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Inflation, Unemployment, the Exchange Rate and Monetary Policy in Israel 1990-1999: A SVAR Approach

by

Joseph Djivre* and Sigal Ribon*

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Research Department, Bank of Israel, מחלקת המחקר, בנק ישראל ת״ד 780 ירושלים 91007
POB 780, 91007 Jerusalem, Israel
www.bankisrael.gov.il

Abstract

In this paper we estimate a four-equation quarterly structural VAR model of the Israeli economy during the years 1990-1999. The estimated system of equations includes an unemployment equation, an inflation equation, a nominal interest equation describing the evolution of the interest rate on monetary instruments controlled by the central bank and a nominal exchange rate equation. We used in our estimation two identification restriction sets, which allowed us to differentiate between two structural models. In the first model, model 1, the supply does not respond on impact to changes in aggregate demand while in the second model, model 2, the supply response is such that it maximizes the impact effect of demand shocks on unemployment.

According to our estimation results positive shocks to the BoI interest rate slow down inflation and are reflected, in both structural models, in arise in the ex-post real interest rate and in unemployment. The inflation response to interest rate shocks is rather fast as a result of the exchange rate response to the changes in the interest rate. There are no drastic differences between the estimation results of the nominal interest rate equation in the two models. In spite of the response of unemployment and inflation to monetary policy shocks, the variance decomposition results suggest that the central interest rate variability may be considered as being the source of a rather small fraction of inflation variability and of an almost negligible fraction of unemployment variability in both structural models.

The analysis of the retrieved actual stuctural shows that deviation of the unemployment rate from its long run equilibrium level, during the period surveyed, should be attributed, in the context of model 1, to supply shocks. This is not however the case in model 2. In this model demand and interest rate shocks did also play a determining role, in addition to supply shocks, in bringing about the fall in unemployment between 1993 and 1995 and its rise between 1996 and 1999. Indeed the expansion of monetary aggregates between 1992 and 1994 was very fast, implying an expansionary monetary policy, while between 1997 and 1998 international trade growth fell following the crises in emerging markets inflicting an aggregate demand shock on the Israeli economy. The fact that model 2 gave rise to an ex-post monetary policy characterization similar to that supported by out of the model empirical evidence and that it identified demand shocks which are known to have occurred, suggests that it may be more suitable than model 1 in describing the Israeli economy during the period surveyed.

I. Introduction

In this paper we estimate a four-equation quarterly structural VAR model of the Israeli economy during the years 1990-1999. The estimated system of equations includes an unemployment equation, an inflation equation, a nominal interest equation describing the evolution of Israel's central bank (hereafter the BoI) interest rate and a nominal exchange rate depreciation equation.

Our paper belongs to a large group of empirical work, which examine the effect of monetary policy on the economy in general and in particular on economic activity, employment and the evolution of prices through the estimation of SVAR models. Our estimation methodology derives from Sims (1980). Our approach however does not assume recursiveness for the identification of the structural model. Most of the empirical work, which has been undertaken in this field relates to the U.S economy. There is however empirical work on other economies as well such as Sims (1992), Eichenbaum and Evans (1995) and Cushman and Zha(1997). Surveys of this empirical work may be found in Todd(1990) and Vinals and Valles(1999). Christiano et al (1998) constitute a very analytical and critical survey relating both to the statistical aspects of the estimation and to their findings. According to this research an unexpected monetary tightening affects initially the monetary aggregates and economic activity, which contract and at a later stage the rate of inflation, which slows down. In much of the empirical work such an unexpected change in monetary policy is also followed by a nominal and a real exchange rate appreciation, which is rather protracted and is reflected in a systematic deviation from uncovered interest rate parity [See for example Eichenbaum and Evans (1995)]. This is in general the response pattern of large and relatively closed economies like the U.S.A. In small and open economies an unexpected tightening of the monetary policy does also lead to nominal and real exchange rate appreciation but the response of output and prices is faster relatively to large and rather closed economies and the price response to the monetary policy shock does not lag behind the output response. This seems to be due to the fast reaction of the exchange rate to changes in

the monetary policy and to the contribution of the former to the evolution of prices [Cushman and Zha(1997)].[1]

The variables used to measure monetary policy in the aforementioned research include the interbank interest rate in the U.S (Federal-funds rate), non-borrowed reserves, total reserves and monetary aggregates such as the monetary base, M1 and M2. The variance decomposition results indicate that the variability of these variables does explain but a small fraction of the output variability relatively to the other variables of the estimated models with the exception of the federal-funds rate. According to the results obtained by Christiano et al.(1998) for the U.S. economy the federal-funds variability explains some 44 percent of the output variability two years after the initial monetary policy shock. Research on smaller and open economies indicates that shocks to monetary policy have even weaker effects on the variability of output. Cushman and Zha(1997) report a maximal contribution of monetary policy shocks to the variability of output of 2.75 percent in the case of Canada with a six month lag after the original monetary policy shock.

In the framework of our model, which will be presented later on, we have to impose six identifying restrictions to fully identify the structural model. In choosing one of these six identification restrictions we followed, with minor modifications King and Watson (1994) and Dolado et al (1996) in order to differentiate between two different structural models. In the first model (hereafter Model 1) the supply does not respond on impact to changes in aggregate demand while in the second model (hereafter Model 2) there is a supply response such that it maximizes the effect of demand shocks on output and hence on unemployment. The remaining five identifying restrictions reflect assumptions which made sense economically giving rise to reasonable results.[2]

According to our estimation results positive shocks to the BoI interest rate slow down inflation and are reflected, in both structural models, in a rise in the real interest rate and in unemployment. The inflation response to interest rate shocks is rather fast as a result of the exchange rate response to the

[1]In some of the research the unexpected tightening of the monetary policy was followed by a nominal exchange rate depreciation Sims(1992). This phenomenon has been termed in the literature as the "exchange rate puzzle". According to Cushman and Zha the origin of the puzzle is the result of inappropriate identification restrictions imposed on the coefficients of the monetary policy equation.

[2]Other combinations, which were equally justified economically, led to improbable results and gave sometimes rise to complex solutions for the coefficients of the of the coincident endogenous variables of the structural model.

changes in the interest rate, in line with similar findings in empirical work on small and open economies.

In spite of the response of unemployment and inflation to monetary policy shocks, the variance decomposition results suggest that the central bank interest rate variability may be considered as being the source of a rather small fraction of inflation variability and of an almost negligible fraction of unemployment variability in both structural models. These results are in line with the findings of Cushman and Zha (1997) on the Canadian economy. Still, in the framework of the second structural model we have estimated, the analysis of the retrieved actual structural shocks implies that the contribution of interest rate and demand shocks to the fall in unemployment between 1993 and 1995 and to its rise between 1996 and 1999 was not negligible.

The estimation results indicate that there is no substantial difference between the central bank reaction functions in the two structural models. It is however preferable, in our opinion, to relate to this equation as describing the central bank interest rate evolution rather than the reaction function of the Bank of Israel. The reason is that the equation's estimated structure does not necessarily reflect central bank preferences [Christiano et al. (1998)]. The two estimated structural models differ though with respect to their reaction to exchange rate depreciation shocks. In particular, unemployment reacts in opposite directions to shocks to the exchange rate depreciation in the two models.

Our paper consists of four additional parts. In the second part we describe the identification procedure of the structural model and the identification restrictions imposed upon the coefficients of the coincident variables in the structural model. In the third part we present the estimation results, the impulse response function and the variance decomposition analyses. The discussion concerning the interaction between the monetary policy and the other three endogenous variables in the estimated models appears in the fourth part, while part five concludes.

II. The Structural Model and its Identification

A. A General Description of the Model

Our model is a structural vector autoregression model (SVAR), which consists of a system of four equations, presented below, describing the relationship between the level of unemployment, the rate of

inflation, the nominal interest rate of the central bank, and the exchange rate depreciation (Shekel vs. basket). The data are quarterly and the estimation of the model refers to the period between 1990 and 1999.

$$U_t = \lambda_1 DP_t + \lambda_2 i_t + \lambda_3 \dot{e}_t + \sum_{i=1}^{k} a_{11}^i U_{t-i} + \sum_{i=1}^{k} a_{12}^i DP_{t-i} + \sum_{i=1}^{k} a_{13}^i i_{t-i} + \sum_{i=1}^{k} a_{14}^i \dot{e}_{t-i} + \varepsilon_t^s \tag{1.1}$$

$$DP_t = \delta_1 U_t + \delta_2 i_t + \delta_3 \dot{e}_t + \sum_{i=1}^{k} a_{21}^i U_{t-i} + \sum_{i=1}^{k} a_{22}^i DP_{t-i} + \sum_{i=1}^{k} a_{23}^i i_{t-i} + \sum_{i=1}^{k} a_{24}^i \dot{e}_{t-i} + \varepsilon_t^d \tag{1.2}$$

$$i_t = \theta_1 U_t + \theta_2 DP_t + \theta_3 \dot{e}_t + \sum_{i=1}^{k} a_{31}^i U_{t-i} + \sum_{i=1}^{k} a_{32}^i DP_{t-i} + \sum_{i=1}^{k} a_{33}^i i_{t-i} + \sum_{i=1}^{k} a_{34}^i \dot{e}_{t-i} + \varepsilon_t^i \tag{1.3}$$

$$\dot{e}_t = \eta_1 U_t + \eta_2 DP_t + \eta_3 i_t + \sum_{i=1}^{k} a_{41}^i U_{t-i} + \sum_{i=1}^{k} a_{42}^i DP_{t-i} + \sum_{i=1}^{k} a_{43}^i i_{t-i} + \sum_{i=1}^{k} a_{44}^i \dot{e}_{t-i} + \varepsilon_t^i \tag{1.4}$$

For the sake of simplicity we omit here the intercept and other exogenous variables which may appear in the system. The reduced form VAR model we have estimated does not include the coincident endogenous variables and it is described by the four following equations:

$$U_t = \sum_{i=1}^{k} b_{11}^i U_{t-i} + \sum_{i=1}^{k} b_{12}^i DP_{t-i} + \sum_{i=1}^{k} b_{13}^i i_{t-i} + \sum_{i=1}^{k} b_{14}^i \dot{e}_{t-i} + e_t^s \tag{2.1}$$

$$DP_t = \sum_{i=1}^{k} b_{21}^i U_{t-i} + \sum_{i=1}^{k} b_{22}^i DP_{t-i} + \sum_{i=1}^{k} b_{23}^i i_{t-i} + \sum_{i=1}^{k} b_{24}^i \dot{e}_{t-i} + e_t^d \tag{2.2}$$

$$i_t = \sum_{i=1}^{k} b_{31}^i U_{t-i} + \sum_{i=1}^{k} b_{32}^i DP_{t-i} + \sum_{i=1}^{k} b_{33}^i i_{t-i} + \sum_{i=1}^{k} b_{34}^i \dot{e}_{t-i} + e_t^i \tag{2.3}$$

$$\dot{e}_t = \sum_{i=1}^{k} b_{41}^i U_{t-i} + \sum_{i=1}^{k} b_{42}^i DP_{t-i} + \sum_{i=1}^{k} b_{43}^i i_{t-i} + \sum_{i=1}^{k} b_{44}^i \dot{e}_{t-i} + e_t^i \tag{2.4}$$

It is worth noting that the coefficients of the lagged variables in the structural model, a ,are different from the coefficients, b ,of the lagged variables in the reduced form VAR model. The same is true about the structural shocks, ε, in the equations of the structural model and the random error terms, *e*, in the reduced form VAR model. In the appendix we describe in some detail the methodology which allows the identification of the equation coefficients of the structural model on the basis of the

estimated coefficients of the VAR model and six additional restrictions, on which we will elaborate later on.

B. The Structural Model Equations

B.1 The Unemployment Equation

$$U_t = \lambda_1 DP_t + \lambda_2 i_t + \lambda_3 \dot{e}_t + \sum_{i=1}^{k} a_{11}^i U_{t-i} + \sum_{i=1}^{k} a_{12}^i DP_{t-i} + \sum_{i=1}^{k} a_{13}^i i_{t-i} + \sum_{i=1}^{k} a_{14}^i \dot{e}_{t-i} + \varepsilon_t^s \tag{1.1}$$

Equation (1.1) which describes the deviation of the unemployment rate from its trend may be interpreted as an inverted Phillips curve in line with the approach adopted by King and Watson (1994) and Dolado (1996). In this case the structural error term stands for a structural shock which shifts this Phillips curve (upwards or to the right) in the inflation-unemployment plane. In the context of an AS-AD model equation (1.1) stands for aggregate supply and the error term ε_t^s for a supply shock.[3]

We assume here that shocks to the BoI nominal interest rate and to the exchange rate depreciation have no coincident effects on the unemployment rate. It is possible to justify this assumption on the ground that the liquidity of the business sector and the import of raw materials is determined at the firm level in advance so that a change in their prices cannot affect output and unemployment coincidentally. This justification is not affected if we relate to equation (1.1) as an inverted Phillips curve. Our assumption is equivalent to setting the coefficients λ_2 and λ_3 in the structural unemployment equation equal to zero. These are two out of the six identification restrictions, which allow the transition from the reduced form VAR model to the structural model.

Different assumptions concerning the coefficient λ_1 allow us to differentiate between the two alternative structural models that were described briefly in the introduction. In model 1 unemployment is insensitive to contemporaneous changes in aggregate demand while in Model 2 unemployment responds to contemporaneous changes in demand so that the impact effect of these changes in demand on unemployment is the maximal possible. It may be shown that a necessary and sufficient condition for unemployment to be insensitive to contemporaneous changes in demand is that the coefficient λ_1

be equal to zero. In the case of model 2 we assumed following Dolado et al. (1996) that the parameter λ_1 is such that it maximizes the impact effect of structural demand shocks on unemployment.[4] This assumption gives the model Keynesian attributes by emphasizing the contribution of aggregate demand in the determination employment in the short run. In particular a positive demand shock is expected to raise output reducing thereby unemployment and as a result the coefficient λ_1 is expected to be negative in model 2.

B.2 The Inflation Equation

$$(1.2) \quad DP_t = \delta_1 U_t + \delta_2 i_t + \delta_3 \dot{e}_t + \sum_{i=1}^{k} a_{21}^i U_{t-i} + \sum_{i=1}^{k} a_{22}^i DP_{t-i} + \sum_{i=1}^{k} a_{23}^i i_{t-i} + \sum_{i=1}^{k} a_{24}^i \dot{e}_{t-i} + \varepsilon_t^d$$

Equation (1.2) represents an inverted aggregate demand. In the context of an AS-AD model the structural shock, ε^d_t, stands for a demand shock which shifts the aggregate demand curve upwards in the inflation unemployment plane.[5] Such a shock is reflected in model 2 in a shift of the AD curve along the unemployment curve defined in (1.1).

We assumed here that changes in the interest rate affect aggregate demand with a lag and as a result $\delta_2=0$. We also assumed that structural shocks to employment have no contemporaneous effect on aggregate demand or on inflation so that $\delta_1=0$. We assumed that aggregate demand does respond to contemporaneous changes in the depreciation of the exchange rate and as a result the coefficient δ_3 has to be different from zero. Other things constant an acceleration in the depreciation of the exchange rate implies a higher real exchange rate depreciation which enhances aggregate demand, requiring δ_3 to be positive.

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[3]The difference between the error terms in the two aforementioned interpretations is a multiplication constant. See King and Watson (1994) and footnote 5 below.

B.3 The Interest Rate Equation

$$i_t = \theta_1 U_t + \theta_2 DP_t + \theta_3 \dot{e}_t + \sum_{i=1}^{k} a_{31}^i U_{t-i} + \sum_{i=1}^{k} a_{32}^i DP_{t-i} + \sum_{i=1}^{k} a_{33}^i i_{t-i} + \sum_{i=1}^{k} a_{34}^i \dot{e}_{t-i} + \varepsilon_t^i \quad (1.3)$$

Equation (1.3) could be regarded as the reaction function of the BoI as it is perceived by the econometrician on the basis of the observed data. In this context the error term in expression (1.3) might stand for random shocks to the central bank preferences as a result, say, of a temporary change in the balance of power in the central bank board, which formulated monetary policy. [Christiano et al. (1998)]. Since in Israel such a board does not exist yet we could give the structural shock a broader interpretation as a random change in the influence that different members of the Bank's management exert on the governor regarding the formulation of monetary policy. Another way of interpreting this shock is as reflecting statistical errors in the data available to the central bank at decision making.[Bernanke and Mihov (1995)].

The inclusion of inflation and unemployment in the BoI interest rate equation is consistent to the same extent with the existence of a unique policy target, say, inflation and of a dual policy target, inflation and unemployment. It is practically impossible to identify on the basis of equation (1.3) the preferences of the central bank. The central bank's reaction, and in that matter that of the BoI, may reflect the fact that the unemployment rate appears in the bank's utility function so that when unemployment rises the central bank will tend to lower interest rates. But it is equally possible that the unemployment rate will also appear in the reaction function of the central bank even if an inflation target is the unique target of the monetary policy. The reason for this is that at a higher unemployment rate it may be possible to attain the same inflation rate with a relatively lower interest rate. Similarly, it is not clear whether the inclusion of the exchange rate depreciation in the interest rate equation reflects the fact that the central bank's utility is affected by, say, the variability of the exchange rate or whether

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[4] For this to happen λ_1 has to fulfill the first order condition for a maximum: $d\left(\frac{dU_t}{d\varepsilon_t^d}\right) / d\lambda_1 = 0$ or equivalently the condition: $d\left(\frac{de_t^s}{d\varepsilon_t^d}\right) / d\lambda_1 = 0$

the inclusion of this variable in equation (1.3) reflects the fact that the exchange rate depreciation affects inflation which constitutes the central bank's unique target. In this respect Christiano et al (1998) point out that a central bank may not relate to variables included in its so-called reaction function but their successful econometric inclusion may reflect the fact that they constitute a reliable measure of unobservable variables. As a result the coefficients of the central bank's feedback rule do not reflect its preferences or its reaction function, but its considerations as they are perceived by the econometrician. It seems therefore preferable to relate to expression (1.3) as an equation describing the evolution of the central bank interest rate rather than as a feedback rule.

We assumed that the BoI does not respond to contemporaneous changes in the unemployment rate because employment data become available with a delay of at least one quarter in Israel. As a result the structural equation coefficient θ_1 is equal to zero. This assumption constitutes our last identification restriction necessary for the identification of the two structural models. The inclusion of the other coincident endogenous variables in the interest rate equation together with the lagged values of all endogenous variables may serve as a predictor for the unemployment rate. As a result it cannot be claimed that our specification disregards, because of our assumption, statistical information concerning current economic activity indicators available to the BoI at decision making. More precisely, if expectations for U_t are formed on the basis of equation (1.1), then the contemporaneous value of U_t may not appear in the specification of the interest rate equation, while contemporaneous estimates of unemployment and of economic activity may indeed be part of the variables taken into consideration in the formulation of monetary policy. This argument warns also against a narrow interpretation of the results as reflecting the policy maker's relative preferences between inflation and real activity and it is consistent with earlier discussion on this subject.

We expect that the central bank will raise interest rates following positive demand and exchange rate depreciation shocks and that consequently coefficients θ_2 and θ_3 should be positive. This assumption is consistent with any kind of central bank targets as long as we assume that it follows a

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[5]The standard demand shock which shifts the AD curve to the left in the inflation unemployment plane is equal to ε^d/δ_1.

stabilizing policy either with respect to inflation or with respect to economic activity or vis-a-vis both of these variables.

The BoI sets its interest rate for a particular month at the end of the preceding month. In view of a fifteen days delay in the announcement of the CPI by the CBS, this interest rate setting procedure implies that the BoI has no exact information about the CPI of two out of the three months making up a particular quarter when it sets the interest rate for the last month of this quarter. We included in the interest rate equation the coincident quarterly inflation rate in spite of the fact that it is partially unobservable because information concerning many of the developments, which affect its determination, is already available both to the public and to the central bank at the time the latter sets the interest rate. Moreover this information affects the formation of inflation expectations, which serve as an input in the decision making process of the BoI, a consideration that helped also in tilting the scales in favour of the introduction of the coincident inflation rate in the interest rate equation[6].

The inclusion of the exchange rate depreciation in the interest rate equation may be justified on the ground that it may contribute to the prediction of future inflation, which affects the determination of the central bank interest rate. In this respect the contemporaneous exchange rate depreciation inclusion in (1.3) conveys some forward looking attributes to the interest rate equation.

B.4 The Exchange Rate Depreciation Equation

$$\dot{e}_t = \eta_1 U_t + \eta_2 DP_t + \eta_3 i_t + \sum_{i=1}^{k} a_{41}^{i} U_{t-i} + \sum_{i=1}^{k} a_{42}^{i} DP_{t-i} + \sum_{i=1}^{k} a_{43}^{i} i_{t-i} + \sum_{i=1}^{k} a_{44}^{i} \dot{e}_{t-i} + \varepsilon_t^{i} \tag{1.4}$$

Equation (1.4) describes the endogenous determination of the nominal exchange rate depreciation in a small and open economy like Israel. We have introduced this equation because the exchange rate plays a primary role in the determination of both the inflation rate and the level of economic activity, the latter through its short run effect on the determination of the real exchange rate. The inclusion of the exchange rate depreciation as an endogenous variable in our model is not however costless. The exchange rate regime in Israel underwent very drastic changes during the period under consideration,

starting with a fixed exchange rate before February 1989, shifting to an horizontal exchange rate band in the beginning of 1989 (30.1.89) and heavy intra-band central bank intervention, and converging to a crawling and gradually widening exchange rate band without any central bank intra-band intervention.[7] Moreover, periods of discrete devaluations in Israel were in general preceded by speculative attacks to which the BoI responded by raising interest rates. This sequence of developments tends to inverse the positive correlation between interest rates and the exchange rate appreciation, requiring also the imposition of additional restrictions identifying periods of speculative attacks. These factors constitute very important regime changes which cannot justify the assumption of stability of the coefficients during the period surveyed. Indeed the imposition of restrictions on the regression coefficients to account for these changes seems necessary to ensure that the extracted structural shocks are the true ones. This is however seriously handicapped by the relatively small number of the available observations, which limit the ability to introduce too many exogenous variables..[8] In an effort to overcome partially this problem we set the beginning of the sample period in 1990 excluding thus the first quarter of 1989, which included the discrete devaluation in January 1989, and the transition period from a fixed exchange rate policy, which had been implemented from the introduction of the stabilization plan in 1985 until January 1989, to a horizontal exchange rate band.

Shocks to the structural equation may measure unrest in foreign asset markets. However, as a result of the lack of flexibility in the specification of policy changes, we cannot exclude the possibility that the structural shocks will also include the effect of some of the exchange rate regime changes.

We assume that the exchange rate, which is determined in the financial markets, is affected without any lags by macroeconomic conditions and it is therefore affected by the coincident unemployment and interest rates and by demand conditions in the goods market.

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[6]A more prosaic reason for including this variable in the equation specification was that setting the corresponding coefficient to zero required the lifting of other restrictions. The results of this experiment led either to complex roots or to unsatisfactory estimation results

[7]The fixed exchange rate regime period was characterized by discrete devaluations with speculative attacks. Discrete devaluations did also characterize the period of the horizontal exchange band during realignments (September 1989, March 1991 and October 1991).

A negative structural shock to the supply side of the economy which is reflected in an unemployment increase is expected to be accompanied by a deterioration in the balance of payments because of a fall in exports and a parallel rise in imports leading to a nominal exchange rate depreciation. Under these conditions the coincident unemployment coefficient η_1 should be positive. The inflation coefficient η_2 measures the impact effect on the exchange rate depreciation of changes in aggregate demand. Our model specification does not differentiate between domestic demand shocks, which are expected to lead to a balance of payments deterioration, giving rise to an exchange rate depreciation, and foreign demand shocks, which are expected to improve the balance of payments conditions of the economy and induce a nominal exchange rate appreciation. It is therefore impossible to define ex-ante the sign of η_2 and we leave its determination to the estimation results. We expect changes in the BoI interest rate to be in general negatively correlated with exchange rate depreciation, in spite of the aforementioned positive correlation during periods of turmoil in the foreign exchange market. The restrictions we have imposed and the signs of the remaining free coefficients are summarized in Table 1. [9]

Table 1: The Coefficients of the Contemporaneous Endogenous Variables

The Equation		**U_t**	**DP_t**	**i_t**	**e_t**
Unemployment (Inverted Phillips Curve or AS)	U_t		$\lambda_1=0$ $\lambda_1<0$	$\lambda_2=0$	$\lambda_3=0$
Infation (AD)	DP_t	$\delta_1=0$		$\delta_2=0$	$\delta_3>0$
The Bank of Israel nominal interest rate	i_t	$\theta_1=0$	$\theta_2>0$		$\theta_3>0$
The Exchange Rate Depreciation	e_t	$\eta_1>0$	$\eta_2?$	$\eta_3<0$	

[8] An attempt to introduce a dummy variable after February 1996 when the BoI discontinued its intervention inside the exchange rate band was not successful. For a discussion on the introduction of additional exogenous variables in the estimation process see following section.

[9] Our choice of the identification restrictions, which appear in Table 1 reflects the combination which gave rise to the most sensible estimation results from the economic point of view.

III. The Data and the Estimation Results

A. The Data

The system we estimated is described by the equations (2.1)-(2.4) and the estimation results appear in Table III.A in Appendix III. The estimation was based on quarterly data from the beginning of 1990 to the end of 1999, a total of 40 observations. The unemployment data are seasonally adjusted data of the Israeli CBS. Following statistical tests we found that the unemployment rate is an I(1) variable in contrast to the rest of the variables which are I(0) variables. In order to establish the same degree of integration for the unemployment rate with the other endogenous variables we detrended the unemployment data using the HP filter (Diagrams 1 and 2). The HP filter serves as a proxy for a moving average, which may be considered as providing a measure for the NAIRU without loosing any observations as it would have happened had we been using a simple moving average method. This is a very important property of the HP filter as far as our estimation is concerned given the limited number of available observations.[10]

The rate of change of the consumer price index and of the exchange rate has been calculated as the change in the average quarterly level of these two variables between two consecutive quarters. The BoI interest rate we have used is the marginal interest rate on the monetary loan at the discount window. Given that the estimated equations did not all contain the same number of lagged variables we used the SUR method for the estimation of our VAR model.

As a result of the limited number of observations and of the degrees of freedom we economized on the number of lagged variables in each of the estimated equations. The lag length was chosen on the basis of the nature of the estimated variable and of the estimation results. The longest lags were four-quarter lags. In the unemployment equation all the endogenous variables appear with four lags. In the aggregate demand (inflation) equation all endogenous variables appear with three lags besides the exchange rate depreciation which appears with two lags only. In the BoI nominal interest

rate equation we have included only two lags of the endogenous variables and in the exchange rate depreciation equation we have included three lagged values of the endogenous variables.

The lag structure in the estimated VAR model and the restrictions imposed on the coincident coefficients of the endogenous variables in the structural model determine the lag structure of the structural model. This is characterized by four lagged values of the endogenous variables in the unemployment and the exchange rate devaluation equation and by three lags in the other two equations.

B. The Exogenous Variables[11]

We have also introduced in three out of the four estimated equations some exogenous variables. In the *unemployment equation* we introduced two exogenous variables: The flow of new immigrants, a population characterized by a higher unemployment rate during the sample period than the non-immigrant population, with a two and three quarters lag, and foreign workers, including workers from the occupied territories, with a three and four quarters lag, expecting to grasp in this way a possible substitution effect.[12] In the *Aggregate Demand* equation we included seven exogenous variables, four our of which are dummy variables. The dummy variables include one seasonal dummy variable for the second quarter because of the seasonality of the CPI, which tends to rise above average during this period. Two additional dummy variables were used so as to account for the lower inflation plateau after 1991 and after 1997. The fourth seasonal dummy was introduced to differentiate between the last quarter of 1998 and the remaining observations to account for the turmoil in the foreign exchange market the substantial exchange rate depreciation and the relatively high inflation during this period.

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[10]There is no considerable difference in the results for different values of the smoothing parameter (1000,1600 or 5000) in the HP filter. The results reported here have been based on a snoothing parameter of 1600.

[11]The exogenous variables were introduced in our model through the reduced form VAR equations. As a result these exogenous variables appear also in the specification of all four structural equations. This is due to the fact of not imposing additional restrictions, which would have limited the inclusion of the exogenous variables in the structural equations that correspond to the reduced form equations in whose estimation we included these exogenous variables.

[12]The influence of the new immigrants on unemployment is partly reflected in the detrended unemployment rate. Similarly to the unemployment data we also detrended the number of foreign workers using an HP filter. This deterending is justified, among others, by the fact that the unemployment data have been also detrended. The inclusion of this variable improved substantially the fit of the model and the results of the dynamic simulation.

The fifth exogenous variable we introduced in this equation is the rate of change of the dollar price of consumption good imports. A rise in the dollar prices of the imported consumption goods, is reflected, other things equal, in a real exchange rate depreciation supporting the expansion of exports and the contraction of imports. The high correlation coefficient between the rate of change of the dollar import prices and the dollar export prices (some 75 percent) implies that the inclusion of this exogenous variable in the aggregate demand equation accounts, in general, for the effect of changes in the price of tradable goods on aggregate demand (or on the inflation rate). The sixth exogenous variable we included in the estimation of the aggregate demand equation is the share of the government civil expenditure in GDP which is expected to be positively correlated, ceteris paribus, with aggregate demand and hence with the inflation rate. The seventh exogenous variable included in this equation is the inflow of new immigrants' with the same specification we used in the Unemployment (AS) equation. The economic rationale behind the introduction of this variable in the AD equation specification is that a rise in the inflow of new immigrants is expected to lead, ceteris paribus, to an increase in aggregate demand, particularly, in demand for non-tradables. In the *exchange rate depreciation equation* we included three exogenous variables, a dummy variable for the last quarter of 1998 for the aforementioned reasons, the nominal interest rate on foreign currency and the flow of foreign direct investment lagged by one quarter. The interest rate on foreign currency we included is the weighted three-month Libor interest rate on the currencies constituting the currency basket in Israel. We decided to introduce the dummy variable for the last quarter of 1998, which was characterized by an extreme and rather discrete exchange rate depreciation, so as to neutralize the effect this extreme depreciation could have on the estimation of the coefficients of the other variables in this equation. The interest rate on foreign currency was introduced to account for the fact that it is the interest rate differential between domestic and foreign interest rates which affects capital flows and thereby the nominal exchange rate depreciation and not the absolute level of the domestic nominal interest rates. The flow of foreign direct investment was introduced because capital flows of which FDI constitutes a substantial component affect exchange rate depreciation but they are not affected by the interest rate spread between domestic and foreign currency, which has been already included in the equation specification.

C. The Estimation Results

In this part we present the estimation results and examine the dynamic evolution of the estimated system through a dynamic simulation, and an Impulse Response Function (IRF) analysis. While the latter allows the evaluation of the effect of a given shock on the endogenous variables of the estimated model the Variance Decomposition analysis, which we also performed, permits to evaluate the effect of a particular shock relatively to other structural shocks on the evolution of a single endogenous variable at different time horizons. This is achieved by focusing on the contribution of a given structural shock to the variability of a particular endogenous variable. Both of the two latter exercises are standard procedure in the analysis of the estimation results of VAR models and are part of statistical PC packages. However standard VAR estimation procedure and structural model identification in these packages and the IRF analysis as well as the Variance Decomposition assume recursiveness - i.e the Choleski Decomposition - which implies that the matrix of the coefficients of the contemporaneous endogenous variables in the structural model is triangular. In this context the ordering of the equations in the estimation process is essential since it implies different assumptions concerning the coefficients of the contemporaneous endogenous variables. In our estimation we have not assumed recursiveness and the same lags for all equations and as a result we had to program both the impulse response function and the variance decomposition (see Appendix II).[13]

C.1 The Coefficients of the Contemporaneous Variables

The estimation results indicate that the sign of the coefficients of the contemporaneous variables of the structural model are in the expected direction. Moreover the coefficient of the inflation rate in the exchange rate depreciation equation, η_2, is negative. This may suggest that structural aggregate demand shocks during the period surveyed originated mainly in shocks to the demand for exports.[14]

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[13] At this stage we do not report confidence intervals for the impulse response function, whose complicated calculation has not allowed us yet to obtain definite results in this direction. The identification of the structural model was made on the basis of our assumptions and by solving simultaneously a six equation system with six unknown variables in line with expression (I.6) in Appendix I, using the mathematical package Mathematica to reach the exact solutions. An alternative statistical package (RATS) allows the identification of any kind of structural model using the maximum likelihood approach. We used this program to test for the robustness of our estimation results. It transpired that the estimation results were highly dependent on the initial values on which the convergence of the coefficient estimation was based.

[14] In order to distinguish between shocks to domestic demand and shocks related to foreign demand we also included in the estimation the change in the volume of international trade and its deviation from its trend, but the results were insignificant or had the wrong sign.

Table 2: The Coefficients of the Contemporaneous Endogenous Variables

The Equation	The Coefficients		Model 1	Model 2
Unemployment	Inflation Rate	λ_1	0	-0.249
	The BoI Nominal Interest Rate	λ_2	0	0
	Exchange Rate Depreciation	λ_3	0	0
Aggregate Demand	Unemployment Rate	δ_1	0	0
	The BoI Nominal Interest Rate	δ_2	0	0
	Exchange Rate Depreciation	δ_3	0.214	0.708
BoI Nominal Interest Rate	Unemployment Rate	θ_1	0	0
	Inflation Rate	θ_2	0.135	0.134
	Exchange Rate Depreciation	θ_3	0.386	0.369
Exchange Rate Depreciation	Unemployment Rate	η_1	1.938	2.777
	Inflation Rate	η_2	-2.076	-2.952
	The BoI Nominal Interest Rate	η_3	-0.054	-0.054

Because of the limited number of available observations and degrees of freedom it was practically impossible to test the robustness of the estimated coefficients. As a result we evaluated the stability of our model using an alternative approach, that of dynamic simulation. According to this methodology the lagged values of the endogenous variables are those derived from the model and they are used to provide a solution for the current values of the endogenous variables. Divergence of the dynamic solution of the model from the actual values of the endogenous variables would imply that our model is not robust. This was not however the case. The results of both the static and the dynamic simulation trace in a satisfactory manner the actual evolution of the endogenous variables (Diagram 3) and we may as a result deduce that we have not omitted in the specification of our model basic explanatory variables. The estimation residuals were tested and were found to be white noise.

C.2 The Impulse Response Function

The impulse response function analysis of the structural model is presented graphically in diagrams 4-7. The contemporenuos effect of the structural shocks on the endogenous variables is presented in Table III.B in Appendix III. The diagrams and the table also include the evolution of the real interest rate. These are derived from a combination of the impulse response function of the nominal interest rate and the inflation rate to different structural shocks. This exercise allows us to trace the transmission mechanism of various structural shocks to our model's endogenous variables and in particular the transmission mechanism of monetary policy. The impulse response function results are in general similar in both models with the exception of the response of unemployment to exchange rate depreciation random disturbances.

The impulse response to *unemployment shocks (AS shocks)* appears in diagram 4. An unemployment augmenting structural shock, which is qualitatively equivalent to a negative supply shock leads on impact to higher unemployment and to an exchange rate depreciation, which induces inflationary pressures. The nominal exchange rate depreciation following this shock may reflect the deterioration in the current account implied in a negative supply shock. The transmission of the supply shock to prices only through the exchange rate channel arises from our identification restriction according to which shocks to unemployment have no coincident effect on aggregate demand and hence on inflation. The exchange rate depreciation and the inflationary pressures on impact are consistent with a rise in the BoI interest rate, in view of the fact that unemployment does not affect on impact the BoI nominal interest rate This rise in the interest rate is not however commensurate to the inflation acceleration and gives rise to a ex-post fall in the real interest rate. The rise in inflation is moderate relatively to the exchange rate depreciation, since it is brought about by the latter, and as a result the structural negative supply shock leads initially to a real exchange rate depreciation.

Following the impact effect of the shock the rise in unemployment weakens aggregate demand and inflationary pressures supporting thus lower nominal interest rates. Convergence to long run equilibrium is characterized in this case by a gradual rise in the interest rate as the inflation rate rises and unemployment falls to their equilibrium level.

The impact effect of *demand shocks* (diagram 5) is different in the two structural models in line with our assumption concerning the inflation coefficient, λ_1 ,in the unemployment equation. We assumed that this parameter is equal to zero in model 1 so that a demand augmenting shock affects on impact only the inflation rate without having any effect on real activity and hence on the unemployment rate. The supply response on impact to such a shock in model 2 is reflected in an increase in real activity and a fall in unemployment, which is accompanied by a relatively moderate rise in prices. The demand shock is followed by a nominal exchange rate appreciation. This is due to the negative sign of the inflation coefficient, η_2, in the exchange rate depreciation structural equation, which implies that demand random disturbances during the period surveyed reflected mainly shocks to exports. Given the relative size of the inflation and exchange rate depreciation coefficients in the structural interest rate equation, the nominal exchange rate appreciation allows on impact for a lower nominal interest rate in spite the rise in inflation. However as inflation remains higher and unemployment deviates downwards from its trend the nominal interest rate rises in both models subsequently to the shock. In spite of the difference between the two models on impact, the evolution of the endogenous variables and their convergence to equilibrium is nevertheless similar and it is oscillatory as far as the nominal, the real interest and the inflation rates are concerned, being characterized by a gradual reduction in the central bank nominal interest rate and a rise in unemployment to their equilibrium level.

Interest Rate Shocks: In line with the identification restrictions we imposed on the estimated structural models the transmission of the shock to the rest of the economy on impact is based on the exchange rate channel. (diagram 6). An unexpected interest rate increase leads to an exchange rate appreciation in both models. However the supply side of the economy does not respond on impact to the exchange rate appreciation in model 1 either directly (λ_3=0) or indirectly through the effect of the latter on aggregate demand (λ_1=0). As a result the unexpected change in the interest rate does not have any impact effect on economic activity as the latter is measured by the unemployment rate. In contrast to model 1, in model 2 a positive interest rate shock affects economic activity and unemployment on impact through the exchange rate appreciation effect on aggregate demand ($\lambda_1 \neq 0$). However, in view

of the relatively small size of the nominal interest rate coefficient in the exchange rate depreciation equation, the impact effect of a positive interest rate shock on the nominal exchange rate and through it on aggregate demand and economic activity is limited. As a result the ex-post response of the two models to interest rate shocks appears to be the same even though the transmission mechanism is substantially different between the two models. As a result the subsequent evolution of the economy is identical in both models.

The interest rate effect on the nominal interest rate is magnified in the subsequent periods during which the higher interest rate affects the unemployment rate directly and indirectly through the lagged effect of the exchange rate appreciation. These developments are accompanied by a weakening of the inflationary pressures which suggests that the contraction effect of an unexpected tightening of the monetary policy through an exchange rate appreciation is transmitted to a large extent by the effect of the later on aggregate demand. This result differs from the results on other economies in which prices react to monetary policy shocks with some delay [Vinals and Valles (1999)]. Our result arises from the relatively quick response of the exchange rate to changes in monetary policy on the one hand and the relative small delay in the transmission of this response into aggregate demand on the other, both characteristics of a small and open economy like Israel. Moreover the convergence of inflation to its original pre-shock level does lag behind that of economic activity (unemployment) and it fast relative to other countries .[15] The convergence process to long run equilibrium is characterized by a fall in the nominal and in the real interest rate and a nominal exchange rate depreciation. .

Exchange Rate Depreciation Shocks (diagram 7): In this case the difference in the evolution between the two models following an unexpected increase in the rate of exchange rate depreciation stands out. In both models such a shock is reflected on impact in a rise in inflation because of the aggregate demand expansion induced by the shock. While in model 1 economic activity is not affected by the shock ($\lambda_1 = \lambda_2 = 0$), in Model 2 the exchange rate depreciation shock is followed by an expansion in economic activity and hence by a fall in unemployment. The nominal interest rate rises on impact

[15] It takes eight quarters for unemployment to converge to its original level in contrast to other countries in which the process is longer, between eight and twelve quarters.

because of the exchange rate depreciation and the inflationary pressures leading to a slow down in economic activity and a rise in unemployment in the following period. In model 2 on the other hand the contraction effect of the interest rate increase is reflected in a slow down of economic activity but from the higher level it attained following the depreciation shock. As a result the convergence process of the economy to its long run equilibrium is characterized by a gradual rise in economic activity and a fall in unemployment in model 1 and by a a gradual slow down in economic activity from its higher levels in model 2.

C.3 The Variance Decomposition

The Variance decomposition results for the two estimated structural models are presented in Table 4 below:

Table 4

The Unemployment Equation (AS)								
Number of quarters since the shock	Supply Shock		Demand Shock		Interest Rate Shock		Depreciation Shock	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	1.000	0.927	0.000	0.043	0.000	0.001	0.000	0.030
3	0.976	0.858	0.013	0.087	0.028	0.030	0.005	0.051
20	0.921	0.819	0.038	0.138	0.023	0.026	0.017	0.018
The Inflation Equation (AD)								
	Supply Shock		Demand Shock		Interest Rate Shock		Depreciation Shock	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0.054	0.237	0.818	0.449	0.001	0.001	0.127	0.312
3	0.125	0.181	0.376	0.230	0.400	0.386	0.102	0.201
20	0.325	0.367	0.300	0.209	0.295	0.291	0.078	0.132
The Interest Rate Equation								
	Supply Shock		Demand Shock		Interest Rate Shock		Depreciation Shock	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0.029	0.016	0.051	0.096	0.850	0.868	0.070	0.020
3	0.028	0.039	0.156	0.160	0.746	0.752	**0.070?**	0.049
20	0.280	0.269	0.121	0.152	0.536	0.543	0.061	0.035
The Exchange Rate Depreciation Equation								
	Supply Shock		Demand Shock		Interest Rate Shock		Depreciation Shock	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0.159	0.069	0.462	0.839	0.001	0.001	0.377	0.091
3	0.128	0.049	0.452	0.772	0.077	0.085	0.342	0.093
20	0.156	0.080	0.417	0.714	0.106	0.115	0.320	0.090

The main conclusions of the variance decomposition analysis may be summarized as follows:

- The contribution of demand, interest rate and exchange rate depreciation shocks to the unemployment variability is limited and the latter is explained mainly by the supply shocks variability. Still the data suggest that there is a certain rise in the contribution of demand shocks to the unemployment variability in the long run in the context of model 2. Vinals and Valles(1999) report similar results for other economies as well with respect to economic activity in which the contribution of monetary policy shocks to output variability does not exceed the 10 percent.
- The contribution of demand shocks to the inflation variability is substantial both on impact and in the long run. The extent of the contribution of supply and interest rate shocks to the long run inflation variability is similar to that of demand shocks, the contribution of supply shocks being more pronounced.
- The variability of interest rates is mainly explained by interest rate shocks, supply shocks have a substantial long run contribution as well in the context of both of the estimated models.
- The variance decomposition results in the case of the exchange rate depreciation equation differ substantially between the two structural models similarly to the impulse response analysis. The contribution of demand shocks to the exchange rate depreciation variability is substantial in the context of model 2 in all time horizons, while in the context of model 1 exchange rate depreciation shocks contribute a substantial part too in the variability of the exchange rate depreciation. The relative contribution of interest rate and supply side shocks is limited under both structural models.

IV. The Role of Monetary Policy

We have already examined some aspects of the changes in monetary policy on the economy through the impulse response function and the variance decomposition. While the impulse response function examines the effect of a change in monetary policy on the evolution of the model's endogenous variables, the variance decomposition gives a relative measure of this effect with respect to structural shocks to other endogenous variables. In both cases the evaluation of monetary policy is made relatively to hypothetical changes in the interest rate. However an valuation of the monetary policy

should also refer to its contribution to the actual evolution of endogenous variables during the surveyed period. To achieve this we calculated estimates of the actual structural shocks, which impinged upon the Israeli economy during the surveyed period on the basis of the model residuals and we identified their contribution to the evolution of the endogenous variables. In this section we shall also report the results of a hypothetical permanent interest rate shock. The role of this exercise is to highlight the transmission mechanism of the monetary policy and not to provide an answer to the question of how is the economy expected to behave following a permanent increase in the interest rate, since such an exercise is liable, and rightly so, to Lucas critique. A protracted monetary tightening which is perceived both by the public and the government as credible could lead, for instance, to changes inducing a fall in the steady state inflation (a dummy in the intercept) and a return of unemployment to its long run level.

In order to evaluate the contribution of the actual monetary policy shocks to the evolution of the economy during the period surveyed we retrieved the structural shocks to all four equations of the structural model based on the estimation residuals and expression (I.4) in Appendix I. The effect of structural shocks in general, and of interest rate shocks in particular, on the dynamic evolution of our model, is measured by the difference between the results of a dynamic simulation containing the retrieved shocks and the results of an unperturbed dynamic simulation.[16]

An important conclusion we reach following this exercise is that the contribution of the derived actual structural shocks to the evolution of unemployment is different under the two estimated structural models (Diagram8). The analysis of the contribution of the different structural shocks to the deviation of unemployment from its unperturbed path (Diagram 9) suggests that the fall in unemployment between 1994 and 1997, below the level foreseen by the model, and the rise in the rate of unemployment in 1998, beyond that implied by our model, were mainly due to structural supply shocks in the context of model 1. In the context of model 2 the contribution of demand and interest

[16] The results of this exercise are identical to the results obtained by comparing the actual evolution of the endogenous variables to the dynamic simulation results obtained when all derived actual shocks are included in the simulation with the exception of the shocks whose contribution we wish to evaluate.

rate shocks is substantial relatively to model 1 but still the contribution of supply shocks is the major one.

More precisely the results suggest that the Israeli economy experienced between the years 1993 and 1995 interest rate and demand shocks which contributed to the fall in unemployment (especially under model 2) while after 1995 interest rate shocks contributed to a rise in unemployment together with demand shocks (after 1997). The latter may reflect the crises in the international markets in 1997 and 1998, which led to a lower rate of international trade expansion. Indeed the international trade expansion fell from an annual average of 8.7 percent between 1995 and 1997 to 3.7 percent per annum between 1995 and 1997, which most probably affected adversely demand for Israeli exports. This interpretation of the facts is also consistent with the negative sign of the inflation coefficient η_2 in the exchange rate depreciation structural equation, as a result of which we interpreted aggregate demand shocks as random disturbances to the demand for exports.

It is interesting to note the positive correlation between the unemployment and the real interest rate deviations from their long run equilibrium level following a shock in the nominal interest rate (diagram 8). The aforementioned deviations of the real interest rate were observed in periods during which monetary policy was considered as particularly lax (1993-94) and tight (1997-1999).[17]

Our inclusion in the AD equation of two dummy variables after the second half of 1991 and after the end of 1997 which are supposed to account for the transition of the israeli economy to lower inflation plateaux prevents us from evaluating the contribution of the derived monetary policy shocks , or the changes in the monetary stance, to this transition.

In spite of the reservations expressed above we also examined the effect of a permanent interest rate increase on inflation and on the unemployment rate. The results of this exercise (diagram 10) are not surprising and indicate that the transmission mechanism of the monetary policy is such that an unexpected tightening of monetary policy lowers inflation and raises the unemployment rate. The rise in unemployment is relatively more limited in the context of model 1 than in the context of model

[17] It is possible that these deviations reflect changes in the monetary policy stance compared to the average interest rate behaviour reflected in the interest rate structural equation as a result of its mispecification. Such an interpretation of facts does not however affect our characterization of the monetary policy during the two aforementioned periods.

2 in which economic activity and hence unemployment respond on impact to changes in aggregate demand.

5. Conclusions

We presented in this paper a structural VAR four-equation model of the Israeli economy during the last decade. These four equations model unemployment (deviations from the unemployment trend), the inflation rate (Aggregate Demand), the BoI nominal interest rate and the nominal exchange rate depreciation of the Israeli shekel relatively to the currency basket. We included the exchange rate depreciation equation in our model in spite of the drastic changes, which characterized the foreign exchange market and the exchange rate regime during the period surveyed and suggest that the risks of mispecification are high. This is especially true in view of our inability to account for the changes in the exchange rate regime because of the small number of observations. We followed this approach because of the importance of the exchange rate channel in the transmission mechanism of the monetary policy in a small and open economy like that of Israel. The identification of the structural model is based on the estimation results of its reduced form VAR model, which does also include some exogenous variables, and on the imposition of restrictions on the coefficients of the structural model. On the basis of these identification restrictions we have differentiated between two different models. In the first model the supply does not respond simultaneously to changes in aggregate demand while in the second model, which has a Keynesian flavour, there is a supply response such that it maximizes the effect of demand shocks on output and hence on unemployment.

The estimation results of the reduced form VAR model attest to the model's ability to reproduce the major changes which characterized the evolution of the endogenous variables during the period surveyed both in the context of a static (one period ahead) and of a dynamic simulation.

- According to our findings monetary policy shocks reflected in an interest rate increase induce a rise in unemployment, because of aggregate demand contraction, and a slow down in the inflation rate. However, in view of the relatively small size of the nominal interest rate coefficient in the exchange rate depreciation equation, the impact effect of a positive interest rate shock on the nominal exchange rate and through it on aggregate demand and economic activity is limited so

that ex-post the response of the two models to interest rate shocks appears to be the same even though the transmission mechanism is substantially different between the two models.

- Prices respond quite fast to changes in the monetary policy and do not lag behind changes in unemployment. This is mainly due to the quick response of the exchange rate to monetary policy shocks, on the one hand, and to the short lags with which changes in the exchange rate affect prices through their effect on aggregate demand and aggregate supply. This is a common feature of small and open economies like Israel, which is not shared by large and relatively closed economies in which the transmission process of changes in the exchange rate to prices is, according to empirical findings, relatively slow.
- In our estimation of the aggregate demand-inflation equation we have included two dummy variables which account for the transition of the Israeli economy to lower inflation plateaux in the second half of 1991 and at the end of 1997. As a result the effect of the actual structural interest rate shocks, we retrieved from the observed estimation residuals, on the inflation rate can only reflect inflation fluctuations around a given inflation plateau and cannot enhance our understanding of the contribution of monetary policy to the transition of the Israeli economy to lower inflation levels.
- In spite of the effect of monetary policy shocks on unemployment and inflation their relative contribution in explaining the variability of these two variables is limited in both of the structural models we estimated. These results are in line with empirical findings on other economies. Moreover our estimation results suggest that supply shocks constitute the main sources of unemployment variability both in the short and in the long run.
- Monetary policy shocks do not constitute an important source of inflation variability in the short run. The importance of such shocks as sources of inflation variability in the medium and in the long run increases and is similar to that of demand shocks, which constitute the major source of inflation variability in the short run, and of supply shocks.
- Analysis of the contribution of the retrieved actual structural shocks, which impinged upon the Israeli economy during the period surveyed suggests that the deviation of employment from its

equilibrium level can be mainly attributed to supply shocks. Nevertheless monetary policy and demand shocks did also contribute, in the context of model 2, to the higher employment between 1993 and 1995 and to the higher unemployment between 1996 and 1999.

- An exchange rate depreciation shock leads to different outcomes in the two estimated structural models. In the context of model 1 the shock is reflected in a substantial exchange rate depreciation inducing an interest rate rise by the BoI which adversely affects economic activity leading in the subsequent stage to a rise in unemployment.

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Appendix I

The structural system of equations (1.1) to (1.4) may be written in matrix form, after shifting all endogenous variables to the LHS, as follows:

(I.1) $a_o X_t = A(L)X_t + \varepsilon_t$, where

$$a_0 = \begin{pmatrix} 1 & -\lambda_1 & -\lambda_2 & -\lambda_3 \\ -\delta_1 & 1 & -\delta_2 & -\delta_3 \\ -\theta_1 & -\theta_2 & 1 & -\theta_3 \\ -\eta_1 & -\eta_2 & -\eta_3 & 1 \end{pmatrix} \quad A(L) = \begin{pmatrix} a_{11}^1 L_1 & a_{11}^k L_k \; a_{12}^1 L_1 & a_{12}^k L_k & a_{13}^k L_k & a_{14}^k L_k \\ a_{21}^1 L_1 & a_{21}^k L_k \; a_{22}^1 L_1 & a_{22}^k L_k & a_{23}^k L_k & a_{24}^k L_k \\ a_{31}^1 L_1 & a_{31}^k L_k \; a_{32}^1 L_1 & a_{32}^k L_k & a_{33}^k L_k & a_{34}^k L_k \\ a_{41}^1 L_1 & a_{41}^k L_k \; a_{42}^1 L_1 & a_{42}^k L_k & a_{43}^k L_k & a_{44}^k L_k \end{pmatrix}$$

and

$$X = \begin{pmatrix} U_t \\ DP_t \\ i_t \\ \dot{e}_t \end{pmatrix} \quad \varepsilon_t = \begin{pmatrix} \varepsilon_t^s \\ \varepsilon_t^d \\ \varepsilon_t^i \\ \varepsilon_t^e \end{pmatrix} \quad \varepsilon_t . \varepsilon_t ' = \Omega = \begin{pmatrix} \sigma_1 & 0 & 0 & 0 \\ 0 & \sigma_2 & 0 & 0 \\ 0 & 0 & \sigma_3 & 0 \\ 0 & 0 & 0 & \sigma_4 \end{pmatrix}$$

In the above expressions L is the lag operator and k measures the lag length. The structural error terms are assumed to be orthogonal so that the variance-covariance matrix of the structural shocks, Ω, is diagonal. The matrix *A(L)* is the matrix of the coefficients of the lagged variables in the structural model. The matrix a_o is the coefficient matrix of the coincident endogenous variables in the structural model. The full identification of the structural model (I.1) requires the full identification of these two matrices *A(L)* and a_o**.** In contrast to the structural model specified above, the estimated VAR model in expressions (2.1)-(2.4) in the main text includes only lagged variables and may be expressed in matrix form as follows:

(I.2) $X_t = B(L)X_t + e_t$;

$$B(L) = \begin{pmatrix} b_{11}^1 L_1 & b_{11}^k L_k \; b_{12}^1 L_1 & b_{12}^k L_k & b_{13}^k L_k & b_{14}^k L_k \\ b_{21}^1 L_1 & b_{21}^k L_k \; b_{22}^1 L_1 & b_{22}^k L_k & b_{23}^k L_k & b_{24}^k L_k \\ b_{31}^1 L_1 & b_{31}^k L_k \; b_{32}^1 L_1 & b_{32}^k L_k & b_{33}^k L_k & b_{34}^k L_k \\ b_{41}^1 L_1 & b_{41}^k L_k \; b_{42}^1 L_1 & b_{42}^k L_k & b_{43}^k L_k & b_{44}^k L_k \end{pmatrix} \quad e = \begin{pmatrix} e_t^s \\ e_t^d \\ e_t^i \\ e_t^e \end{pmatrix}$$

The estimated regressor coefficient matrix and the regression residuals serve as estimates for matrix B(L) and the error terms e^s, e^d , e^i and e^e for the unemployment, inflation, interest and exchange rate depreciation equations in (I.2). By inspection of equations (I.2) and (I.3) above we may easily deduce that:

(I.3) $a_o B(L) = A(L)$,

and that:

(I.4) $a_o e_t = \varepsilon_t$.

It is clear from expressions (I.3) and (I.4.) that once the VAR model in (I.2) has been estimated providing an estimate for *B(L)*, then the identification of matrix a_0 allows the complete identification of the structural model. The identification of matrix a_0 does also allow to form estimates, in line with (I.4), for the structural shocks of the model, ε_t, which are not observable, from the regression residuals, which are observable, and serve as estimates for the error terms e_t in (I.4). This expression does also imply that:

(I.5) $Var(\varepsilon_t) = \varepsilon_t \varepsilon_t' = \Omega = a_0 e_t e_t' a_0' = a_0 W a_0'$

or, in a more explicit manner, that:

(I.6)

$$\begin{pmatrix} \sigma_1^2 & 0 & 0 & 0 \\ 0 & \sigma_2^2 & 0 & 0 \\ 0 & 0 & \sigma_3^2 & 0 \\ 0 & 0 & 0 & \sigma_4^2 \end{pmatrix} = \begin{pmatrix} 1 & -\lambda_1 & -\lambda_2 & -\lambda_3 \\ -\delta_1 & 1 & -\delta_2 & -\delta_3 \\ -\theta_1 & -\theta_2 & 1 & -\theta_3 \\ -\eta_1 & -\eta_2 & -\eta_3 & 1 \end{pmatrix} \begin{pmatrix} w_{11} & w_{12} & w_{13} & w_{14} \\ w_{12} & w_{22} & w_{23} & w_{24} \\ w_{13} & w_{23} & w_{33} & w_{34} \\ w_{14} & w_{24} & w_{34} & w_{44} \end{pmatrix} \begin{pmatrix} 1 & -\delta_1 & -\theta_1 & -\eta_1 \\ -\lambda_1 & 1 & -\theta_2 & -\eta_2 \\ -\lambda_2 & -\delta_2 & 1 & -\eta_3 \\ -\lambda_3 & -\delta_3 & -\theta_3 & 1 \end{pmatrix}$$

The exact identification of matrix a_0 and of the diagonal elements of matrix Ω requires solving (I.6), given that the estimate for the symmetric variance-covariance matrix of the error terms, e_t, W, is known. This system of equations includes sixteen unknown parameters (twelve parameters of the a_0 matrix and the 4 variance elements of Ω), and only ten independent equations in view of the symmetric variance-covariance matrices W and Ω. Six additional equations in the form of exogenously imposed restrictions on elements of matrix a_0 are therefore required. Expression (I.6)

does also imply that, it is possible to obtain from the same VAR model different structural models based on different identification restrictions.[18]

Appendix II

A. The Impulse Response Function

The impulse response function of the estimated system of equations as well as the Variance decomposition are based on the MA representation of a VAR model. This representation may be written in general form as follows:

(II.1.A) $$X_t = \sum_{i=0}^{\infty} C_i e_{t-i},$$

where C_i is a 4X4 matrix of the estimated VAR model error term coefficients e_{t-i}. The AR representation of the model in matrix notation is given by expression (II.2.A) below:

(II.2.A) $$X_t = \sum_{i=1}^{k} B_i X_{t-i} + e_t ,$$

where X_t is the four-row vector of the endogenous variables including the unemployment, the inflation, the interest rates, and the exchange rate depreciation. B_i is a 4x4 matrix of the estimated coefficients of the i^{th} lag, the lag length being equal to k. The error term vector of the estimated reduced form VAR model is given by e_t.

By substituting equation (II.1.A) into equation (II.2.A), we get:

(II.3.A) $$\sum_{i=0}^{\infty} C_i e_{t-i} = B_1 \sum_{i=0}^{\infty} C_i e_{t-i-1} + B_2 \sum_{i=0}^{\infty} C_i e_{t-i-2} + ... + B_k \sum_{i=0}^{\infty} C_i e_{t-i-k} + e_t$$

rearranging (II.3.A) yields:

(II.4.A) $$(C_0 - I)e_t + (C_1 - B_1 C_0)e_{t-1} + (C_2 - B_1 C_1 - B_2 C_0)e_{t-2} + ... + \sum_{i=k+1}^{\infty} (C_i - \sum_{j=1}^{k} B_j C_{i-j})e_{t-i} = 0$$

[18]The Choleski decomposition consists in assuming that matrix a_0 is lower triangular so that all the elements above the diagonal are zero.

Since the error terms are in general different from zero satisfying equation (II.4.A) for any value of e_t requires that each one of the expressions in parenthesis be equal to zero. Using instead of the B_i matrices their VAR estimates we may solve recursively for C_i the system of equations (II.5.A) below:

$$C_0 = I$$
$$C_1 = B_1 C_0$$
(II.5.A) ....
$$C_i = \sum_{j=1}^{k} B_j C_{i-j} \qquad \text{for} \quad i \geq k$$

Once we have solved for C_i we may derive the MA representation of our model with respect to the structural shocks, ε_t, on the basis of (II.6.A) recognizing that the matrix a_o in (I.5) has been identified, and is therefore known, and that $a_0^{-1}\varepsilon_{t-i} = e_{t-i}$ This MA representation allows us to trace the evolution of our system following supply, demand interest and exchange rate depreciation structural shocks (Impulse Response Function).

(II.6.A) $X_t = \sum_{i=0}^{\infty} C_i a_0^{-1} \varepsilon_{t-i}$,

<u>B. The Variance Decomposition</u>

Based on the MA representation (II.6.A), and by letting $C_i a_0^{-1}$ be equal to N_i we may write the deviation of the n-periods ahead forecast $E_t(X_{t+n})$ from the actual value of X_{t+n}, as being equal to:

(II.1.B) $X_{t+n} - E_t(X_{t+n}) = \sum_{i=0}^{n} N_i \varepsilon_{t+n-i}$, or more explicitly equal to:

(II.2.B) $X_{t+n} - E_t(X_{t+n}) = \sum_{i=0}^{n} N_i^U \varepsilon_{t+n-i}^s + \sum_{i=0}^{n} N_i^{DP} \varepsilon_{t+n-i}^d + \sum_{i=0}^{n} N_i^i \varepsilon_{t+n-i}^i + \sum_{i=0}^{n} N_i^e \varepsilon_{t+n-i}^e$.

In (II.2.B) N_i^U, N_i^{DP},N_i^i N_i^e are the column vectors of matrix N_i. The ε's in the above equation are the error terms of the unemployment, inflation and interest rate structural equations (1.1)-(1.4). Therefore, the vector of variances of the n-period forward estimation of the vector X may be written as a sum of four components in view of the orthogonality assumption among the four structural error terms ε^s,ε^d , ε^i and ε^e:

(II.3.B) $Var(X_{t+n} - E_t(X_{t+n})) = \sigma_1^2 \sum_{i=0}^{n} (N_i^U)^2 + \sigma_2^2 \sum_{i=0}^{n} (N_i^{DP})^2 + \sigma_3^2 \sum_{i=0}^{n} (N_i^i)^2 + \sigma_4^2 \sum_{i=0}^{n} (N_i^e)^2$.

$\sigma_1^2, \sigma_2^2, \sigma_3^2$ and σ_4^2 are the corresponding variances of the structural error terms in expression (I.6) in Appendix I. The variance decomposition consists in calculating the weight of each of the three variance components in equation (II.3.B) in the total variance as i, the forecast horizon, increases.

Appendix III

Table III.A: The Estimation Results of the VAR model 1990-1999.

	U	DP	i	De
U(-1)	**0.749**	**0.675**	0.020	0.276
U(-2)	-0.198	-0.456	**-0.691**	0.413
U(-3)	**0.332**	**-0.982**		-0.119
U(-4)	-0.133			
DP(-1)	-0.038	**-0.292**	**0.989**	0.114
DP(-2)	-0.063	0.136	**-0.340**	0.023
DP(-3)	-0.047	**-0.199**		-0.027
DP(-4)	**0.118**			
i(-1)	0.056	**-0.391**	**0.509**	**-0.422** #
i(-2)	-0.029	0.051	-0.114	-0.041#
i(-3)	-0.020	**-0.217**		0.026#
i(-4)	0.041			
De(-1)	0.006	**0.089**	**-0.200**	**-0.568**
De(-2)	0.039	**-0.093**	**0.166**	**-0.389**
De(-3)	**0.068**			-0.010
De(-4)	0.006			
Constant	-1.185	3.619	**6.498**	**8.105**
Dolim23	**0.010**	**0.009**		
Efor_terr34	**$1.1*10^{-5}$**			
DQ2		**0.578**		
D913aft		**-2.109**		
D973aft		**-2.208**		
D98q4		**4.251**		**11.64**
Ggdp		**0.312**		
Dpim		**0.132**		
FDI(-1)				**-0.003**
i*(-1)				**-2.663**
i*(-2)				**4.350**
i*(-3)				**-1.804**
Adj. R^2	*0.815*	*0.877*	*0.729*	*0.758*

* Characters in bold indicate statistical significance at a level of at least 10 percent.
# The explanatory variable in the exchange rate equation (all lags) is the differential between domestic and foreign interest rates.

List of Variables

U	– The deviation of unemployment from the HP trend.
DP	– Quarterly change in CPI (%).
i	– BoI marginal interest rate on the discount window (%).
De	– rate of change of the nominal exchange rate of the basket vs. Shekel (%).
DQ2	– Dummy variables for 2^{nd}quarters.
D913aft	– Dummy variable = 1 starting from 3^{rd} quarter 1991.
D973aft	- Dummy variable = 1 starting from 3^{rd} quarter 1997.
D98Q4	– Dummy variable = 1 in the 4^{th} quarter of 1998.
Dolim23	- Influx of new immigrants (with 2 and 3 quarter lag)
Dpimc	- Rate of change in dollar prices of imported consumption goods.
Eterr_for34	- Foreign and Palestenian workers, deviation from HP trend (with 3 and 4 quarter lag)
FDI	- Foreign direct investment ($).
Ggdp	– Civilian government consumption ratio to GDP (Seasonally adjusted).
i*	- Foreign interest rate – weighted according to the basket.

Table III.B: The Impact of Shocks on Endogenous Variables

	Supply Shock		Demand Shock		Interest Rate Shock		Depreciation Shock	
On	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Unemployment	1.000	0.864	0.000	-0.070	0.000	0.003	0.000	-0.049
Inflation	0.282	0.545	0.696	0.283	-0.008	-0.011	0.146	0.196
Nominal interest rate	0.549	0.357	-0.454	-0.336	0.984	0.993	0.283	0.129
Rate of change of the exchange rate	1.321	0.771	-1.420	-1.013	0.984	0.993	0.681	0.277
Real interest rate	-0.525	-1.535	-2.631	-1.195	-0.037	-0.015	-0.272	-0.557

Figure 1:The unemployment rate (deviation from trend), Inflation rate, interest rate and exchange rate, 1990-1999

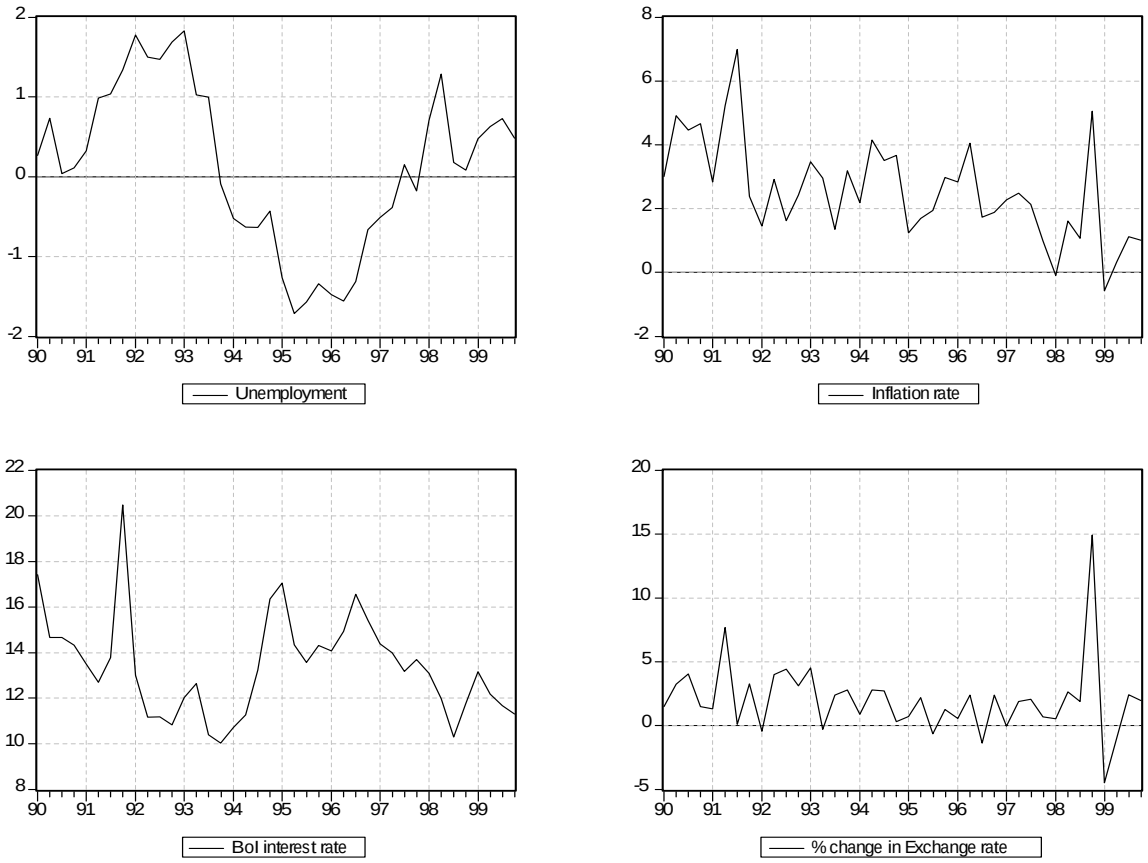


Figure 2: Unemployment – Original data and HP-filtered

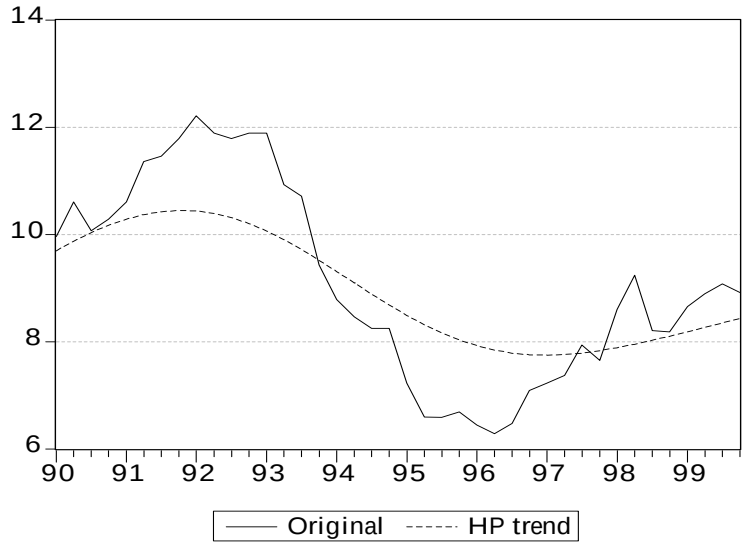


Figure 3: Simulation Results

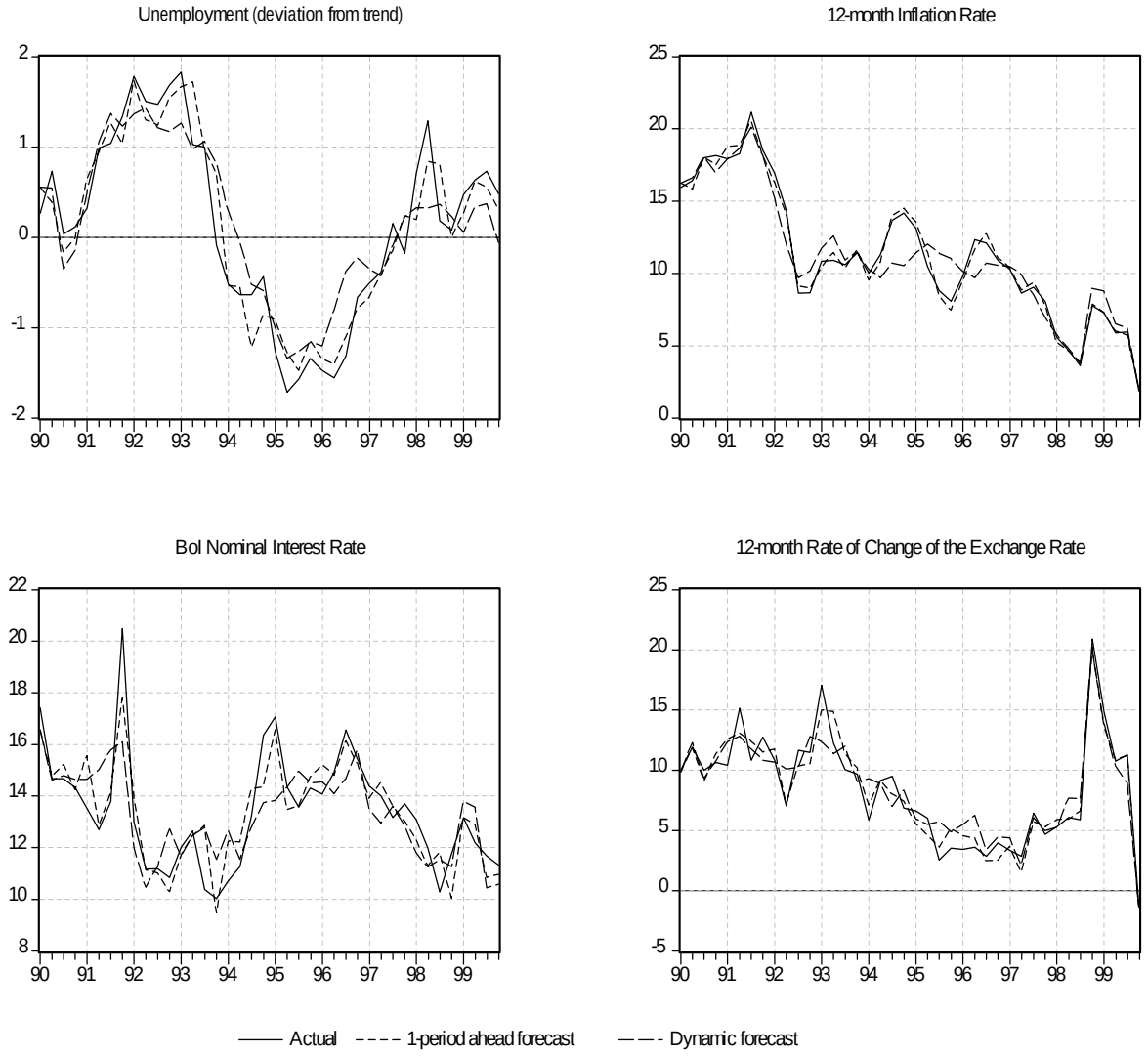
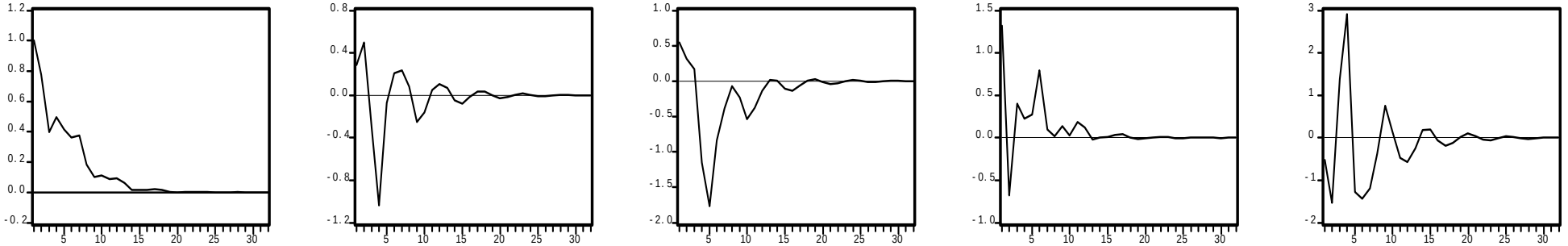


Figure 4: The Impulse Response Function to Supply Shocks

On Unemployment	On Inflation	On the Nominal Interest Rate	On the Rate of Change of the Exchange Rate	On Real Interest Rate

Model 1



Model 2

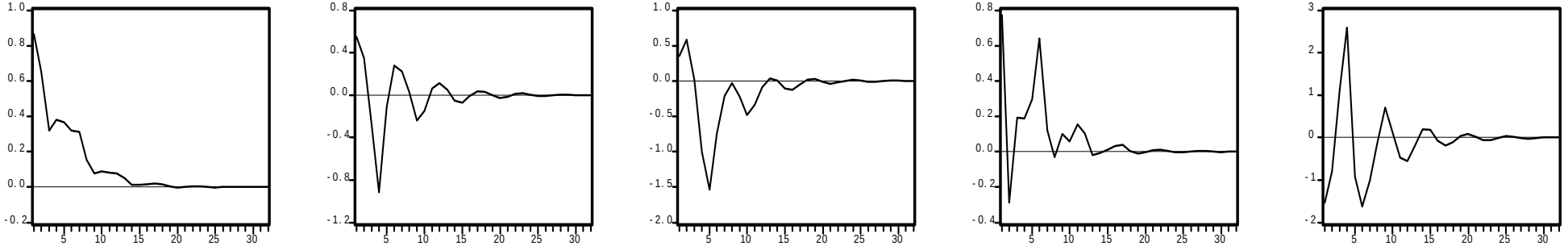
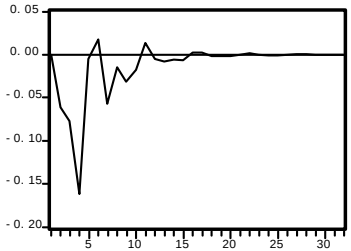
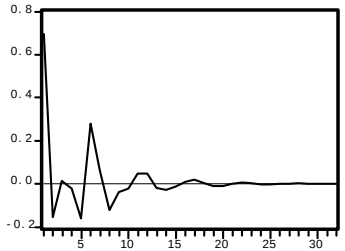


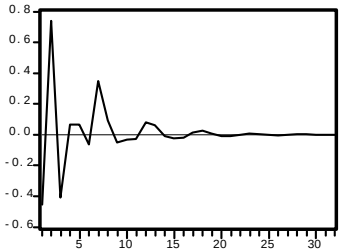
Figure 5: The Impulse Response Function to Demand Shocks

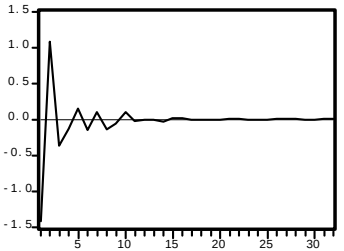
On Unemployment	On Inflation	On the Nominal Interest Rate	On the Rate of Change of the Exchange Rate	On Real Interest Rate

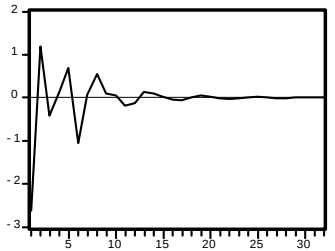
Model 1



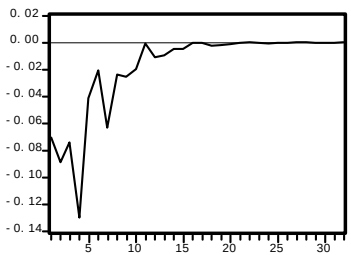


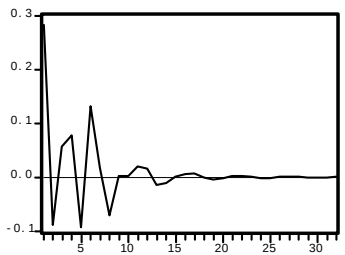


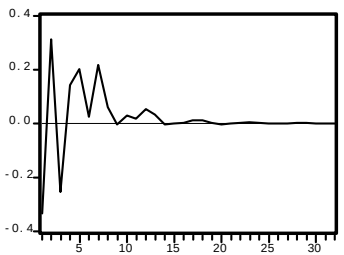


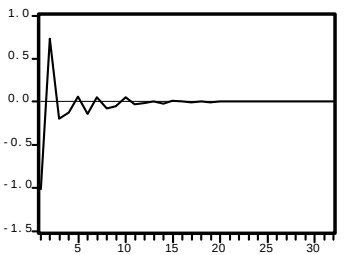


Model 2









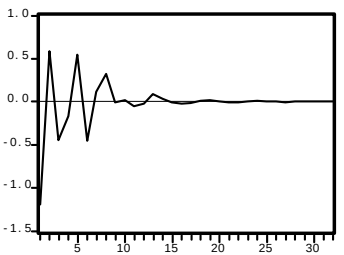
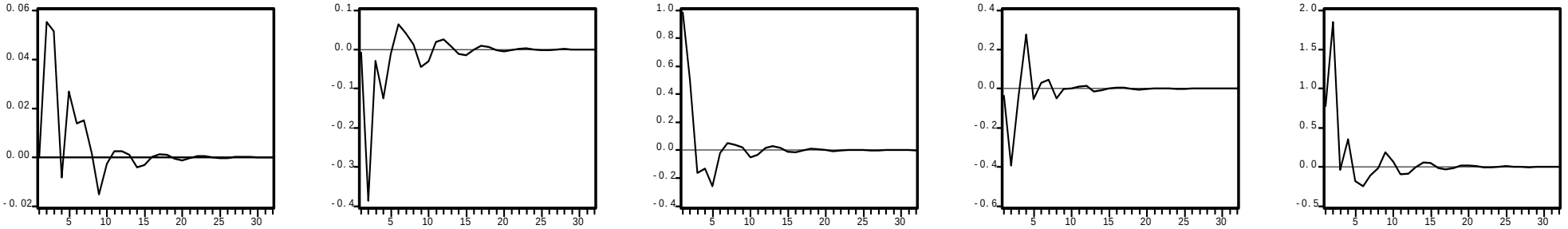


Figure 6: The Impulse Response Function to Interest Rate Shocks

On Unemployment	On Inflation	On the Nominal Interest Rate	On the Rate of Change of the Exchange Rate	On Real Interest Rate

Model 1



Model 2

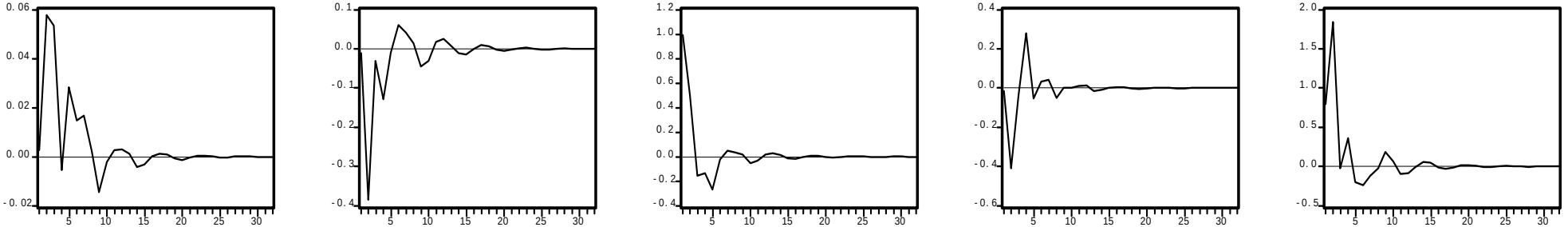
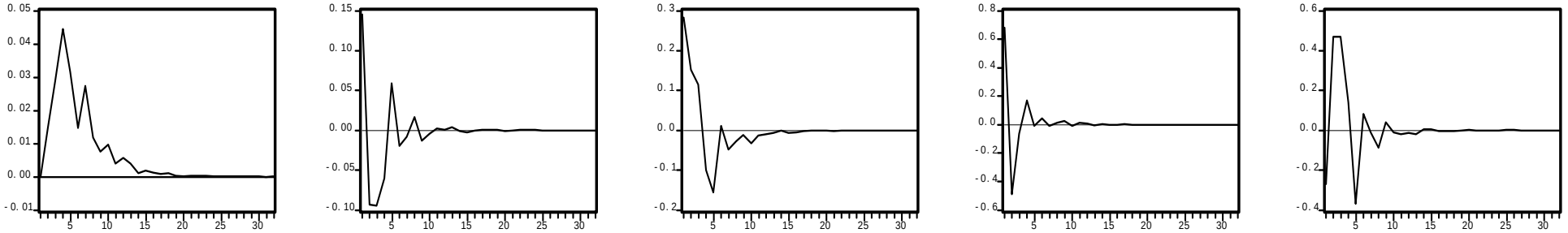


Figure 7: The Impulse Response Function to Exchange Rate Shocks

On Unemployment	On Inflation	On the Nominal Interest Rate	On the Rate of Change of the Exchange Rate	On Real Interest Rate

Model 1



Model 2

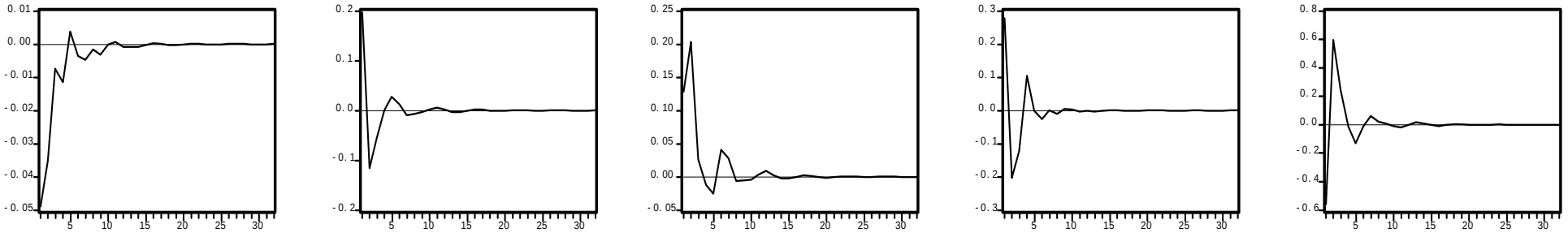
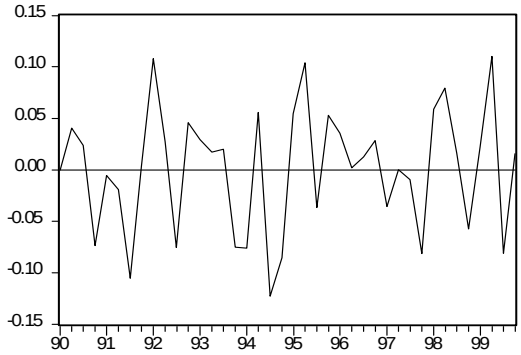
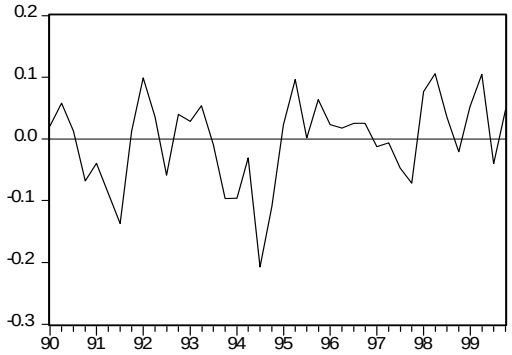


Figure 8: The Contribution of the Actual Structural Shocks to Monetary Policy

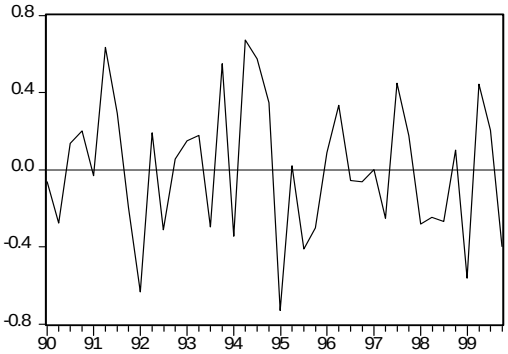
Model 1 Model 2

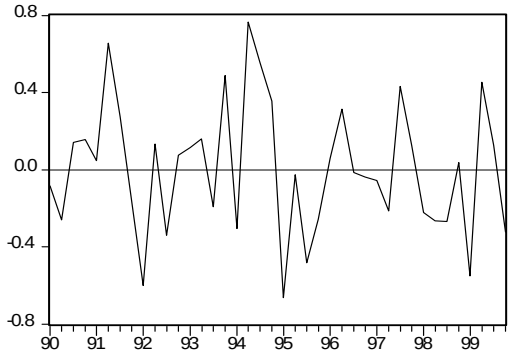
To the Unemployment Rate Gap:



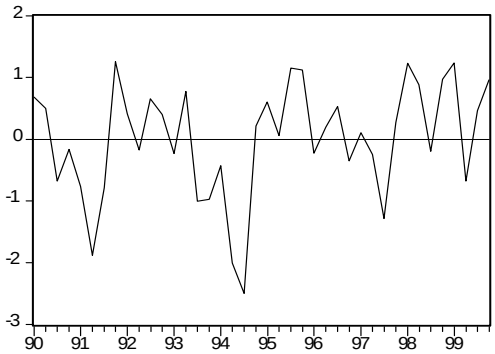


To Inflation:





To the Real Interest Rate:



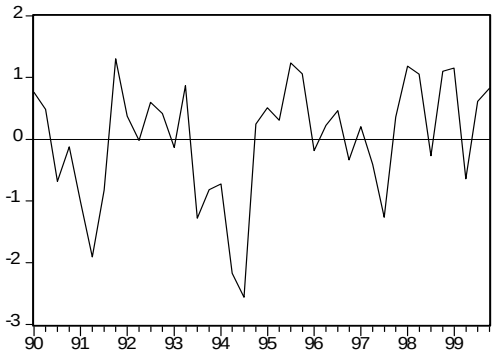
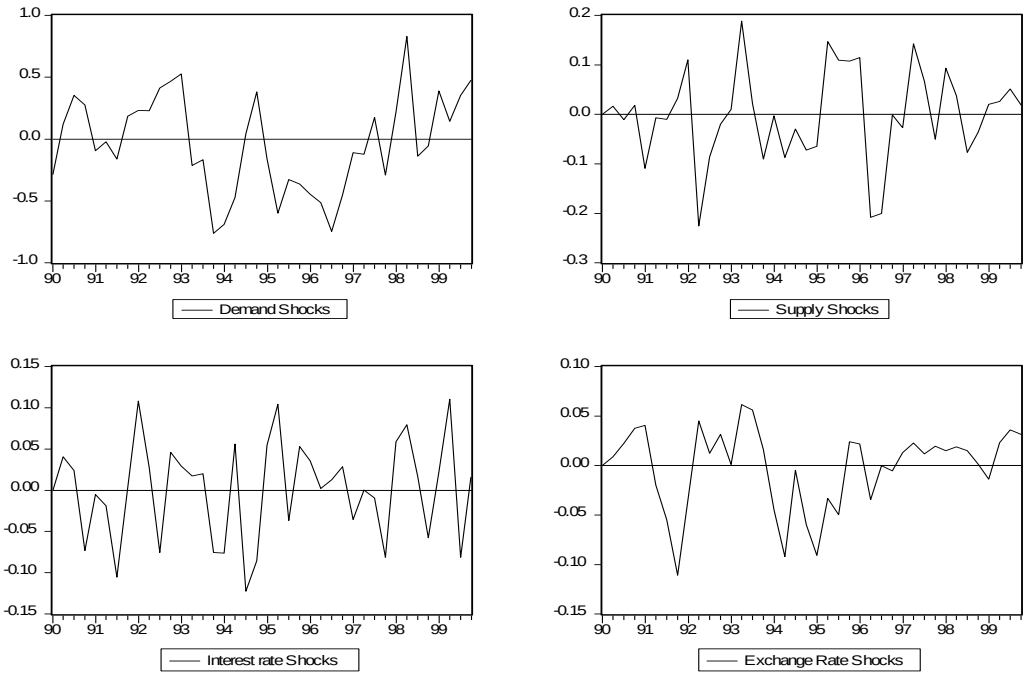


Figure 9: The Contribution of Supply, Demand and Interest Rate Shocks to Unemployment

Model 1



Model 2

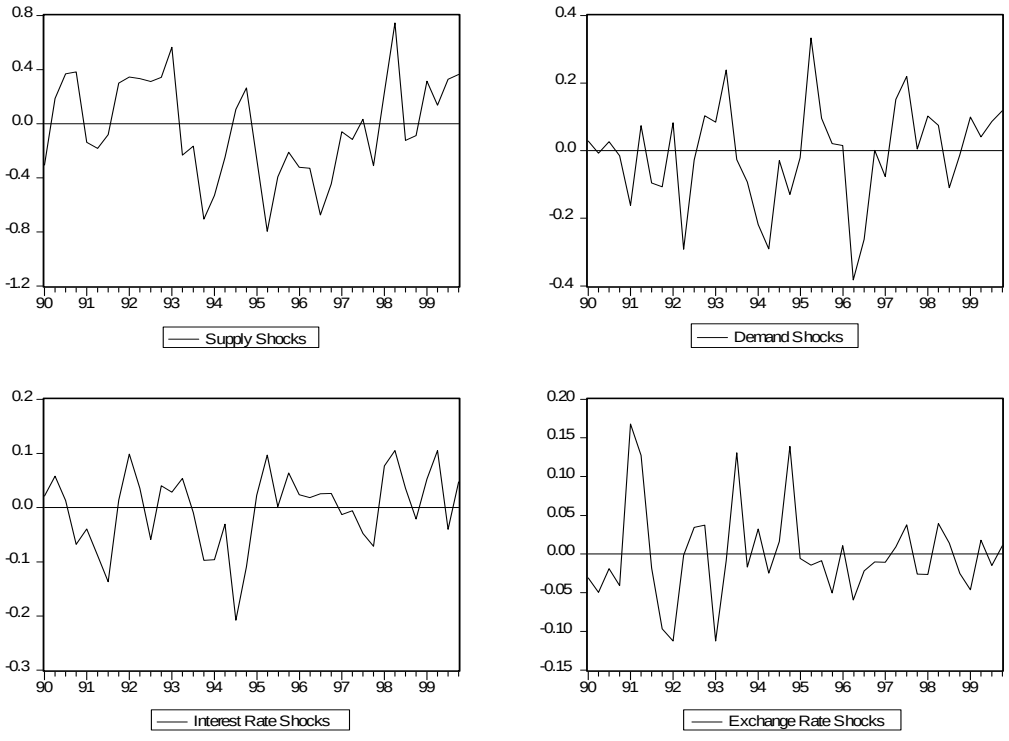
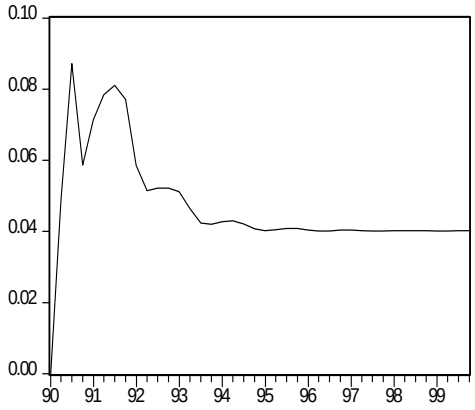
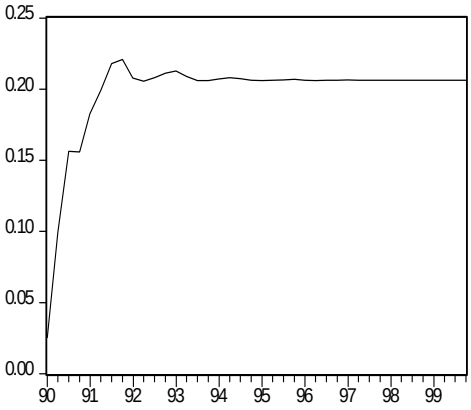


Figure10: The Response to a Permanent Monetary Policy Shock

Model 1 Model 2

To the Unemployment Rate Gap





To Inflation