77	-0.86	-1.27
5	Clothing and footwear	0.43	-0.40	-0.77	-0.96	-0.93
6	Education, culture and entertainment	-0.59	-0.66	-0.65	-0.66	-1.10
7	Health	-0.33	-0.52	-0.63	-0.69	-0.66
8	Transport and communication	-0.96	-1.00	-0.96	-0.96	-0.74
9	Other	-0.20	-0.53	-0.70	-0.79	-0.96
	Total CPI	-0.67	-0.84	-0.89	-0.93	-0.86
	Weighted average *	-0.66	-0.80	-0.88	-0.92	-0.95
	Weighted std *	0.54	0.50	0.51	0.54	0.56

* Computation based on 38 groups. For weights, see table 1.

Table 2b: Accumulated response of prices to an interest rate shock, different horizons, by groups and total CPI, ALL version

	Group name	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
0	Fruits and vegetables	-0.46	-0.26	-0.11	-0.03	0.03
1	Food	-0.26	-0.45	-0.47	-0.46	-0.45
2	Housing	-0.74	-0.63	-0.45	-0.34	-0.26
3	Dwellings maintenance	-0.44	-0.67	-0.66	-0.62	-0.60
4	Furniture and household equipment	-0.30	-0.58	-0.62	-0.61	-0.60
5	Clothing and footwear	0.40	-0.17	-0.45	-0.54	-0.61
6	Education, culture and entertainment	-0.44	-0.43	-0.33	-0.27	-0.22
7	Health	-0.32	-0.47	-0.48	-0.45	-0.43
8	Transport and communication	-0.53	-0.43	-0.25	-0.16	-0.10
9	Other	-0.22	-0.51	-0.58	-0.58	-0.57
	Total CPI	-0.45	-0.50	-0.42	-0.37	-0.32
	Weighted average *	-0.45	-0.48	-0.42	-0.36	-0.32
	Weighted std *	0.35	0.28	0.27	0.27	0.28

* Computation based on 38 groups. For weights, see table 1.

Most components are affected more strongly by a shock to the interest rate according to the RN version relative to the ALL version. The weighted standard deviation remains stable for all horizons, meaning that the change in relative prices stabilizes. The "price puzzle" – an increase in prices in reaction to a positive shock to the interest rate is not present in this model. But, contrary to evidence form the US which show the price puzzle in some simple VAR specifications and find that the FAVAR method may resolve this anomaly, in Israel this problem does not show up in alternative VAR models and other macroeconomic models.

Comparing the magnitude of the effect on total CPI to other results obtained in other research in recent years, this result is similar, although somewhat higher, especially the results according to the (preferred) RN version. The magnitude of the response of annual CPI after a year, in a quarterly DSGE model developed in the Research Department of the Bank of Israel. (Argov et. al., 2010) is about 0.9 pp. In an error-correction type quarterly model based on Barnea & Djivre (2004) the magnitude of response is much weaker – about 0.2 pp. In a monthly 5-variable SVAR, Azoulay and Ribon (2010) show a decline of 0.7 pp in annual CPI after a year, in response to a 1 pp increase in the BoI interest rate and in a constrained structural VAR, using quarterly data Djivre and Yachin (2010) get a response of about 0.5 pp.

The response to a shock in the Dollar/Shekel exchange rate: Since the exchange rate is an observable variable in our system, we are able to examine the effect of a shock to the exchange rate on the disaggregated price groups. The results are presented in tables 3a and 3b.

Table 3a: Accumulated response of prices to an exchange rate shock, different horizons, by groups and total CPI, RN version

	Group name	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
0	Fruits and vegetables	0.022	-0.026	-0.017	-0.008	-0.001
1	Food	0.098	0.084	0.047	0.024	0.006
2	Housing	0.106	0.038	0.023	0.014	0.007
3	Dwellings maintenance	0.145	0.115	0.066	0.034	0.010
4	Furniture and household equipment	0.119	0.111	0.062	0.031	0.008
5	Clothing and footwear	0.207	0.237	0.122	0.058	0.009
6	Education, culture and entertainment	0.061	0.019	0.010	0.006	0.003
7	Health	0.086	0.075	0.044	0.023	0.007
8	Transport and communication	0.080	0.010	0.004	0.004	0.004
9	Other	0.115	0.112	0.062	0.031	0.008
	Total CPI	0.099	0.057	0.032	0.017	0.006
	Weighted average *	0.098	0.055	0.031	0.017	0.006
	Weighted std *	0.060	0.070	0.041	0.021	0.006

* Computation based on 38 groups. For weights, see table 1.

Table 3b: Accumulated response of prices to an exchange rate shock, different horizons, by groups and total CPI, ALL version

	Group name	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
0	Fruits and vegetables	-0.011	-0.031	0.009	0.038	0.059
1	Food	0.065	0.061	0.060	0.065	0.069
2	Housing	0.093	0.082	0.139	0.181	0.212
3	Dwellings maintenance	0.134	0.131	0.142	0.155	0.166
4	Furniture and household equipment	0.090	0.094	0.091	0.095	0.099
5	Clothing and footwear	-0.029	0.005	-0.070	-0.104	-0.130
6	Education, culture and entertainment	0.042	0.029	0.058	0.081	0.099
7	Health	0.089	0.093	0.102	0.111	0.118
8	Transport and communication	0.043	0.015	0.058	0.091	0.116
9	Other	0.073	0.082	0.073	0.073	0.074
	Total CPI	0.067	0.057	0.082	0.103	0.120
	Weighted average *	0.068	0.055	0.082	0.103	0.120
	Weighted std *	0.063	0.069	0.083	0.098	0.110

* Computation based on 38 groups. For weights, see table 1.

According to the preferred RN version (table 3a), the effect of a temporary shock to the exchange rate on the inflation rate diminishes in the long run[13]. In the short run the rate of transmission is about 0.1 which is weaker than the conventional 0.2-0.3 for Israel, during earlier periods, due to the strong link that existed in the past between the exchange rate and housing prices (consisting 25% of CPI), and is similar to more updated estimates of the exchange rate passthrough. In particular, the coefficient for housing is only about 0.1 (RN version), similar to other CPI components.

4.3 Explaining the reaction of different prices

The next step in investigating the responses of prices is to learn which economic characteristics affect the response of different price aggregates. We saw that there are differences in the magnitude of the response of the various price groups. This means that monetary policy has a differential effect on prices, and therefore has (at least in the short-term) some effect on relative prices. Can these differences be explained by the characteristics of these prices?

Before going into the formal econometric analysis, some impulse responses of partial groups of prices are presented. We examine several aggregated CPI sub-groups using

[13] Note that the impulse response demonstrates the dynamics of inflation in response to an exchange rate shock, taking into account the response of all other variables in the system, and in particular the interest rate.

assigning dummy variables[14]. The impulse responses are shown in Diagram A.5 in the Appendix.

From a first glance, impulse responses for both versions - RN and ALL seem similar. The first row in the set of diagrams shows that the effect of a monetary shock on CPI excluding housing is weaker than its effect on total CPI, although not substantially, reflecting a stronger effect of the shock on the housing component, as was shown in the previous tables. The diagram in the second row shows that tradables are affected in the medium term more that non tradables – with or without housing prices. This probably reflects the indirect effect of the exchange rate, which is influencd by a shock to the interest rate.

Comparing the effect on durables (excluding housing) to the effect on non-durables in the third row shows a stronger response of durable goods. Services (excluding housing) seem to respond less to a monetary shock than prices of other goods[15], as shown in the next row of the diagram. Government controlled prices show a slightly smaller response compared to other prices (excl. housing). The last row depicts some specific products and services, and shows that prices of dental services tend to react less to the shock than bread prices (partially supervised) and less than the effect on the price of electric home appliances (mostly imported). This finding supports the result that tradable goods react more than non-tradable goods. This result suggests that the primary transmission channel of monetary policy to prices (at least in the short run) is through its effect on the exchange rate.

Examining the reaction of the same price groups to a shock in the exchange rate (Diagram A.10 in the Appendix), there is no significant difference in the response of total CPI and the CPI excluding housing to a shock in the exchange rate, indicating again that the exchange rate pass-through is not a significant mechanism any more in the housing sector. Tradables and durables (which have a significant imported share) tend to react more, and the prices of services, which are usually non-tradable, tend to react less to a shock in the exchange rate – as assumed.

Looking more closely into the sources of differences in the magnitude of the affect on different prices, we will look at two types of characteristics. The first type consists of statistical attributes and includes the (inverse of the) historical standard deviation of the seasonally adjusted price changes of the group, the proportion of variance explained by the

[14] See Table A.2 in the Appendix for dummy definitions. Some of the dummy variables can have values between 0 to 1, because for the 38-groups partition, it may be that a price group only partly belongs to a certain category.

[15] The correlation between a price group defined as "non-tradable" and as "services" is about 50%.

factors, (R^2) and the persistence in the residual and in the fitted values from the equation connecting between the common factors and the specific price index. (See table 1). The second type of explanatory variables is the economic attributes of a price group: being tradable, supervised or set by the government, durables, energy products, services, clothing and footwear, fruits and vegetables or housing prices.

We choose to estimate the effect of each set of attributes – economic or statistical – separately due to the existence of non-negligible correlation between some of the variables in these two groups[16], meaning that the two sets of partitions of the data, according to economic or statistical attributes are to some extent substitutes rather than complements. Therefore they are not included together in the regressions.

We check the effect of these characteristics on the accumulated response of inflation after 3, 6, 12, 18 and 24 months using OLS estimation with Newey-West correction for heteroskedasticity. The results are presented in tables 4a and 4b for the statistical attributes and tables 5a and 5b for the group dummies.

Generally, the main results are similar for the RN and ALL versions. Note that on average, the responses of prices to a hike in the interest rate are negative, i.e., a positive shock to the interest rate results in a decline in prices. Therefore, a negative coefficient means that for a larger value of the explanatory variable, the negative response of the price group will tend to increase.

Let us look first at the statistical properties of the price groups. A positive coefficient for the inverse of the standard deviation in the price group means that less volatile price groups tend to react less to a monetary shock. This attribute was not found to have a significant effect on the response of prices. A larger proportion of explained variance by the factors tends to increase the effect of a monetary shock in the medium and long run. If macro conditions account for a larger share of the volatility of price changes, a shock to monetary policy is expected to have a larger effect. The effect of the degree of autocorrelation in the fitted value of the price changes is insignificant in both versions, while the negative effect of the autocorrelation on the residuals is signidicant and large, meaning that the greater the autocorrelation in the idiosyncratic shocks, the larger will be the effect of a shock to monetary policy.

[16] See table A.3 in the Appendix.

Table 4a: Statistical attributes affecting the accumulated response of price groups to an interest rate shock (RN option)

	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
Intercept	-0.25	-0.44	-0.51	-0.55	-0.59
1/std.	0.002	0.002*	0.002	0.002	0.002
R^2 of factors	-0.18	-0.63*	-0.80**	-0.90**	-0.98**
AR_fit	-0.22	-0.36	-0.39	-0.42	-0.43
AR_residuals	-1.05**	-0.91**	-0.82**	-0.80**	-0.78**
R^2	0.11	0.13	0.10	0.10	0.09

*, **, *** - coefficient significant in 10%, 5% or 1% , accordingly.

Table 4b: Statistical attributes affecting the accumulated response of price groups to an interest rate shock (ALL option)

	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
Intercept	-0.08	-0.20	-0.23	-0.23	-0.23
1/std.	0.002*	0.002*	0.001	0.001	0.001
R^2 of factors	-0.23	-0.70***	-0.82***	-0.83***	-0.85***
AR_fit	-0.73*	-0.61**	-0.38	-0.27	-0.19
AR_residuals	-0.58**	-0.20	0.09	0.20	0.29*
R^2	0.14	0.16	0.16	0.18	0.19

*, **, *** - coefficient significant in 10%, 5% or 1% , accordingly.

Boivin, Giannoni and Mihov (2007) obtain similar results, showing that higher volatility and persistence imply more price flexibility, i.e. a larger response to the shock. They also find, using information on industry competitiveness that more competitive industries have higher price flexibility. Mumtaz, Zabczyk and Ellis (2009) find an opposite effect – sectors with higher variability (which they interpret as larger sectoral shocks) respond less to policy. They relate this result to the literature on state dependent pricing that claims in the presence of higher idiosyncratic volatility more weight should be put on these shocks than on policy shocks and hence the response to these shocks is expected to be smaller. Gertler and Leahy (2008) show that firms that are affected more by idiosyncratic shocks will adjust their prices more in response to a monetary shock.

According to the estimation including economic attributes (Tables 5a and 5b), there is a significant stronger effect on energy prices[17] and dwelling prices – both for house owners

[17] Energy prices are included in the transportation component and in the housing maintenance component of the CPI, and where both found to react relatively strong to a shock in the exchange rate.

(measured by new and renewed rent contracts) and for renters (measured by the stock of existing contracts), and a stronger effect on prices of tradables in the medium and longer run.

Table 5a: Group attributes affecting the accumulated response of price groups to an interest rate shock (RN option)

	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
Intercept	-0.37***	-0.46***	-0.48***	-0.50***	-0.51***
Owner dummy	-0.79***	-0.77***	-0.73***	-0.73***	-0.73***
Rent dummy	-0.48***	-0.55***	-0.58***	-0.60***	-0.628***
Tradables dummy	0.14	-0.14	-0.29*	-0.36*	-0.42**
Energy dummy	-1.06***	-1.08***	-1.07***	-1.09***	-1.10***
Clothing &ftwr. dummy	0.48***	0.10	-0.06	-0.14**	-0.19***
R^2	0.25	0.16	0.16	0.16	0.17

*, **, *** - coefficient significant in 10%, 5% or 1% , accordingly.

Table 5b: group attributes affecting the accumulated response of price groups to an interest rate shock (ALL option)

	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
Intercept	-0.31***	-0.32***	-0.27***	-0.23***	-0.20*
Owner dummy	-0.43***	-0.27***	-0.12	-0.05	0.00
Rent dummy	-0.41***	-0.44***	-0.37***	-0.32***	-0.28***
Tradables dummy	0.05	-0.24**	-0.36***	-0.39***	-0.42**
Energy dummy	-0.39**	-0.35***	-0.20***	-0.14	-0.01
Clothing &ftwr. dummy	0.54***	0.36***	0.19***	0.12**	0.01
R^2	0.22	0.18	0.24	0.29	0.33

*, **, *** - coefficient significant in 10%, 5% or 1% , accordingly.

In theory, the response of tradable prices could be expected to be smaller than other prices because their prices are linked to prices abroad and set according to them. On the other hand, their local price is affected by the exchange rate, so if a shock to the interest rate is reflected in a significant (and immediate) response of the exchange rate, this group of prices will react faster than the prices of non-tradables.[18]

[18] The impulse response of the exchange rate to the interest rate is shown in Diagram A.2.

Table 6a: Group attributes affecting the accumulated response of price groups to an exchange rate shock (RN option)

	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
Intercept	0.068***	0.050***	0.028***	0.015***	0.005***
Fruits and veg. dummy	-0.124	-0.171*	-0.103*	-0.052	-0.013
Owner dummy	0.037***	-0.019**	-0.009**	-0.003	0.002***
Rent dummy	0.041***	0.010	0.008	0.005**	0.003***
Tradables dummy	0.057***	0.069***	0.036***	0.018***	0.003***
Energy dummy	0.085***	0.022	0.017	0.011	0.007***
Clothing &ftwr. dummy	0.072***	0.099***	0.047***	0.021***	0.002***
R^2	0.42	0.56	0.48	0.44	0.24

*, **, *** - coefficient significant in 10%, 5% or 1% , accordingly.

Table 6b: group attributes affecting the accumulated response of price groups to an exchange rate shock (ALL option)

	After 3 months	After 6 months	After 12 months	After 18 months	After 24 months
Intercept	0.054***	0.053***	0.066***	0.077***	0.086***
Fruits and veg. dummy	-0.120	-0.156	-0.115	-0.091	-0.074
Owner dummy	0.028***	0.014	0.062***	0.094***	0.118***
Rent dummy	0.077***	0.073***	0.107***	0.130***	0.148***
Tradables dummy	0.020	0.025	0.004	-0.007	-0.015
Energy dummy	0.150***	0.119***	0.153***	0.177***	0.196***
Clothing &ftwr. dummy	-0.094***	-0.069***	-0.120***	-0.147***	-0.168***
R^2	0.31	0.29	0.20	0.20	0.20

*, **, *** - coefficient significant in 10%, 5% or 1% , accordingly.

Dwelling prices, although basically non-tradable, were for most of the sample period heavily linked to the Dollar-Shekel exchange rate. Therefore the estimated effect apparently reflects the same exchange rate mechanism as is apparent in the tradable and energy prices, and is probably biased relative to the current reaction of dwelling prices to monetary policy, after the link to the exchange rate has been effectively abolished. We did not find in the estimated equations evidence for a faster response of prices of durable goods as was found in Boivin, Giannoni and Mihov (2007) and in Baumeister, Liu and Mumtaz (2009). Both sets of equations, for the RN and for the ALL versions explain only less than 20% percent of the variability in the response of the different price groups to an interest rate shock.

We check the response of different price groups to a shock to the exchange rate and find that the statistical attributes that had some relevance for the interest rate shock, have no significant contribution in explaining the response of individual price groups. We present in tables 6a and 6b the group attributes that influence these responses. Tradables, energy prices and housing prices tend to be affected by a shock to the exchange rate more than other groups and the magnitude of the effect weakens as the horizon lengthens, so that after 2 years it is significant but close to zero. The R^2 of the equation is relatively high suggesting that the distinction between tradables (including energy) and other products and services is fundamental in explaining the response of prices to exchange rate shocks.

Support to the assumption that the exchange rate is an important transmission mechanism of monetary policy may be found in the significant response of the exchange rate to a shock to the interest rate (Diagram A.2) together with the significant response of prices to a shock in the exchange rate. In addition, we find high (negative) correlation between the response of each of the 38 price groups to a shock to the interest rate and to the exchange rate, which support this assumption. Table 7 presents these correlations for different horizons and for the two alternative models.

Table 7: The Correlation between response to an exchange rate shock and an interest rate shock (across 38 price components)

Horizon (months)	RN	ALL
3	-0.40	-0.77
6	-0.52	-0.93
12	-0.75	-0.81
18	-0.84	-0.63
24	-0.96	-0.48

5. Concluding Remarks

The paper studies the effect of monetary policy on the Israeli consumer price index and its components using a Factor Augmented VAR approach. This approach, which was first presented by Bernanke, Boivin and Eliasz (2005), allows extending the standard VAR model, which usually consists of a small number of variables, to a broader and more comprehensive analysis of the effect of monetary policy on a wide range of variables. In particular this paper looks into the differential response of 38 individual price groups that make up the aggregate CPI index. We include in the model two observable variables: in addition to the interest rate, which is usually included in this kind of FAVAR models, we

also include the exchange rate. This allows us to identify two distinct structural shocks – to the interest rate and to the exchange rate.

We find that a shock to the interest rate has an effect on relative prices, at least for some periods, due to a distinct effect on partial price aggregates. Generally, there is no "price puzzle" and most prices decline in response to an increase in the interest rate, with the effect on the housing (rent) component being the most significant. Price aggregates that are better correlated with macro factors, or that are characterized by serial correlation in their idiosyncratic shocks tend to react more to a monetary shock. Housing and energy prices tend to react stronger to a shock in the interest rate; A shock to the exchange rate affects prices of traded goods, energy and housing stronger than its effect on other prices. Our findings suggest that the main transmission channel of monetary policy to prices is through the exchange rate.

Due to the capability of the FAVAR technique to deal with a large number of variables it provides a framework for the examination of many interesting questions. A worthwhile extension of the analysis presented here is to allow time varying (Bayesian) coefficients in the VAR system in order to capture the variation of the relationship between the factors and monetary policy over time. This may be especially important considering the diminishing effect of the exchange rate on the housing component in the CPI.

A better understanding of the effect of the policy interest rate not only on aggregate CPI, but also on its components and therefore on relative prices is essential for improving the conduct of monetary policy. Expanding our knowledge, using various approaches is bound to be beneficial.

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Appendix 1 – data description

	REAL VARIABLES	
1	DRT_DUR_M_SA	Retail commerce index - Durables
2	DRT_FOOD_M_SA	Retail commerce index - Food
3	DRT_FUEL_M_SA	Retail commerce index - Fule
4	DRT_MDU_M_SA	Retail commerce index - excl. fule, gas and durables
5	DTOUR_HOTEL_BNTT_M_SA	Hotels - no. of bed-nights in tourist hotels - total
6	DTPR_M_SA	Industrial production index - total (excl. diamonds)
7	DTPR_HIGH_M_SA	Industrial production index - High technology
8	DTPR_LOW_M_SA	Industrial production index - Low technology
9	DTPR_MEDIUM_HIGH_M_SA	Industrial production index - Medium-high technology
10	DTPR_MEDIUM_LOW_M_SA	Industrial production index - Medium-low technology
11	DS3_IM_C_M_SA	Imports - consumer goods
12	DS3_IM_CAP_M_SA	Imports - capital goods
13	DS3_IM_INP1_M_SA	Imports - intermediate goods
14	DS3_EX_B_HIGH_M_SA	Manufacturing exports - High technology industries
15	DS3_EX_B_LOW_M_SA	Manufacturing exports - Low technology industries
16	DS3_EX_B_MED_HIGH_M_SA	Manufacturing exports - Medium-High technology industries
17	DS3_EX_B_MEDIUM_LOW_M_SA	Manufacturing exports - Medium-Low technology industries
18	DREVENUE_ST_M_FP_SA	Revenue index - Commerce and services
19	DREVENUE_E_M_FP_SA	Revenue index - Commerce
20	DREVENUE_F_M_FP_SA	Revenue index - Food and accomodation services
21	DREVENUE_H_M_FP_SA	Revenue index - Banking and financial institutions
22	DREVENUE_I_M_FP_SA	Revenue index - Business services
23	D_B_PMI_M_SA	Dun and Bradstreet PMI index
24	LFFL_M_S	Housing completions - Total
25	LSFL_M_S	Housing starts - Total
26	DEP_8__FRN_M_S	Employee posts - Total public services
27	DEP_B__FRN_M_S	Employee posts - Manufacturing - Israelis
28	DEP_BS_M_SA	Employee posts - Business sector - incl. territories & foreigners
29	DEP_M_SA	Employee posts - Total - incl. territories & foreigners
30	DAW_8__FRN_M_S	Average monthly wages per employee post - total public services
31	DAW_B_M_S	Average monthly wages per employee post - manufacturing
32	DAW_BS_M_SA	Average monthly wages per employee post - Business sector
33	DAW_M_SA	Average monthly wages per employee post - Total - incl. territories & foreigners
34	DRW_8__FRN_M_S	Average monthly real wages per employee post - total public services
35	DRW_B_M_S	Average monthly real wages per employee post - manufacturing
36	DRW_BS_M_SA	Average monthly real wages per employee post - Business sector
37	DRW_M_SA	Average monthly real wages per employee post - Total - incl. territories & foreigners

Continued on the next page…

NOMINAL VARIABLES

38	DCP	Consumer's index - Total
39	DCP01	Consumer's index - Excl. fruits and vegetables
40	DCP04	Consumer's index - Excl. housing
41	DWP	Industry production price index
42	DBIP	Construction inputs prices index - Total
43	DIND_FLT_M	House price index
44	DCP000100	Consumer's index - Fruits & vegetables - Fresh vegetables
45	DCP000200	Consumer's index - Fruits & vegetables - Fresh fruits
46	DCP000300	Consumer's index - Fruits & vegetables - Frozen, canned and preserved vegetables
47	DCP000400	Consumer's index - Fruits & vegetables - Dry and preserved fruits
48	DCP010100	Consumer's index - Food - Bread pastry and grains
49	DCP010200	Consumer's index - Food - Eggs
50	DCP010300	Consumer's index - Food - Meet, poultry & fish
51	DCP010400	Consumer's index - Food - Oils & margarine
52	DCP010500	Consumer's index - Food - Milk & products
53	DCP010600	Consumer's index - Food - Other
54	DCP010700	Consumer's index - Food - Beverages
55	DCP010800	Consumer's index - Food - Sugar, jams & candies
56	DCP010900	Consumer's index - Food - Non domestic meals
57	DCP020100	Consumer's index - Housing - Rents
58	DCP020200	Consumer's index - Housing - Owned apartments
59	DCP020400	Consumer's index - Housing - Other housing expenses
60	DCP030100	Consumer's index - Housing maintenance - Municipal taxes
61	DCP030200	Consumer's index - Housing maintenance - Housekeeping
62	DCP030300	Consumer's index - Housing maintenance - House and yard improvement
63	DCP030400	Consumer's index - Housing maintenance - Electricity, fuel and water
64	DCP030500	Consumer's index - Housing maintenance - Miscellaneous
65	DCP040100	Consumer's index - Furniture & house equip. - Furniture
66	DCP040200	Consumer's index - Furniture & house equip. - Beds utensils & decoration
67	DCP040300	Consumer's index - Furniture & house equip. - Non-electric equip.
68	DCP040400	Consumer's index - Furniture & house equip. - Electric equip.
69	DCP050100	Consumer's index - Clothing & footwear - Clothing
70	DCP050200	Consumer's index - Clothing & footwear - Footwear
71	DCP060100	Consumer's index - Education, culture & entertainment - Education
72	DCP060200	Consumer's index - Education, culture & entertainment - Culture & entertainment
73	DCP070100	Consumer's index - Medical services - Medical services
74	DCP070200	Consumer's index - Dentistry
75	DCP070300	Consumer's index - Medicines & medical equip.
76	DCP080100	Consumer's index - Communication & transportation - Transportation
77	DCP080200	Consumer's index - Communication & transportation -Private vehicle and maintenance
78	DCP090100	Consumer's index - Other - Cigarettes & tobacco
79	DCP090200	Consumer's index - Other - Cosmetics & private services
80	DCP090300	Consumer's index - Other - Jewelry & watches
81	DCP090400	Consumer's index - Other - Bags & briefcases
82	INFL_TARGET	Inflation target
83	REP_F90107A_M	Market based inflation expectations
84	DREP_F40000B_M	money base (H)
85	DM1_M	M1
86	DREP_F40013B_M	M2
87	DREP_F40003B_M	Deposits - overnight
88	DREP_F40004B_M	Deposits - nonindexed 1 week - 3 months
89	DREP_F40007B_M	Deposits - nonindexed 3 months - 1year
90	DREP_F40008B_M	Deposits - CPI indexed 3 months - 1year
91	DREP_F40012B_M	T-Bills (MAKAM)
92	DREP_F40030B_M	M3
93	DREP_F40014B_M	Deposits - long term CPI indexed
94	DREP_F40015B_M	Deposits - long term nominal
95	DREP_F40034B_M	Saving deposits
96	DREP_F40036B_M	Bank credit - local currency total
97	DREP_F40037B_M	Bank credit - foreign currency
98	DREP_F40043B_M	Bank credit - local currency, nonindexed
99	TSB_BAGR_MAKAM_03M_M	Gross yield to maturity - Treasury bills, fixed interest 3 months to redemption
100	TSB_BAGR_MAKAM_12M_M	Gross yield to maturity - Treasury bills, fixed interest 12 months to redemption
101	TSB_ZND_03Y	Gross yield to maturity- nominal govt. bonds, fixed interest - 3 years
102	TSB_ZRD_03Y	Gross yield to maturity- Indexed govt. bonds, fixed interest - 3 years
103	TSB_ZRD_05Y	Gross yield to maturity - Indexed govt. bonds, fixed interest - 5 years
104	TSB_ZRD_10Y	Gross yield to maturity - Indexed govt. bonds, fixed interest - 10 years
105	DREP_F70049B_M	Bond price index - TASE
106	DREP_F70050B_M	Stock price index - TASE
111	RATIO_DOL	Share of dollar-linked rent contracts
112	IBOI	Bank of Israel key rate
113	DMAT01_MA	Dollar/Shekel exchange rate

GLOBAL VARIABLES

107	DIPUS	US industrial production index
108	DPCMDTS	Merril Lynch commodity price index
109	DPOIL	oil price, cushing, barrel
110	IFED	US federal reserve key interest rate

Table A.1: Correlation between the principal components and selected variables

a: Separate principal components for real and nominal variables (RN version)

Variables – Real group*	**1st PC**	**2nd PC**	**3rd PC**
Retail commerce -total excl. gas and petrolium	0.22	0.11	-0.16
Industrial production - total	0.35	-0.15	0.38
Exports – High-tech industries	0.09	-0.04	0.14
Revenue – total	0.62	-0.38	0.28
Housing starts	0.14	-0.01	0.04
Employee posts - total	0.47	-0.31	-0.19
Average monthly wages per employee post	0.13	0.68	0.58
Average monthly real wages per employee post	0.14	0.68	0.59
Variables – Nominal group*	**1st PC**	**2nd PC**	**3rd PC**
Construction inputs prices	0.26	0.36	-0.03
CPI	0.73	0.79	-0.15
CPI – housing (rent) prices	0.30	0.44	0.18
House prices	0.27	0.42	-0.05
Wholesale prices	0.50	0.59	-0.19
M1	-0.03	0.32	0.52
Yield to maturity – 3 year indexed gov. bonds	-0.21	-0.32	0.09
Yield to maturity – 12 months non-indexed bills (MAKAM)	0.09	0.06	-0.04

* Separate principal components are different for each of the 2 groups of variables.

b: Joint principal components for all variables (ALL version)

Variable	1st PC	2nd PC	3rd PC	4th PC	5th PC	6th PC
Retail commerce -total excl. gas and petroleum	0.05	0.00	0.04	0.32	0.04	-0.07
Industrial production - total	-0.02	0.20	0.29	0.16	-0.07	0.13
Exports – High-tech industries	0.03	-0.01	0.11	0.05	0.01	0.08
Revenue – total	-0.04	0.19	0.33	0.56	-0.21	0.51
Housing starts	0.51	-0.28	0.20	0.26	0.05	0.17
Employee posts - total	0.04	0.24	0.36	0.22	0.07	0.01
Average monthly wages per employee post	0.05	0.02	-0.04	0.28	0.66	-0.06
Average monthly real wages per employee post	-0.02	0.10	-0.07	0.28	0.66	-0.06
Construction inputs prices	0.26	-0.29	0.8	0.16	-0.09	-0.22
CPI	0.70	-0.78	0.22	-0.05	-0.04	-0.03
CPI – housing (rent) prices	0.27	-0.43	-0.12	0.08	-0.06	-0.04
House prices	0.16	-0.27	0.10	0.10	0.06	0.05
Wholesale prices	0.43	-0.49	0.36	0.02	-0.28	-0.27
M1	-0.07	-0.31	-0.47	0.19	0.03	0.03
Yield to maturity – 3 year indexed gov. bonds	0.18	-0.02	-0.06	0.06	0.10	0.07
Yield to maturity – 12 months non-indexed bills (MAKAM)	0.56	-0.37	0.17	0.20	0.11	0.07

Table A.2: Price category characteristics

		Trada-bles	services	Govern-ment	energy	durables	housing	Clothing & footwear	Fruit & veget-ables
0	FRUIT&VEG-FRESH VEG.	0	0	0	0	0	0	0	1
0	FRUIT&VEG-FRESH FRUIT	0	0	0	0	0	0	0	1
0	FRUIT&VEG-FROZEN	1	0	0	0	0	0	0	0
0	FRUIT&VEG-DRIED	1	0	0	0	0	0	0	0
1	FOOD-BREAD	0	0	0.37	0	0	0	0	0
1	FOOD-EGGS	0	0	1	0	0	0	0	0
1	FOOD-MEAT	1	0	0	0	0	0	0	0
1	FOOD-OIL	1	0	0	0	0	0	0	0
1	FOOD-MILK	0	0	0.93	0	0	0	0	0
1	FOOD-OTHER	1	0	0	0	0	0	0	0
1	FOOD-BEVERAGES	1	0	0	0	0	0	0	0
1	FOOD-SUGAR	1	0	0	0	0	0	0	0
1	FOOD-AWAY FROM HOME	0	1	0	0	0	0	0	0
2	RENT	0	0	0	0	0	1	0	0
2	OWNED DWELLING	0	0	0	0	0	1	0	0
2	DWELLING-OTHER	0	1	0	0	0	0	0	0
3	MAINTNC. - TAXES	0	0	1	0	0	0	0	0
3	MAINTNC - HELP	0	1	0	0	0	0	0	0
3	MAINTNC - MNTNC.	0	1	0	0	0	0	0	0
3	MAINTNC. - ELECTRICITY&WATER	1	0	1	0.8	0	0	0	0
3	MANITNC. - OTHER	1	1	0	0	0	0	0	0
4	FURNITURE	1	0	0	0	1	0	0	0
4	FURNITURE-BEDDING	1	0	0	0	1	0	0	0
4	FURNITURE-NON-ELECT.	1	0	0	0	1	0	0	0
4	FURNITURE-ELECTRIC	1	0	0	0	1	0	0	0
5	CLOTHING	1	0	0	0	0	0	1	0
5	FOOTWEAR	1	0	0	0	0	0	1	0
6	EDUCATION	0	1	0.78	0	0	0	0	0
6	CULTURE	0	0.57	0	0	0.17	0	0	0
7	HEALTH	0	1	0.68	0	0	0	0	0
7	HEALTH-DENTAL	0	1	0	0	0	0	0	0
7	HEALTH-MEDICINE	1	0	0	0	0	0	0	0
8	TRANSPORT	0.44	0	0.06	0.25	0.22	0	0	0
8	TELECOM	0	1	1	0	0	0	0	0
9	CIGARETTES	1	0	1	0	0	0	0	0
9	COSMETICS	0.5	0.5	0	0	0	0	0	0
9	JEWELRY	1	0	0	0	1	0	0	0

Table A.3: Correlation between statistical attributes and group dummies

	1/std.	R^2 of factors	AR_fit	AR_residuals
Durable dummy	-0.09	-0.14	0.33	0.06
Gov. dummy	0.05	-0.26	-0.15	0.16
Owner dummy	-0.08	-0.05	-0.02	0.40
Rent dummy	-0.07	-0.05	0.06	0.35
Services dummy	0.63	0.18	0.29	-0.29
Tradables dummy	-0.42	0.13	-0.15	-0.21
Energy dummy	-0.10	0.09	-0.06	0.16
Fruit&veg. dummy	-0.33	-0.27	-0.33	0.10
Clothing&ftwr dummy	-0.30	-0.17	-0.43	0.02

Diagram A.1: Impulse response to a BoI interest rate shock - various variables

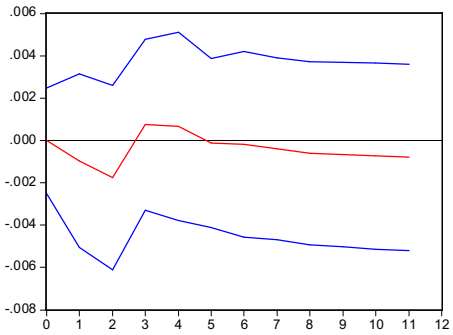
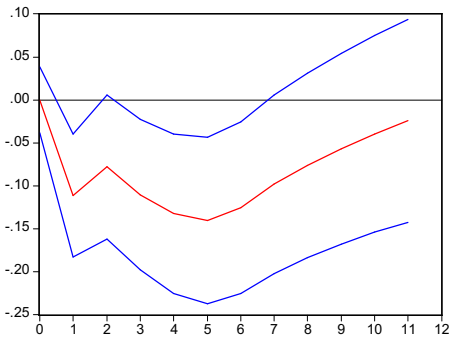
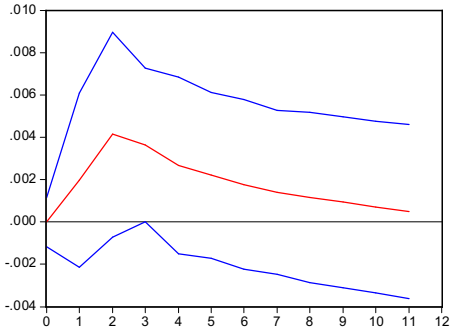
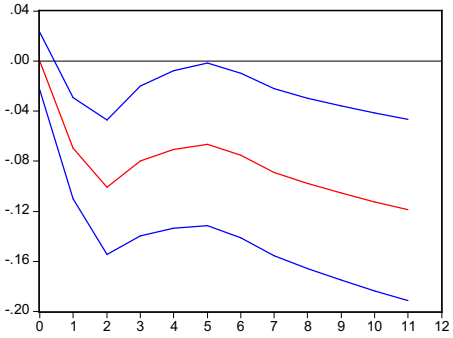
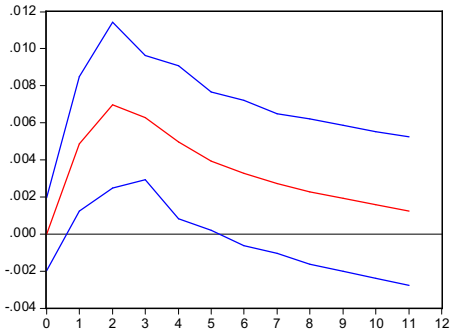
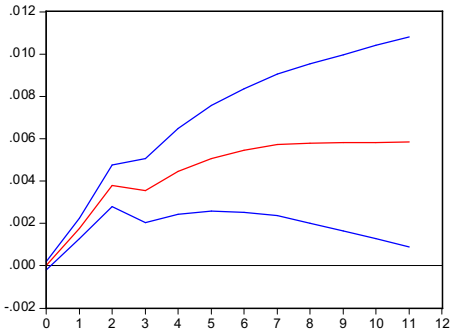
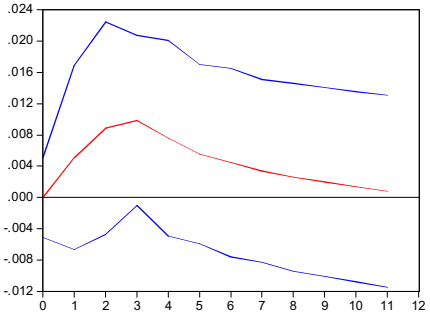
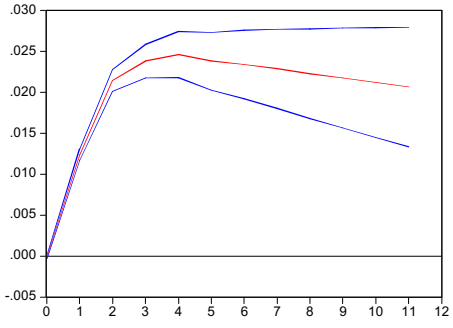
	RN version	ALL version
Retail sales		
Industrial production		
Business sector revenues		
Consumption goods' imports		

Diagram A.2: Impulse response to a BoI interest rate shock - various variables

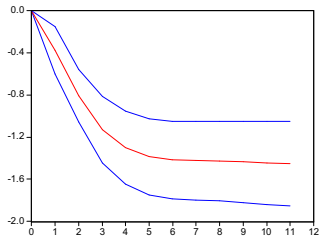
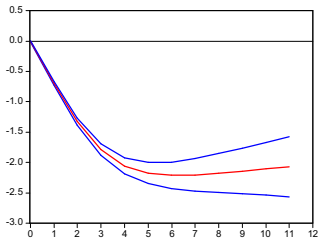
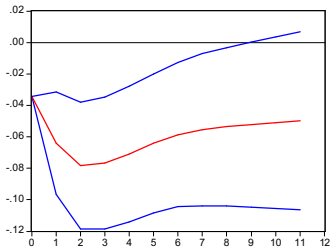
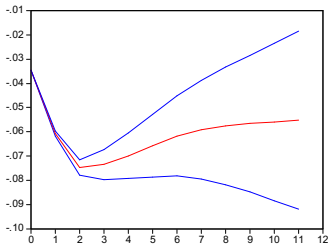
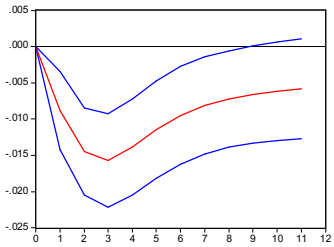
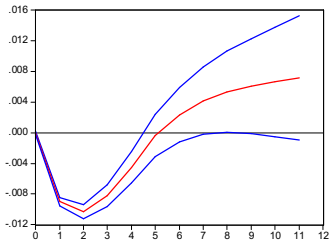
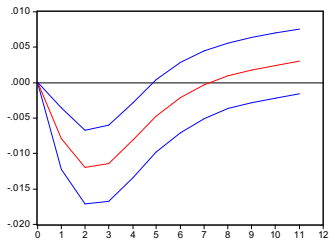
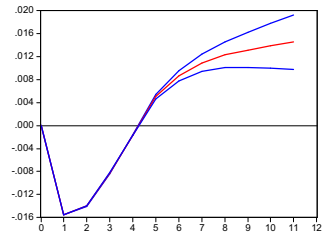
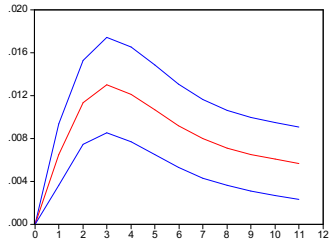
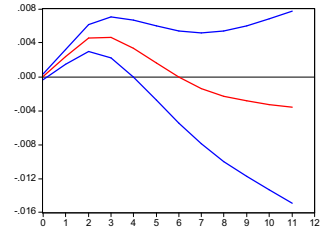
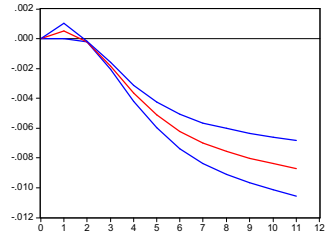
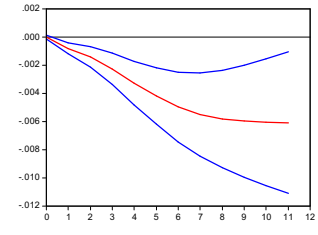
	RN version	ALL version
Market-based inflation expectations		
Dollar/Shekel exchange rate		
M1		
Overnight deposits		
Time deposits		
Local currency non-indexed bank credit		

Diagram A.3: Impulse response to a BoI interest rate shock - various variables

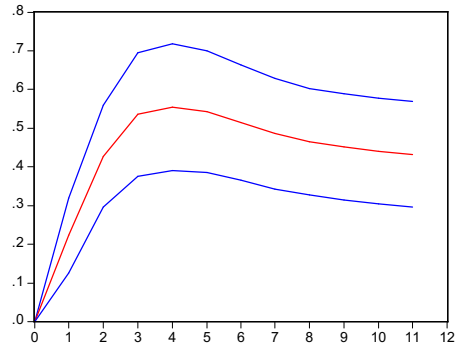
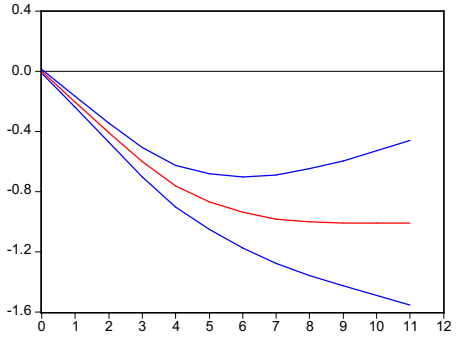
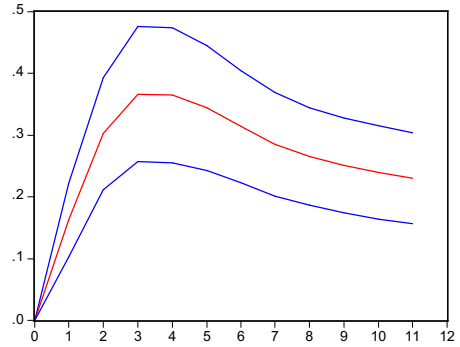
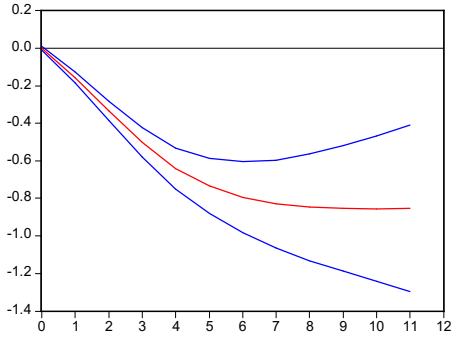
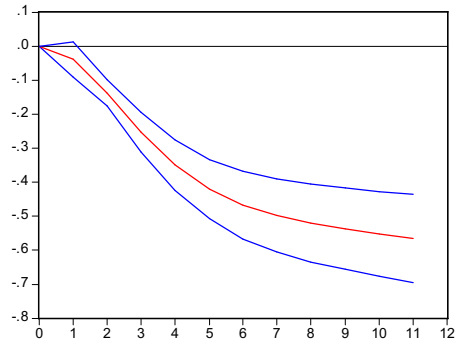
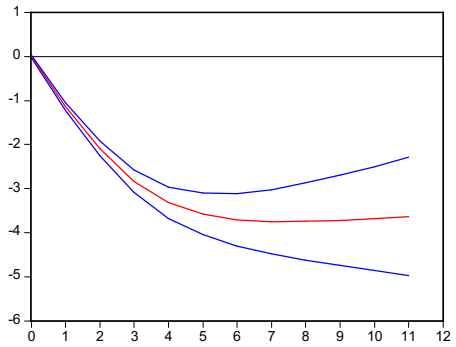
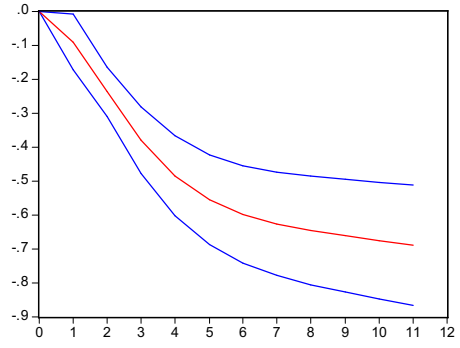
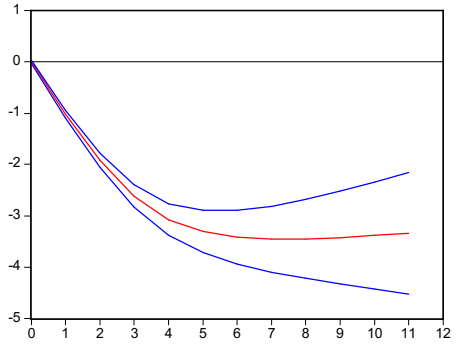
	RN version	ALL version
Yield on 3Y indexed Gov. bonds		
Yield on 5Y indexed Gov. bonds		
Yield on 3month non-indexed Gov. bonds (Makam)		
Yield on 12month non-indexed Gov. bonds (Makam)		

Diagram A.4: Impulse response to a BoI interest rate shock - various variables

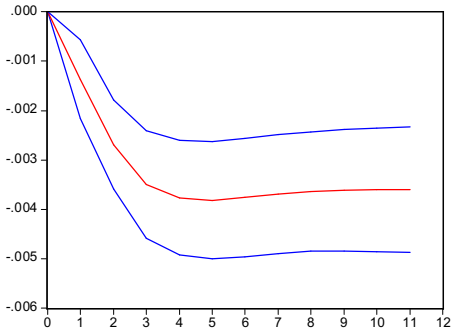
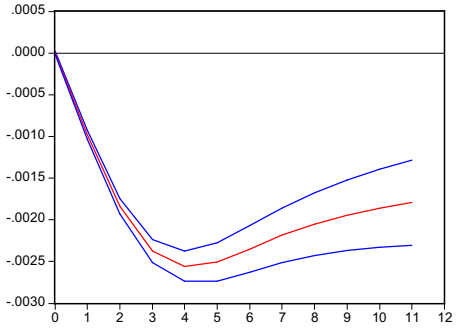
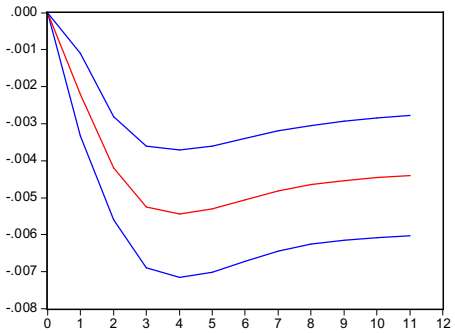
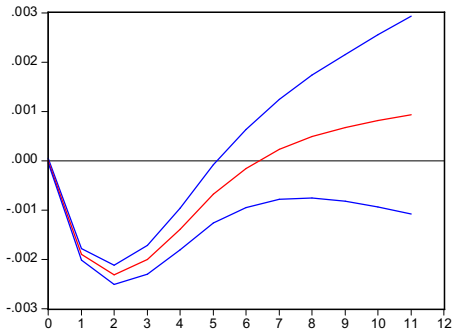
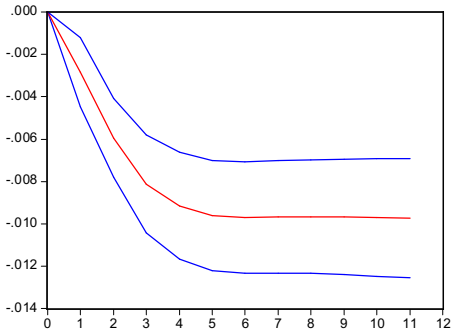
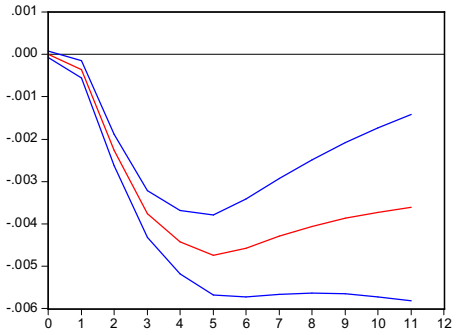
	RN version	ALL version
Construction input Prices		
House prices		
Wholesale prices		

Diagram A.5: Impulse response to a BoI interest rate shock - various price aggregates

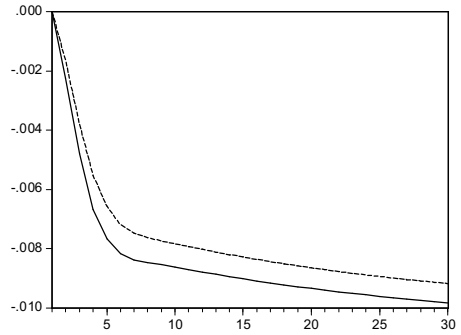
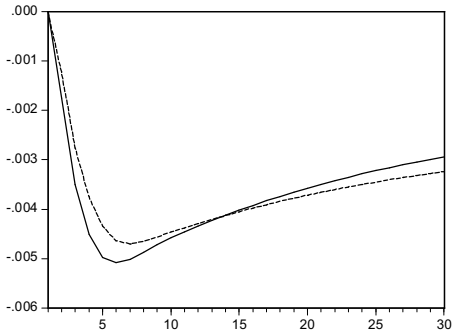
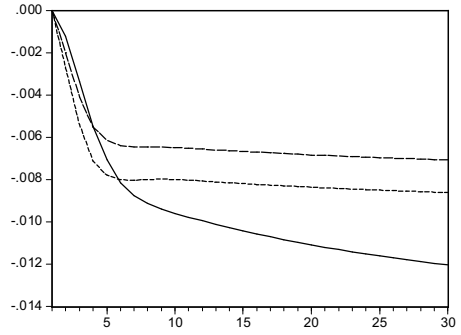
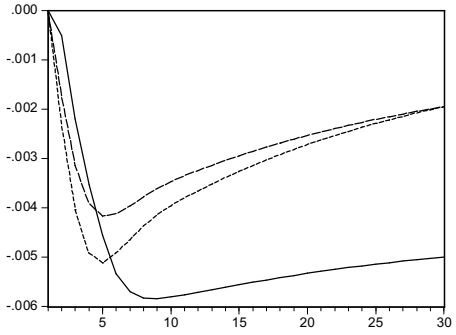
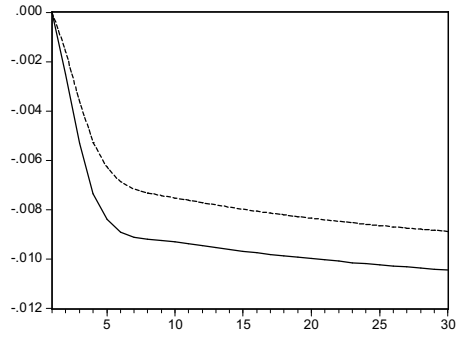
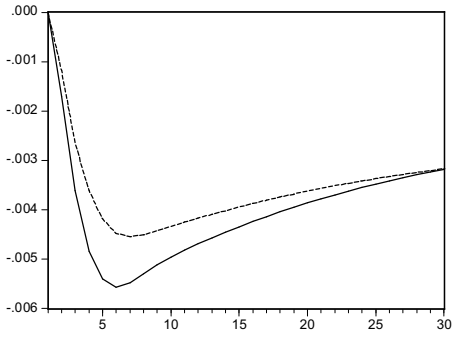
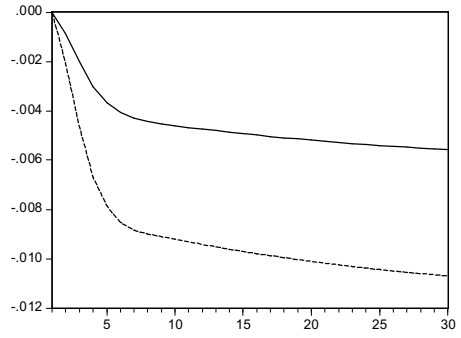
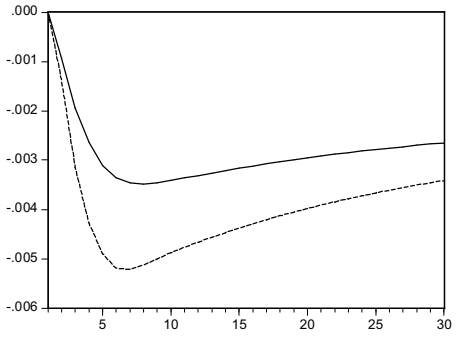
	RN version	ALL version
Total CPI (solid) **and CPI excl. housing** (dotted)		
Tradables (solid), **non-tradables** (dotted) **and non-tradables excl. housing** (broken)		
Durables, excl. housing (solid) **and non-durables** (dotted)		
Services excl. housing (solid) **and non-services** (dotted)		

Diagram A.5, cont'd: Impulse response to a BoI interest rate shock - various price aggregates

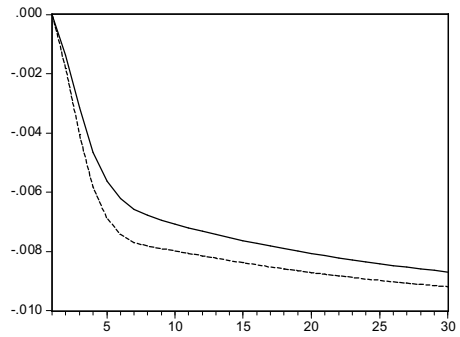
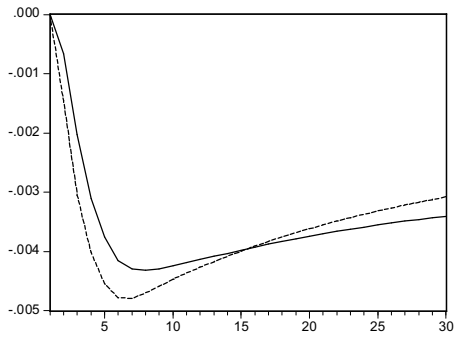
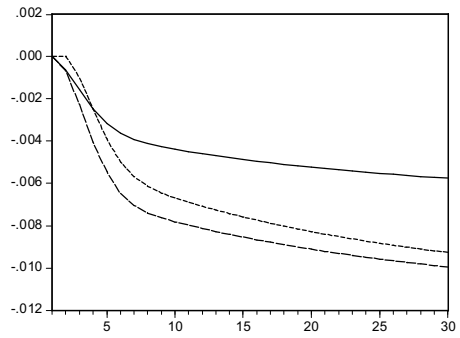
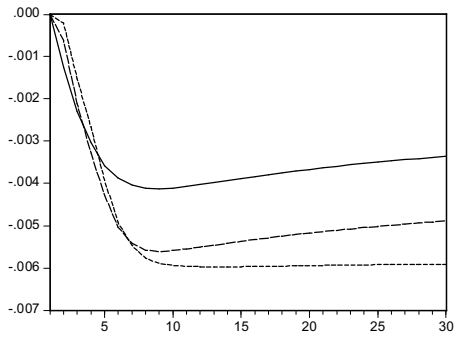
	RN version	ALL version
Government controlled (solid) **and other prices excl. housing** (dotted)		
Dental services (solid)**, bread**(dotted) **and electric home appliances** (broken line)		

Diagram A.6: Impulse response to an exchange rate shock - various variables

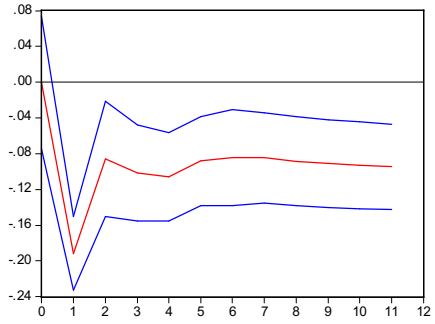
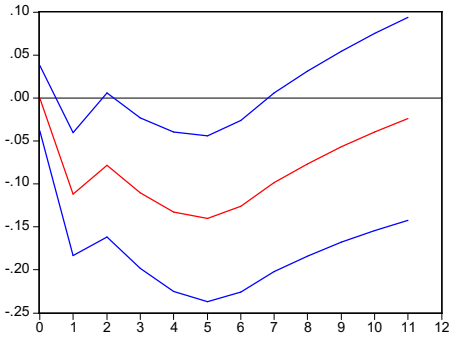
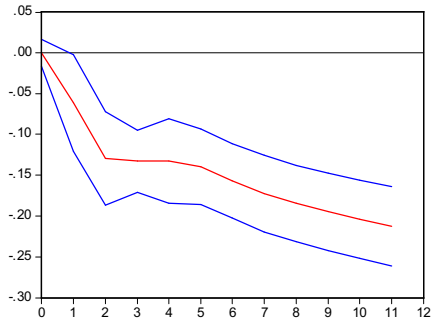
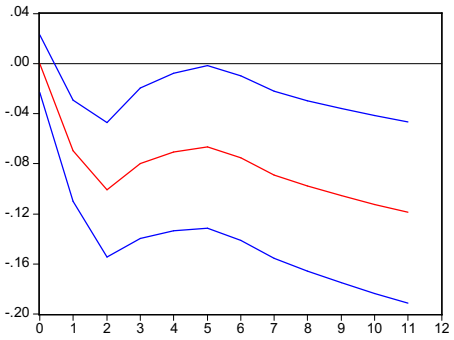
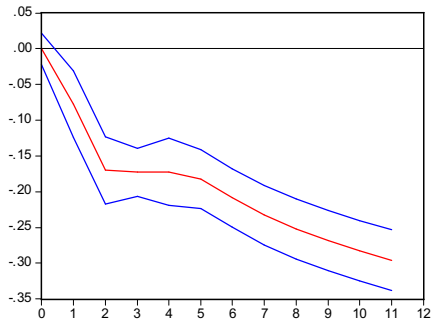
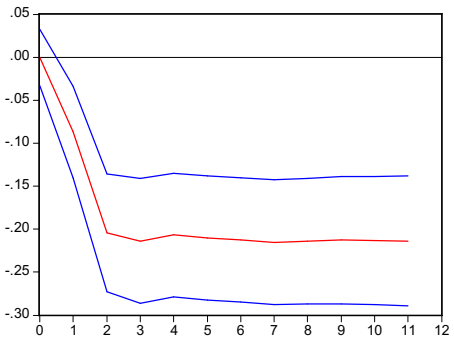
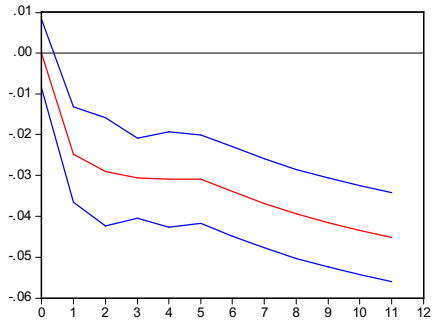
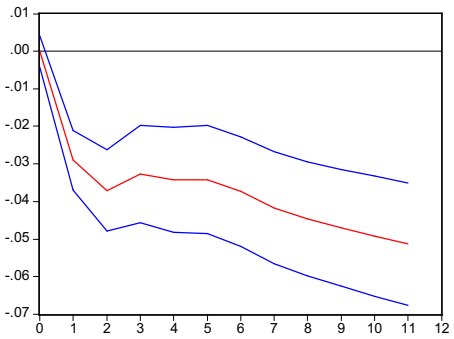
	RN version	ALL version
Retail sales		
Industrial production		
Business sector revenues		
Consumption goods' imports		

Diagram A.7: Impulse response to an exchange rate shock - various variables

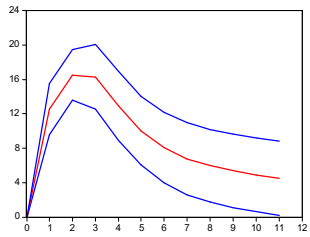
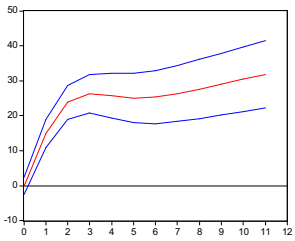
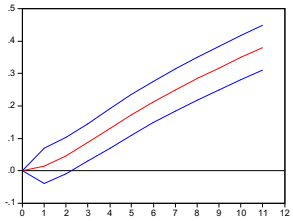
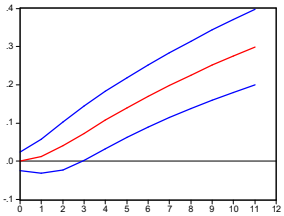
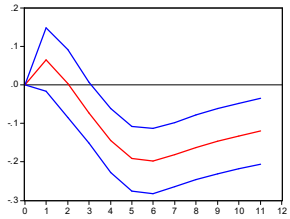
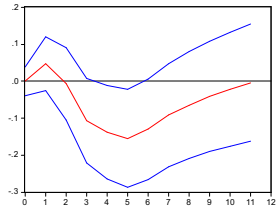
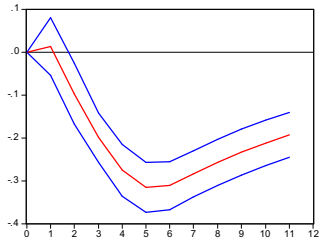
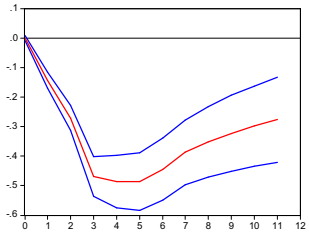
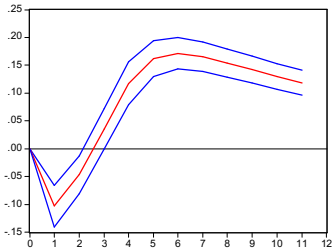
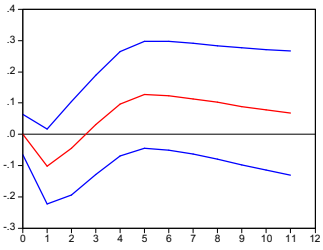
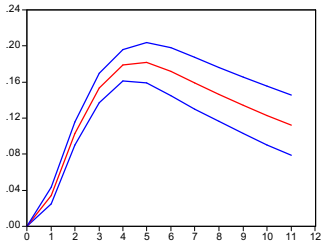
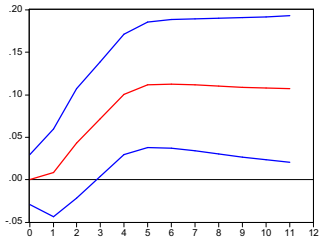
	RN version	ALL version
Market-based inflation expectations		
BoI interest rate		
M1		
Overnight deposits		
Time deposits		
Local currency non-indexed bank credit		

Diagram A.8: Impulse response to an exchange rate shock - various variables

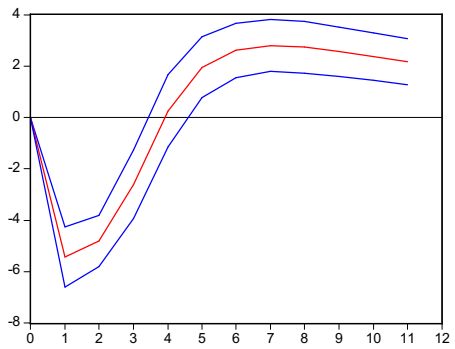
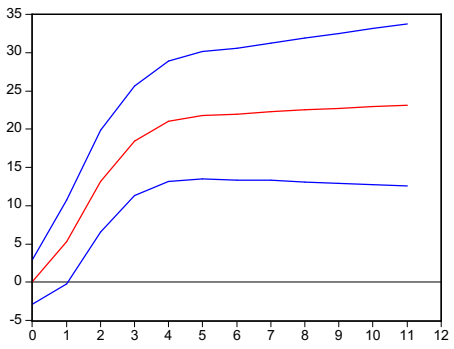
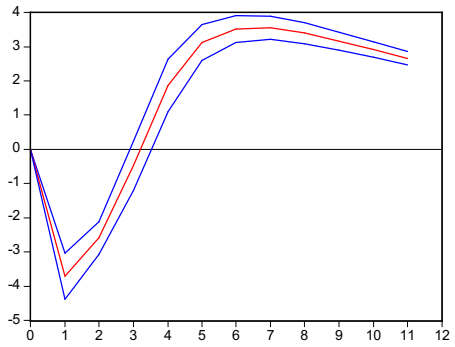
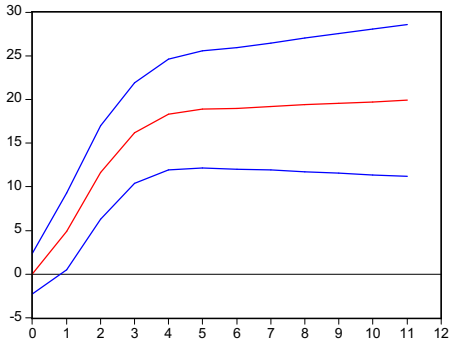
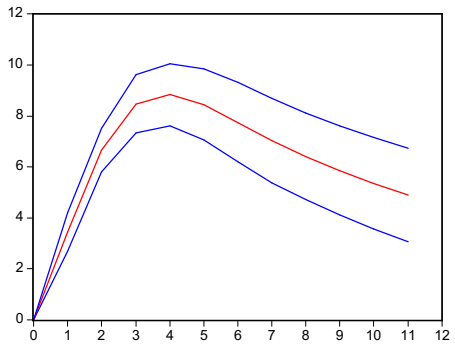
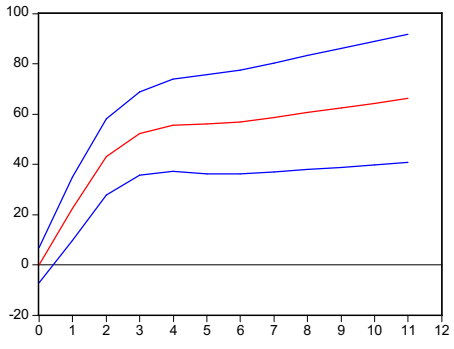
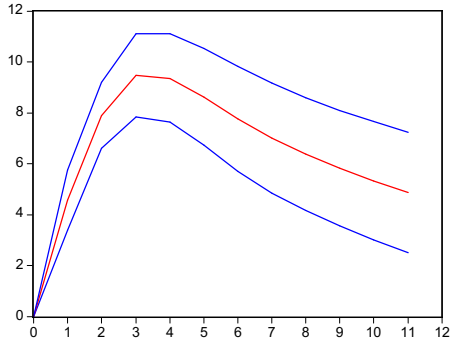
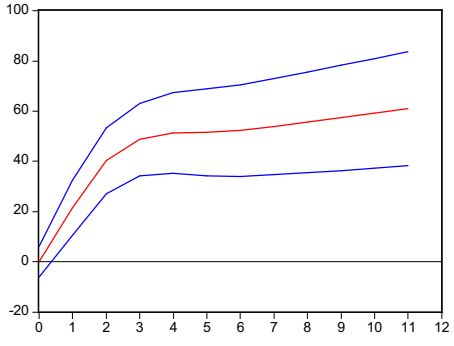
	RN version	ALL version
Yield on 3Y indexed Gov. bonds		
Yield on 5Y indexed Gov. bonds		
Yield on 3month non-indexed Gov. bonds (Makam)		
Yield on 12month non-indexed Gov. bonds (Makam)		

Diagram A.9: Impulse response to an exchange rate shock - various variables

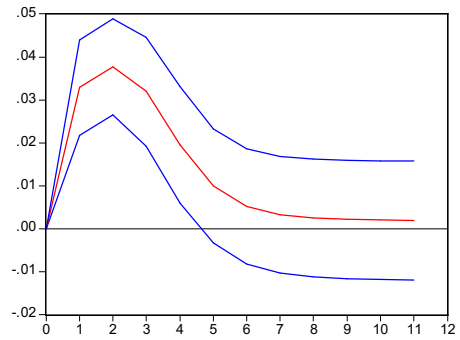
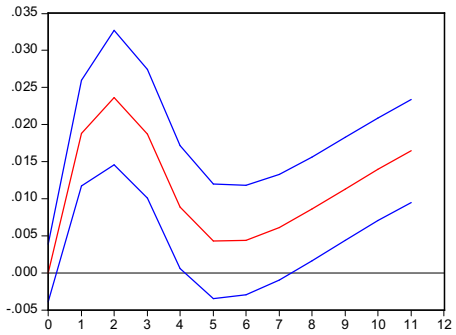
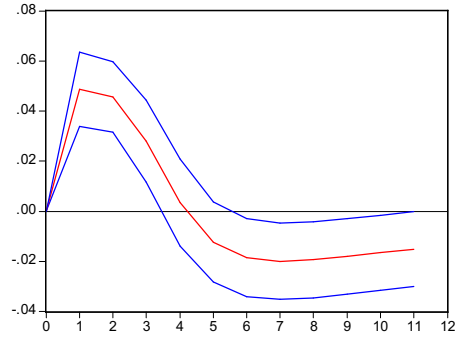
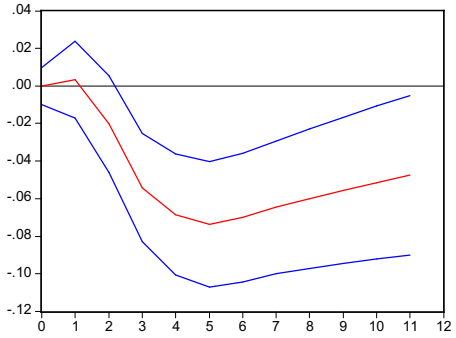
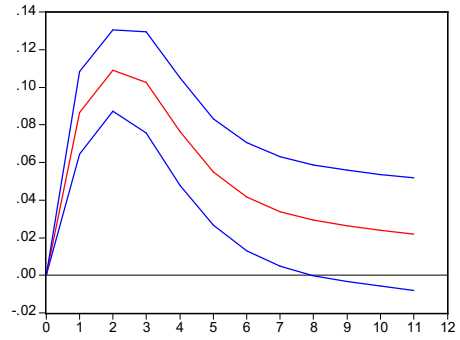
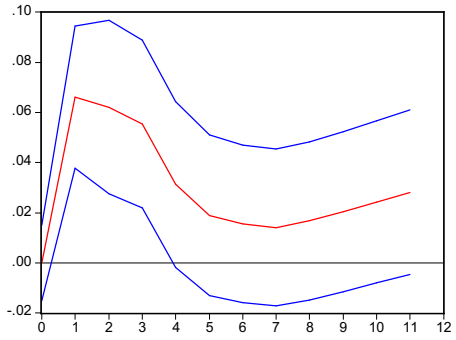
	RN version	ALL version
Construction input Prices		
House prices		
Wholesale prices		

Diagram A.10: Impulse response to an exchange rate shock - various price aggregates

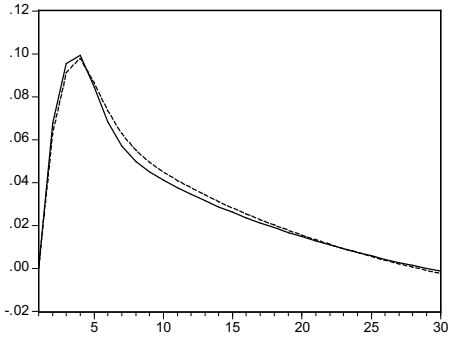
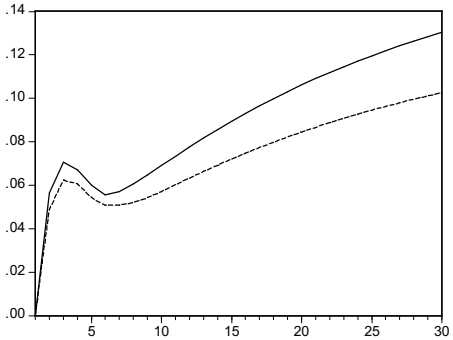
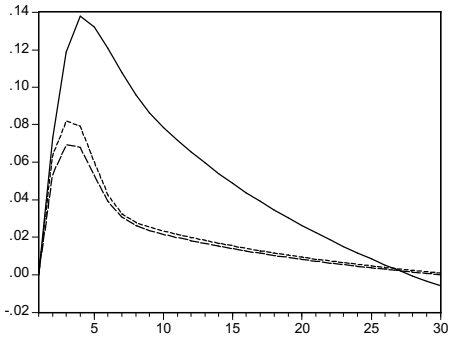
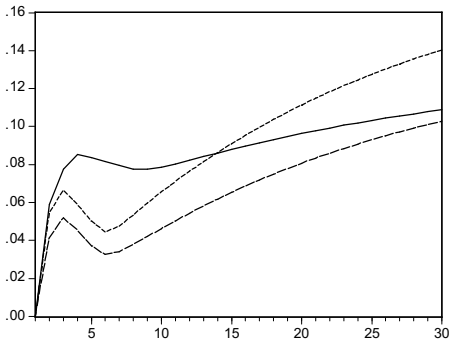
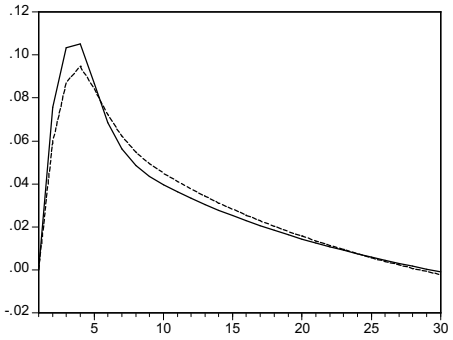
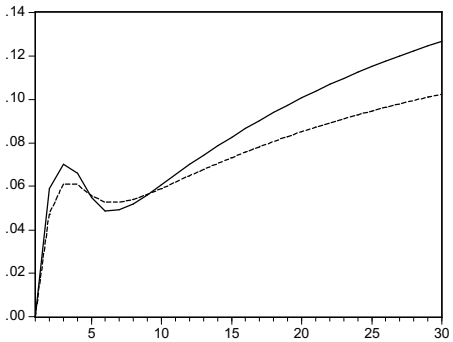
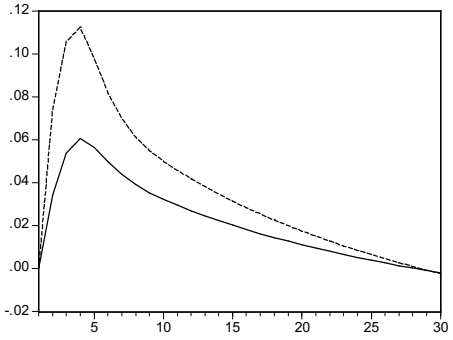
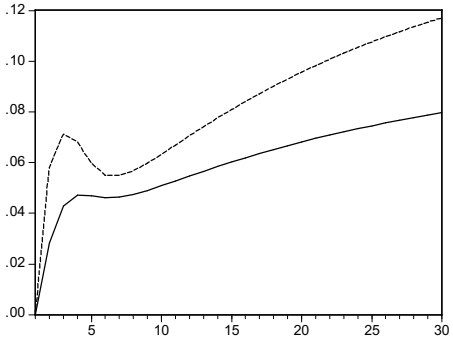
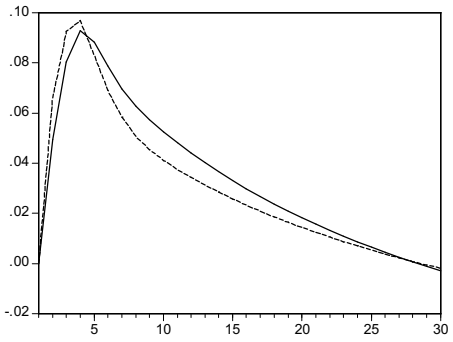
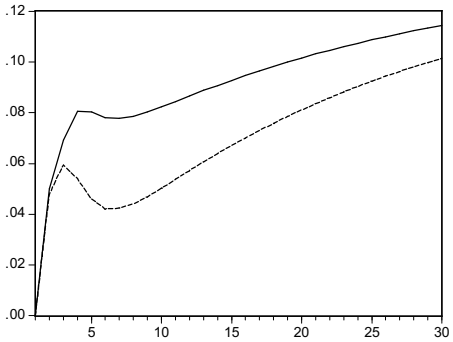
	RN version	ALL version
Total CPI (solid) **and CPI excl. housing** (dotted)		
Tradables (solid), **non-tradables** (dotted) **and non-tradables excl. housing** (broken)		
Durables, excl. housing (solid) **and non-durables** (dotted)		
Services excl. housing (solid) **and non-services** (dotted)		

Diagram A.10, cont'd : Impulse response to an exchange rate shock – various price aggregates

	RN version	ALL version
Government controlled (solid) **and other prices excl. housing** (dotted)		
Dental services (solid)**, bread**(dotted) **and electric home appliances** (broken line)