בנק ישראל מחלקת המחקר

# Changes in Monetary and Exchange Rate Policies and the Transmission Mechanism in Israel, 1989.IV – 2002.I[1]

by

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Discussion Paper No. 2004.13
October 2004

[1] We would like to thank Maurice Chico, Hezi Lifschitz, Ohad Reich and Tania Slovodnitski, for their research assistance. We also thank Sigal Ribon, Nissan Liviatan and Rafi Melnick for their suggestions, Joseph Zeira for his comments on the diagrammatic exposition of the model and the participants in the Bank of Israel Research Department seminar and in the Macro economics seminar at the T.A University for their comments.

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## Abstract

This paper presents a macro-economic model for a small open economy under a floating exchange rate regime, with monetary policy based on a Taylor-rule and demand determined output in the short run. We used this model as a benchmark for the estimation of a 3sls quarterly model of the Israeli economy between 1990 and 2002. We found evidence of interest rate smoothing by the Bank of Israel and of structural breaks in its setting of the interest rate, in the interest rate's effect on the exchange rate and in the latter's impact on the model's endogenous variables. These breaks which differentiate among three different policy regimes affected the transmission mechanism of the monetary policy especially after 1997 and are related to the increasing inflation aversion of the Bank of Israel over time and to the gradual transition to a floating exchange rate regime. The dynamic simulations performed indicate that the tightening of monetary policy over time induced a fall in inflation at the cost of a higher output gap. From the impulse response functions comparing the three different regimes transpires that the ability of the Bank of Israel to affect prices in the short run increased after 1997 and was accompanied by higher nominal interest rate volatility. In spite of the increasing inflation aversion of the Bank of Israel, the inflation volatility rose on impact following shocks to the nominal exchange rate and the output-gap after 1997. This was the outcome of the combined effect of three factors, the higher inflation aversion of the Bank of Israel, the rise in the sensitivity of the exchange rate to changes in the interest rate and the shortening of the lag with which the former affect the CPI inflation. In the long-run inflation volatility decreased because of the more aggressive reaction of monetary policy to inflationary pressures after 1997. We also found that when the closure of the output-gap, following shocks, is brought about by changes in the nominal exchange rate shifting the real exchange rate away from equilibrium, then the policy regime changes in 1997 can account for the higher output volatility in response to these shocks.



*Keywords:* Monetary transmission mechanism, Taylor rules, Phillips curve, Real exchange rate.

*JEL classification*: C32, E27, E31, E52, E61, F32, F41.

## I. Introduction

The objective of the present research is to examine the effects of the changes in the monetary and in the exchange rate policies in Israel during the period 1990-2002 on the monetary policy transmission mechanism in the context of a quarterly econometric model of the Israeli economy. This period was characterized by a gradual liberalization of the Israeli capital market. This liberalization was the outcome of the weakening of the government's monopolistic position in the absorption of funds, because of its decreasing needs to finance its shrinking budget deficit. It was reflected in the liberalization of capital flows and in the eventual transition from a policy of exchange rate management to the adoption of inflation targets and a free float.

This paper consists of three distinct parts in which we present an ad-hoc benchmark model for a small open economy model under a floating exchange rate regime with monetary policy based on a Taylor-rule and demand determined output in the short-run, the 3sls estimation results of an econometric model of the Israeli economy and an assessment of the effect of the policy changes identified in the model estimation on the evolution of economic activity and inflation.

The structure of this benchmark model and its specification has affinities with models developed in the context of inflation targeting policies in the presence of nominal frictions in closed (Taylor (1993), Furher (1997a, 1997b), Furher and Moore (1995), Clarida et al (1999) ) and in open economies (Batini and Haldane (1991), Ball (1999), Svenson (2000), McCallum and Nelson (2001))[1]. Unlike some of these models, however, the short-run specification of our model is not based on optimization considerations on the part of the firms, the households or the central bank. It allows nevertheless the convergence of the economy to its long-run equilibrium following temporary shocks to its parameters. The real exchange rate overshoots following a temporary increase in the foreign interest rate and the initial depreciation is

[1] See also Haldane (1995), Bank of England (1999)), Spain (Andres et al. (1997)) and Duguay (1994). For empirical work on components of our model and especially on the Phillips curve see Fuhrer (1995), King and Watson (1994). For a survey see a collection of papers in "Monetary Policy and the Inflationary Process", B.I.S, 1997.

followed by a process of real and nominal exchange appreciation along the convergence path to the steady state equilibrium. Along this path aggregate demand is greater than potential output, inflation is above target and the real interest rate is higher than its s.s level.

The empirical model we estimated on a quarterly basis using the 3SLS methodology constitutes an augmented version of our benchmark model. Its specification derives from Djivre and Ribon (2000) and has affinities with the quarterly small macroeconomic model of the Israeli economy estimated by Azoulai and Elkayam (1999) and Elkayam (2001) and does not contain a detailed specification of the real sector of the Israeli economy, unlike previous empirical work on the Israeli economy (Beenstock et al. (1994), Drachman and Zilberfarb (1987), Condor (1983), Artstein et al (1982), Cukierman et al.(1977), Evans (1970)) [2].

In the specification of the empirical model we differentiated between the evolution of the CPI and the GDP-deflator inflation and between the Bank of Israel (BoI) nominal interest rate and market interest rates affecting aggregate demand. Moreover we introduced in our Phillips curve both forward and backward looking characteristics with respect to inflation like Furher (1997a, 1997b), Furher and Moore (1995) and Clarida et al (1999). Another difference between the benchmark and the estimated models is that in the empirical version of the model we modeled indirectly the steady state (s.s) rate of inflation which is usually de-facto assumed to coincide with the inflation target. A low inflation target, inconsistent with the public sector fundamentals, may or may not force eventually the government to a fiscal consolidation. This potential conflict between inflation and fiscal targets has not been addressed in any of the aforementioned models creating thereby the impression that attaining a certain level of inflation depends solely on the setting of a particular inflation target. To gauge the stance of fiscal policy we have used a special index consisting of a weighted measure of the budget deficit and the ratio of public debt to GDP.

[2] See, for instance, recent research on the estimation of the Phillips curve Lavi and Sussman (1997), Bufman and Leiderman (1995). See also Fiorella del Fiore(1998) on the transmission of Monetary Policy in Israel since 1990, which has followed a different methodology (Romer-Romer Dates). Aviran (1998) estimated the effect of monetary policy on inflation and on economic activity through independent equation estimation and not through an integrated model allowing for the calculation of dynamic multipliers.

The estimation results identify the existence of two major transmission channels of the monetary policy to prices, a nominal and a real activity channel, which are interdependent and as a result of which the monetary policy effect on prices is characterized by a double dip (peak). The first dip, in the case of monetary tightening, can be attributed to the nominal exchange rate channel and lasts for eight quarters after interest rates are raised. This channel is characteristic of small and open economies like Israel (Ball(1999) and Djivre and Ribon (2003)). The second dip can be attributed mainly to the delayed effect of real interest and exchange rates changes on economic activity , 8 -16 quarters after the change in interest rates, and through it on inflation. The delay with which real activity affects inflation in Israel puts the Israeli economy relative to other economies, at the higher end of the domain regarding the lag with which the real activity channel becomes effective. While the real interest rate component of the output-gap channel constitutes the conventional channel of monetary policy transmission characterizing large and closed economies (Mankiw (2000) and Vinals & Valles (1999)), the real exchange rate effect of the output-gap channel is particular to open economies only.

The estimation results indicate also that when the long-run relationship among wages, prices and productivity is perturbed the adjustment is made by nominal wages, prices and productivity remaining exogenous to this process.

The policy changes reflected in the estimation results identify two structural breaks: the first in 1994.II and the second in 1997.III, which divide the sample period into three sub-periods. These breaks reflect the growing inflation aversion of the BoI and the transition from exchange rate targeting to inflation targeting under a floating exchange rate regime with free capital flows. These developments were interdependent and were also affected by the gradual fiscal consolidation of the public sector, first with the implementation of the stabilization plan in 1985 and afterwards, after 1991, by the adoption of a gradually decreasing path for budget deficits. Indeed as a result of its shrinking budget deficit, the government could afford liberalizing capital flows without risking higher interest on its debt and high exchange rate volatility because of uncertainty with respect to fiscal policy. Fiscal consolidation facilitated thus the transition to a floating exchange rate regime with inflation targets which in its turn imposed market discipline on fiscal policy forcing the government to adjust its budget deficit in tandem with these targets[3].

The outcome of a dynamic simulation within the sample indicates a satisfactory goodness of fit excluding labor productivity and wage inflation which perform rather poorly and indicate that an alternative way of estimation of labor productivity may be necessary.

The evaluation of the contribution of the aforementioned policy changes to the evolution of economic activity and of inflation is based on two distinct exercises. Both of them lead to the conclusion that the substantial break in monetary policy did not occur in 1994 with the formal adoption of inflation targets, but in 1997 with the further tightening of monetary policy. The first exercise traces the evolution of the economy by performing dynamic simulations under the different policy regimes over a given time period. The results of this exercise indicate that the monetary regime between 1994 and 1997 was relatively inefficient because it led at the end of the simulation period to lower economic activity relative to the previous regime, without attaining a significantly lower inflation rate. The 1997 monetary policy regime led, on the one hand, to weaker economic activity but achieved, on the other hand, lower inflation.

In the second exercise we examined the changes in the impulse response functions of CPI inflation and of the output gap brought about by the aforementioned policy changes. We found that the transition to the 1997 regime was characterized by a faster and more substantial reaction of inflation to changes in the BoI interest rate reflected in a higher CPI inflation volatility in the short-run. This was the result of the combined effect of three factors, of the higher inflation aversion of the Bank of Israel, of the rise in the sensitivity of the exchange rate to changes in the interest rate, because of the liberalization of capital flows and of the transition to a pure float, and the shortening of the lag with which the former affect the CPI inflation. In

[3] For a more detailed description of the interdependence between the aforementioned policy changes see Djivre and Tsiddon (2002).

the long-run, however, inflation volatility decreased because of the more aggressive reaction of monetary policy to inflationary pressures after 1997. The higher short-run efficacy of the monetary policy allowed more substantial and frequent changes in the direction of the nominal interest rate by the BoI increasing thereby its volatility.

Similar exercises performed on the output-gap. Their results indicate that when the closure of the output-gap, following shocks to the exchange rate, to the CPI inflation and to the output-gap, is brought about by changes in the interest rate which shift the real exchange rate away from equilibrium, then the structural changes under the 1997 policy regime can account for the higher output volatility observed in response to these shocks.

The paper proceeds as follows: In the following section we present a small macro-economic model of an open economy with capital flows and a floating exchange rate regime. We then present the estimation results of our econometric model and the results of the exercises performed to assess the effect of the changes in policy on the transmission mechanism of the monetary policy concluding afterwards.

## II. The Benchmark Model[4]

a. The Model's Structure

The economy described in the six following equations is a small open economy with imperfect capital mobility and a floating exchange rate regime.

(1) $Gap_t = a_1 \cdot (r_t - \bar{r}) - a_2 \cdot (q_t - \bar{q})$

(2) $i_t = \bar{r} +_{t-} \pi_t^e + b_1 \cdot (_{t-}\pi_t^e - \pi^T) - b_2 \cdot Gap_t$

(3a) $KA = f(i - i^*)$

(3b) $CA = -a_2 \cdot (q_t - \bar{q})$

(4) $\pi_t = \lambda \cdot \hat{W}_t + (1-\lambda) \cdot (\hat{e} + \pi_t^*) - \phi_1 \cdot Gap_{t-1}$

[4] We would like to thank Nissan Liviatan and Rafi Melnick for suggesting to us this diagrammatic approach and Joseph Zeira for his useful comments.

(5) $\hat{W}_t = {}_{t-}\pi_t^e - \phi_2 \cdot Gap_{t-1}$

The first equation is a simplified IS schedule, in deviations from steady state (s.s) equilibrium defining the output-gap which gets positive values when aggregate demand falls short of potential output. The second equation describes the setting of the short-term interest rate by the central bank. Equation 3(a) defines the capital inflows while equation 3(b) describes the current account deficit. Under a floating exchange rate regime the capital account should finance the current account so that the right hand expressions of these two equations should be equal. The fourth equation is a Phillips curve describing how firms adjust their prices while the last equation describes the rate of nominal wages adjustment by labor unions. All coefficients in the above specification are positive and rates of change have been approximated by the log difference of the levels of the corresponding variables.

We assumed, as it is conventionally done, that the deviation of actual from potential output. measured by the output-gap, increases with (the positive) deviation of the real interest rates from its s.s level, $\bar{r}$, and decreases with the upward deviation of the real exchange rate, q, from its s.s value, $\bar{q}$. The real exchange rate has been expressed here as the ratio between foreign and domestic prices, the current account deficit decreasing with q, while the ex-ante real interest rate $r_t$ is equal to the difference between the nominal interest rate and expected inflation, $i_t - {}_{t-}\pi_t^e$. According to our specification of the capital-flows equation (3a) a positive interest rate differential between interest rates on domestic currency denominates assets (liabilities) and on foreign currency denominated assets (liabilities) leads to capital inflows[5]. We have also assumed that the central bank enjoys an informational superiority over the public so that it can react to the actual level of economic activity on real time. The interest rate equation, we refer to as the Monetary Policy (MP) equation, is consistent with the Fisher

[5] For reasons of simplicity and tractability we have not included the output-gap in the definition of the current account equation nor have we introduced the expected depreciation of the nominal exchange rate in the capital account equation.

equation in the long-run and penalizes upward deviations of economic activity from potential and of expected from targeted inflation. The Phillips curve (PC) reflects the rate of adjustment of prices by the business sector and is homogeneous with respect to production costs measured in terms of nominal wages and the prices of imported raw materials in domestic prices. The PC includes also an aggregate demand factor, measured by the output-gap, which affects negatively the rate of price adjustment. The s.s values of economic activity, the real exchange and the interest rates are supply determined and given that the present model is demand driven they are exogenously defined, similarly to the inflation target. Since the whole model is expressed in deviations from its s.s level the balance of payments equation should be also expressed in terms of deviations from its s.s value. To do this we utilize a Taylor expansion assuming that the s.s real interest and inflation rates at home and abroad are $\bar{r}, \pi^T, \bar{r}*$ *and* $\bar{\pi}*$, respectively.

Under these assumptions the financing of the current account deficit (out of the s.s) is therefore consistent with the following equality:

(3) $$-a_2 \cdot (q_t - \bar{q}) = f_1 \cdot (i_t - (\bar{r} + \pi^T) - (i_t^* - (\bar{r}* + \bar{\pi}*))$$

and after substituting for the nominal interest rate from equation (2):

(3') $$-a_2 \cdot (q_t - \bar{q}) = f_1 \cdot ((1 + b_1) \cdot ({}_{t-}\pi_t^e - \pi^T) - b_2 \cdot Gap_t - (r_t^* - \bar{r}*) + (\pi_t^* - \bar{\pi}*))$$

Substituting the wage equation into the PC equation allows us to write the former as follows:

(4' ) $$\pi_t = \lambda \cdot {}_{t-}\pi_t^e + (1 - \lambda) \cdot (\hat{e} + \pi_t^*) - \theta \cdot Gap_{t-1}$$

Rearranging and using the definition for the real exchange rate depreciation yields:

(4'') $$\lambda \cdot \pi_t = \lambda \cdot {}_{t-}\pi_t^e + (1 - \lambda) \cdot (q_t - q_{t-1}) - \theta \cdot Gap_{t-1}$$

where $\theta = \phi_1 + \lambda \cdot \phi_2$. Applying the expectations operator on equation (4'') and assuming rational expectations (RE) we get:

(4''') $$({}_{t-}q_t^e - q_{t-1}) = \frac{\theta}{1 - \lambda} \cdot Gap_{t-1}$$

Figure 1 below provides a diagrammatic solution to the present model without tedious algebraic calculations. We start by deriving from the two first equations, an expression describing the output gap as a function of expected inflation and of the real exchange rate, similarly to the derivation of the standard aggregate demand equation in the context of an IS-LM model (Figure 1a). In Figure 1b we describe the derivation of equation (3'). We solve for the two derived equations, in the two previous diagrams, in Figure 1c and using the PC equation we obtain a dynamic equation for the real exchange rate (Figures 1d-1f) under the assumption of rational expectations.

In Figure 1(a) higher inflation expectations shift the MP schedule upwards leading to higher real interest rates and a wider output gap at point B in the partial equilibrium described in this diagram. Similarly a higher real exchange rate is consistent, other things equal, with higher economic activity and a lower gap, implying a shift of the IS curve to the left in figure 1(a). Equilibrium is established in this case at a higher real interest at point C, reflecting the central bank's reaction to higher economic activity. We obtain, as a result, the output gap as an increasing function of expected inflation or a decreasing function of the real exchange rate $q_t$. For reasons of convention we refer to this equation as the AD equation.

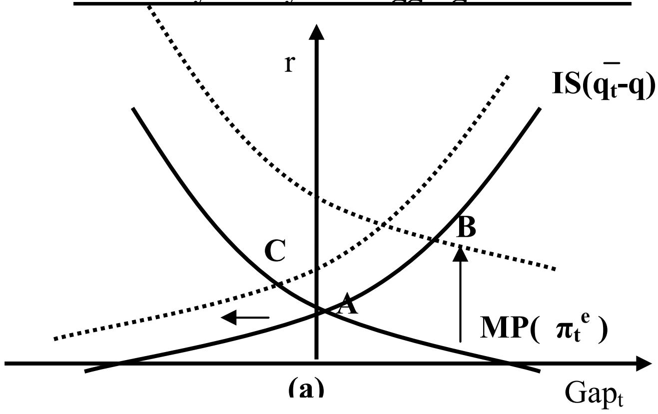
In Figure 1(b) equation (3) appears as a downward sloping line since a higher real exchange rate reduces the deficit in the current account lowering the demand for capital inflows which is consistent with a lower nominal interest rate. The MP equation is described by a horizontal line, because the nominal interest rate set by the central bank is independent of the real exchange rate. Higher inflation expectations are consistent, according to the MP specification, with an upward shift of the MP line supporting a higher interest rate in equilibrium which reflects the central bank's reaction to the higher inflation expectations.

The higher interest rate at the new equilibrium at point B induces capital inflows and a lower real exchange rate. If the real exchange rate is to remain unaltered at its initial level, $q_A$, in spite the higher inflation expectations, economic activity has to fall, shifting the MP line back to its previous position. This outcome is consistent with a positive relationship between expected inflation and the output-gap for a constant value of the real exchange rate. This relationship is described by equation (3') and depicted by the flatter positively sloped curve in figure 1(c).

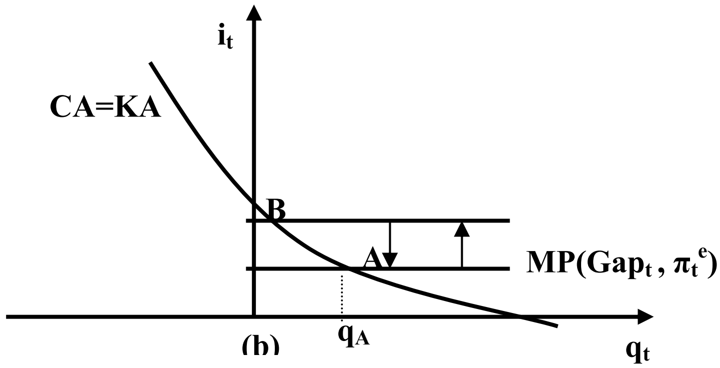
The economic reasoning behind it is that a rise in the nominal interest rate, as a reaction to higher expected inflation, induces capital inflows and a real exchange rate appreciation unless economic activity falls, allowing the central bank to keep the interest rate unchanged in spite of the higher expected inflation.

**Figure 1**

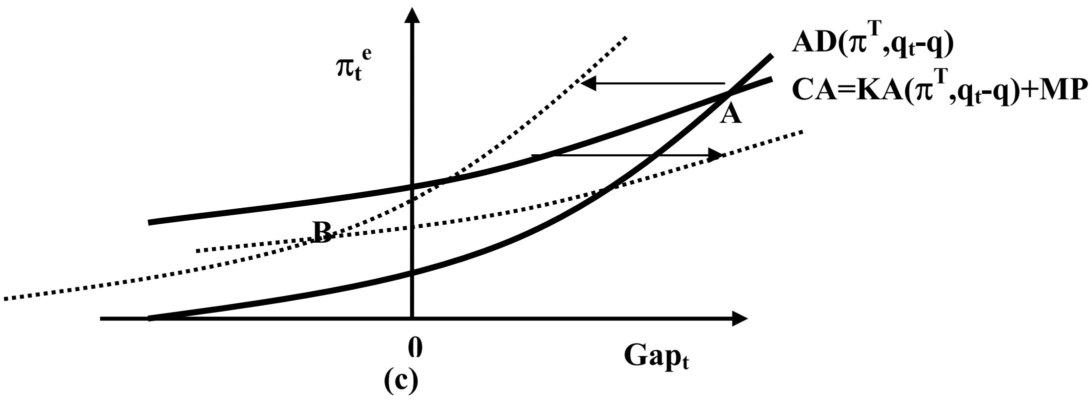
**Monetary Policy and Aggregate Demand**




**Monetary Policy and the Balance of Payments**

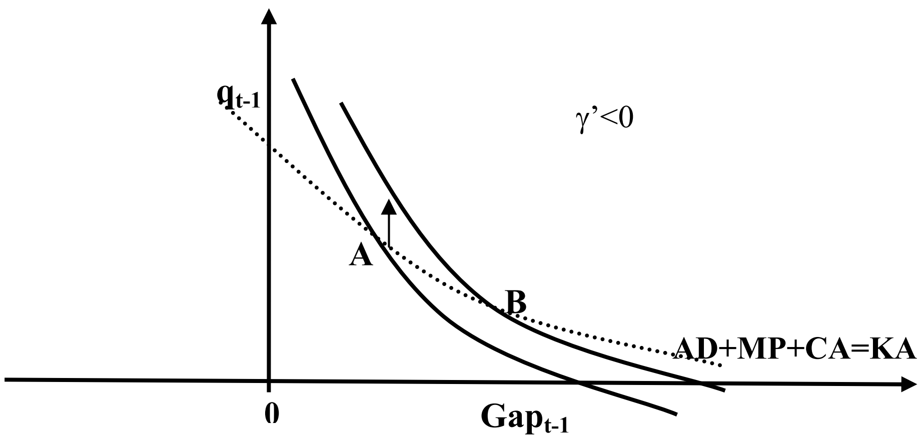



**Aggregate Demand the Balance of Payments and Monetary Policy**



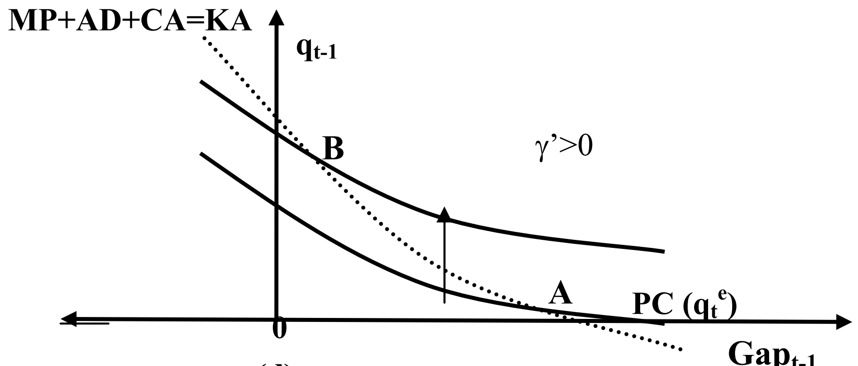

In Figure 1(c), a higher real exchange rate induces higher economic activity and a lower gap given inflation expectations, shifting the AD line to the left. As a result of the same rise in the real exchange rate, the current account deficit is reduced. This lower current account deficit is consistent in equilibrium with a fall in capital flows brought about by lower interest rates as a result of a slowdown in economic activity, given the level of expected inflation. This implies a shift of the CA=KA schedule to the right establishing equilibrium at point B at a lower output-gap, which may be expressed consequently as a decreasing function of the contemporaneous real exchange rate. It can be shown our assumptions imply that the AD schedule in figure 1(c) will be always steeper than the curve depicting equation (3'). As a result a higher real exchange rate will be always reflected in a lower output gap, even after the monetary policy reaction to higher economic activity has been taken into consideration. This relationship between the real exchange rate and the output-gap lagged by one period appears in Figure 1(d) together with expression (4''') derived from the PC.

The PC schedule is negatively sloped with respect to $q_{t-1}$ and in this context a higher expected level for the real exchange rate, $q_t^e$, is consistent with a higher $q_{t-1.}$ This is reflected in an upward shift of the PC schedule in Figure 1(d) establishing a dynamic equation between $q_t^e$ and $q_{t-1.}$ It is possible to obtain either a positive or a negative relationship between $q_t^e$ and $q_{t-1}$ depending on the way the two downward sloping schedules intersect in Figure 1(d) [6]. The sign of the relationship between these two variables depends on an expression we term $\gamma'$[7].



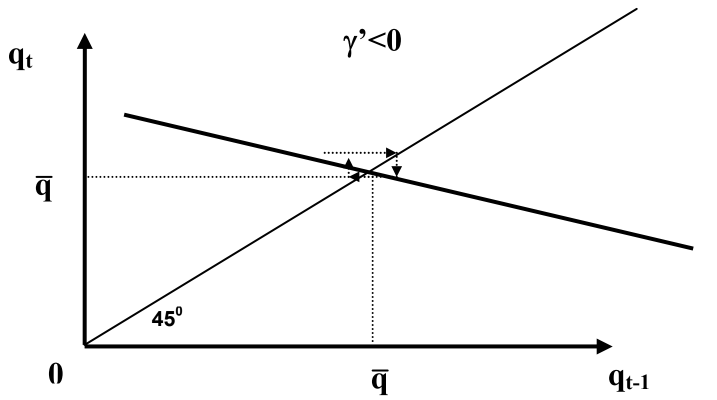

[6] To obtain a similar dynamic equation in terms of $q_t$ we substitute in PC the actual value of the real exchange rate, $q_t$, instead of its expected value, $q_t^e$, adjusted for any shocks which might have created a divergence between them.

[7] This expression is equal to $[1 - \frac{\theta \cdot a_2 \cdot [f_1 \cdot (1+b_1) \cdot + a_1 \cdot b_1]}{(1-\lambda) \cdot f_1 \cdot (1+b_1+a_1.b_2)}$ and measures the slope of the line describing the difference equation between $q_t$ and $q_{t-1}$.

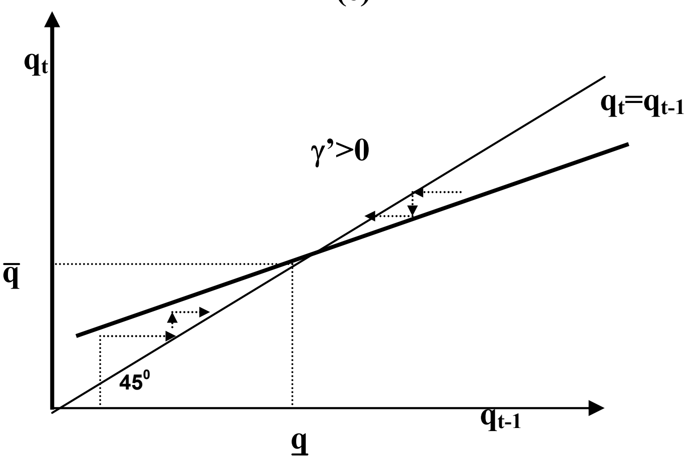


(d)

A negative value for γ implies a negative relationship between $q_t$ and $q_{t-1}$, giving rise to an oscillatory convergence to or divergence from s.s equilibrium as in Figure 1(e). A positive value for γ implies a positive relationship between $q_t$ and $q_{t-1}$, consistent with a stable equilibrium in Figure 1(f). In the following analysis we assume the latter to be the case.



(e)



(f)

**b. Comparative Dynamics**

The effect of positive shocks to the foreign interest rate.

We examine here the dynamics of our model by analyzing the effect of a rise in foreign interest rates which is equivalent to an interest rate reduction by the central bank. We assume that this shock, while unexpected when it occurs, becomes perfectly anticipated for as long as it lasts so that the timing of the return of the economy to conditions similar to those prevailing before the shock is known with certainty. We show below that higher foreign interest rates are consistent, in the context of our model, with a real exchange rate depreciation brought about by the ensuing capital outflows. This depreciation is characterized by an overshooting of the real exchange rate which gives rise, in the periods following the change in foreign interest rates, to a process of a gradual appreciation during which the real exchange rate remains above its s.s value $\bar{q}$. In line with expression (4'') the PC equation on impact may be expressed as follows:

$$\pi_t = {}_{t-}\pi_t^e + \frac{(1-\lambda)}{\lambda} \cdot (q_t - q_{t-1}) - \frac{\theta}{\lambda} \cdot Gap_{t-1}$$

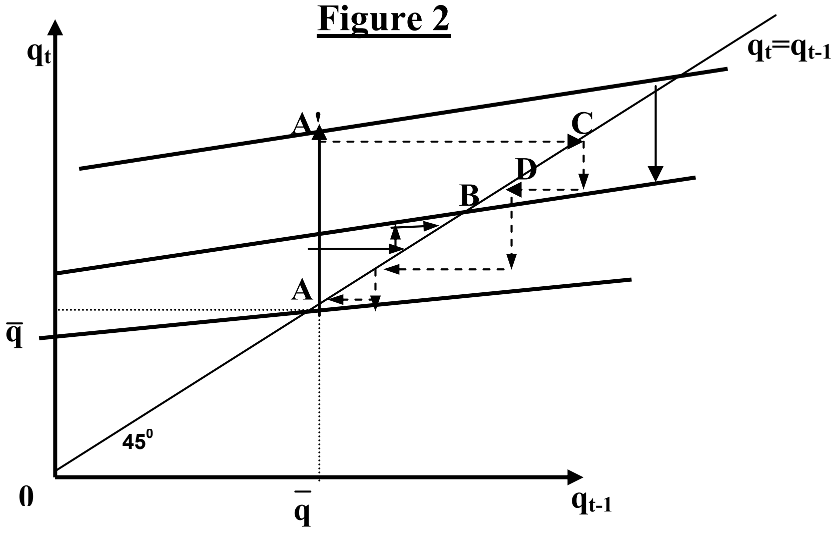
Since the economy has been assumed to be at its s.s prior to the shock, the lagged value of the gap will be equal to zero while the lagged value of the real exchange rate will be equal to $\bar{q}$. By the same token expected inflation will be equal to the inflation target, $\pi^T$. As a result the above expression may be rewritten, after rearranging terms as follows:

$$\pi_t - {}_{t-}\pi_t^e = \pi_t - \pi^T = \frac{(1-\lambda)}{\lambda} \cdot (q_t - q_{t-1}) = \frac{(1-\lambda)}{\lambda} \cdot (q_t - \bar{q})$$

The unexpected shock creates a wedge between expected and actual inflation which is proportional to the wedge between the actual real exchange rate and $q_{t-1}$ which is equal to $\bar{q}$.

It can be shown that under our assumptions the real exchange rate will depreciate on impact, as a result of capital outflows, the relevant dynamic schedule shifting from the initial equilibrium at point A to a point like A' , in Figure 2, the output-gap turning negative. We show in Appendix 2 that in the second period after the shock, when its effect becomes fully anticipated and is incorporated in the lagged values of the output gap in the Phillips curve, the

**Figure 2**




real exchange rate experiences an appreciation, remaining however higher than $\bar{q}$. This implies that output is beyond its potential level and that the dynamic schedule compared to the first period shifts downwards but remains higher than its position prior to the shock. This outcome is possible only if the real exchange rate overshoots on impact, shifting in the second period to point C above point B. Economic activity beyond potential together with the inflationary effect of the nominal exchange rate depreciation, because of capital outflows, lead to a tightening of monetary policy. Monetary tightening is reflected in a nominal and real exchange rate appreciation, allowing the convergence of the economy in the direction of point B, along the dotted arrows, and then in the direction of the initial s.s equilibrium A, after the shock disappears, when the economy hits point D. We show in Appendix 2 that in this process inflation remains above the inflation target and the nominal and real interest rates remain also higher than their s.s value converging gradually to it. However as long as the real exchange rate, $q_{t,}$ remains higher than $\bar{q}$, equation (3) implies that the rise in the domestic interest rate falls short of the foreign interest rate shock. Had point A' been below point B, then the economy would have settled on a path characterized by a real exchange rate depreciation, as it is indicated by the convergence arrows below point B.

## II. The Econometric Model

### a. An overview

We discuss briefly below the difference between our benchmark model presented in the previous section and its estimated version.

We have assumed a two-stage production process in which capital and labor are used first to produce the business sector's domestic product. In the second stage domestic product is used to produce final goods using also imported materials as inputs. We estimated as a result two inflation regressions: one for the business sector GDP price inflation and another one for the CPI inflation. The first regression was estimated as a Phillips curve while the second was specified as a time derivative of the log of the CPI, derived from the dual equation of the corresponding production function for consumption goods. The fact that the CPI inflation constitutes a weighted average of the GDP price inflation and the imported raw materials' inflation required the estimation of an additional regression linking the business sector GDP inflation with the general GDP inflation which serves as a regressor in the CPI inflation regression.

For the performance of dynamic simulations we estimated some additional regression equations and used some identities allowing the determination of variables serving as regressors in the estimated equations. More precisely, our relaxing the benchmark model's assumption of rational expectations (RE) and our using instead data on the inflation expectations, derived after imposing a no-arbitrage condition on the returns on non-indexed treasury bills and indexed government bonds of the same maturity, made necessary the estimation of an inflation-expectations regression. We assumed that the long run inflation rate depends on the size of the public sector’s budget deficit so that in the long run expected inflation is an increasing function of the expansionary stance of fiscal policy. To measure this stance we used as a regressor an index, constructed in the Research Department of the BoI (Dahan and Strawczynski (1997))[8].

We estimated also three additional regressions for nominal wage inflation, for labor productivity and for commercial-bank interest rates. The estimation of the first two equations was made necessary by the need to calculate the unit labor costs used as a regressor in the PC regression. The third regression was required in view of the use of the bank interest rates as a regressor in the output-gap and in the real exchange rate depreciation regressions.

With respect to the identities used we only mention briefly here that the nominal exchange rate path has been derived from the evolution of the estimated real exchange rate and from that of the domestic product prices. In a similar way the estimated nominal wages and interest rates equation determine together with the estimated inflation rate the evolution of real wages and of short run real ex-post interest rates.

The specification of the output-gap, the real exchange depreciation rate and the BoI interest rate equations derive from Djivre and Ribon (2000). The main difference between the latter and the present model lies in the assumption that output is determined by aggregate demand and not in the context of an AD-AS model.[9] All estimation results are reported in Appendix 3.

**b. The Regression Equations**

**b.1 The Output-Gap**

The output-gap, **gap,** measures deviations of the business sector product from its full capacity level in log terms[10]. **Gap** is positive in downturns and negative in upturns in economic activity.

[8] When the output-gap converges to zero, our Phillips curve specification describes the co-movements in the rates of change of different nominal variables, such as unit labor costs, the nominal exchange rate and expected inflation while the level of s.s inflation rate is determined in the inflation expectations equation as a function of the budget deficit

[9] See also Djivre and Ribon monetary planning for 2002-03.

[10] The full capacity level of economic activity is obtained after introducing in a separately estimated production function of the business sector the long run trend values for labor and the actual capital-stock derived from current investment and the rate of discard (Djivre and Ribon (2000)).

We assumed output is demand determined in the short-run so that the output-gap depends only on aggregate demand variables, domestic and international. These include a moving average of the ex-post short term real interest rate, **rhhd**. and a moving average of the government budget deficit-GDP ratio, **pdefgdp**. We assumed that the s.s real interest rate is constant over time. This assumption allowed us to use as a regressor the actual level of the real interest rate, letting the s.s component of its deviation from equilibrium to be incorporated in the intercept.

The variables measuring foreign demand include a moving average of the deviations of the real exchange rate from its equilibrium level, **tfpres1,** a moving average of the deviations of the log of the world trade volume from its trend, **log(wt)**, which is calculated as an HP filter of quarterly data, and the deviations of tourist entries to Israel from tourist services in the U.S.A, **log(tour_entry)-log(tour_us)**. This variable provides a proxy for the disruption in foreign demand caused by a deterioration in the domestic security conditions. The estimated regression includes also a lagged value of the dependent variable and an AR factor [11].

**(1)** **gap =** ***g(0)*** **–** ***g(1)*****MA(tfpres1(-1),3) +** ***g(2)*****MA(rhhd(-2),3) -** ***g(3)*****MA(log(wt(-1))**
**- Lwt_hp(-1),3) –** ***g(4)*****MA((log(tour_entry) – log(tour_us),4)**
**-** ***g(5)*****MA(pdefgdp(-2),4) +** ***g(6)*****gap(-1) –** ***g(7)*****AR(1)**.

The regression coefficients have the conventionally expected sign assigned to them in equation (1). Monetary policy affects economic activity through two distinct channels according to equation (1). The first is the real exchange rate channel and the second is the real interest rate channel. While the lag with which monetary policy affects real activity is one to two quarters, its effect is more prolonged and lasts for three quarters in either channels.

A Wald test performed on the estimated regression coefficients indicates that we cannot reject the hypothesis that the coefficients of the real interest rate and of the lagged output-gap

[11] The notation ma(x(-n),m) stands for a moving average of $x_{t-n}$ over m quarters.

add-up to one. This finding implies that an increase in the real short-term interest rate by one percentage point beyond its long run-level brings about, other things being equal, a commensurate rise in the output-gap.

**b.2 The Real Exchange Depreciation Rate.**

This equation has been specified in terms of the rate of depreciation, **dRER,** of the real exchange rate in the context of an error correction process. We have defined as real exchange rate (**RER**) the ratio of the price of exports in local currency to the GDP deflator. Short-term changes in the real exchange rate, dRER, are brought about by the error correction factor measured by the residual, **tfpres1**, of the long-run co-integration equation for the RER and by additional factors[12].

The additional factors affecting the short run evolution of the real exchange rate include the lagged dependent variable, the output-gap, the differential between the interest rate on domestic currency denominated liabilities, **ihhd**, and the interest rate on foreign currency liabilities, **Eurosal**. This is a weighted interest rate calculated on the basis of the currencies in Israel's currency basket. We have allowed the transition to a floating exchange rate after 1997 to affect the interest rate differential coefficient through the introduction of a dummy variable, $\mathbf{d_{973aft}}$, in the slope coefficient. This specification derives from our benchmark model in which the change in the real exchange rate along its convergence path depends on the level of the domestic and foreign interest rates. We have also included in the estimated equation the rate of change of the dollar price of exports, **d(log(pgexp))**, that has been allowed to decrease over time, to account for nominal price rigidities affecting the short run determination of the real exchange rate, and a dummy variable, $\mathbf{d_{98q4}}$, accounting for the exchange rate crisis in the last quarter of 1998.

[12] The economic reasoning behind the long-run co-integration equation, presented in appendix 2, is that a relative increase in the productivity in the tradeable goods sector over time gives rise to a real exchange rate appreciation, see Zusman(1998) and Djivre Ribon (2000). See appendix 2 for the estimation results of the cointegrating equation.

Lower economic activity expressed in a higher value of the output-gap is consistent with a real exchange rate depreciation arising from either lower domestic or foreign demand and a positive output-gap coefficient in the estimated regression. A higher interest rate on domestic currency liabilities supports capital inflows leading in the short run to a nominal and real exchange rate appreciation implying a negative sign for the interest rate differential. While accounting for short-term capital flows, our model does not account for the short- run effect on the real exchange rate evolution of capital flows arising out of long-run considerations.

$$\textbf{(2)}\quad \mathbf{dRER} = q(0) - q(1)\mathbf{dReR(-1)} - q(2)\mathbf{tfpres1(-1)} - q(3)(\mathbf{i_{hhd}} \ \mathbf{-eurosal})$$
$$- q(4)\mathbf{d_{973aft}}\ (\mathbf{i_{hhd}} \ \mathbf{-eurosal}) + q(5)\mathbf{D(log(pgexp))*(1+1/log(T))}$$
$$+ q(6)\mathbf{gap(-2)} + q(7)\mathbf{d_{98q4}}$$

The estimated coefficients of the output-gap and of the interest rate differential have the expected sign. We also found that the coefficients of the rate of change of export prices, of the interest rate differential and the dummy variable $\mathbf{d_{98q4}}$, are all significantly different from zero. This finding implies that the Israeli economy was characterized during the estimation period by nominal rigidities since changes in the aforementioned variables which should affect only the nominal sector of the economy affected also relative prices such as the real exchange rate.[13] This finding justifies also the specification of the Phillips curve inflation equation in which price adjustments are partly backward looking and is as a result characterized by nominal rigidities in the short run.

The size of the interest rate differential coefficient prior to 1997 suggests that the widening of the interest rate differential by one percentage point led to a quarterly real exchange rate appreciation of a one quarter of a percentage point. This finding implies that on an annual basis there existed a one to one relation between the interest rate differential and the exchange rate appreciation during the estimation period. After the transition to a pure float, in July 1997, this effect increased by 0.43 percentage points in annual terms.

[13] The decreasing effect of export price changes reflects the liberalization in the goods market and the rising competition as a result of which a lower extent of rigidities should be observable.

### b.3 The Price Equations

All price equations are expressed in terms of rates of change and include the inflation rate in terms of the business sector GDP deflator, the inflation rate in terms of the GDP deflator, the inflation rate in terms of consumer prices and the equation for inflation expectations. The nominal exchange rate depreciation belongs also to this group of equations. It constitutes though an identity and not an equation being derived from the real exchange depreciation rate, and the inflation in terms of GDP prices and in terms of the dollar prices of foreign trade.

<u>The Business Sector Price Inflation (The Phillips Curve)</u>

The dependent variable of this equation is the business sector quarterly GDP price inflation, **dlpgdp_bs**, including start-up firms as of 1995. We have assumed that the business sector consists of two types of firms, exporting firms, whose prices are determined in the international market, and firms producing for the local market. The latter are of two types: forward and backward looking firms. Forward looking firms adjust their prices according to the expected inflation rate, while backward looking firms adjust their prices according to past changes in their unit labor costs. The Phillips curve (PC) equation may be therefore formulated as a function of expected inflation, **Exp**, for the forward looking firms, of past changes in unit labor costs, net of productivity gains, **dw-dprod**, for the backward looking firms, and of the depreciation of the nominal exchange rate, **dldol**, for exporting firms[14]. This specification differs from the conventional approach in which the exchange rate depreciation factor reflects production factor costs.

We have also assumed that firms take into consideration when adjusting their prices the level of economic activity and in particular its deviation, the gap, from its full-capacity level. Domestic product lower than its full-capacity level mitigates price increases and vice versa so that the coefficient of the output gap is expected to be negative.

[14] The introduction of the change in export prices in dollar terms in the estimated regression did not give rise to a significant coefficient

Inflation expectations, **exp,** are measured here by the twelve month-ahead expected inflation as the latter is derived by imposing a no arbitrage condition between returns on government indexed bonds and zero coupon nominal treasury bills (Makam) of the same maturity. The inflation expectations used here are in terms of consumer prices and not in terms of business-sector GDP prices. The high correlation coefficient between GDP price inflation and expected CPI inflation justifies, however, this contravention. In order to introduce only the forward-looking element of these inflation expectations as a regressor in the estimated equation, we introduced as a regressor the average inflation rate during the two previous quarters, **(dlpgdp_bs(-1)+ dlpgdp_bs(-2))/2,** which is expected to account for the backward-looking component of expected inflation giving rise to a negative coefficient. The estimated regression includes also seasonal dummy variables and dummy variables accounting for the classification changes in the reporting of wages and of the business sector product as of 1995, $\mathbf{d_{951}}$, and for the exchange rate band realignment in March 1991.

We examined and found that the price level, nominal wages and labor productivity measured by the product of the business sector per unit of labor input, are co-integrated. The coefficients of nominal wages and productivity in the co-integrating equation are very close to unity as it is expected to be under perfect competition. We also introduced as a result in the estimated equation (3) below an error correction factor, **ECP** [15].

$$\text{(3)}\quad \mathbf{dlPgdp_{bs}} = \mathit{P(0)} + \mathit{P(1)}\mathbf{d_{9112}} - \mathit{P(2)}\mathbf{d_{951}} + \mathit{P(3)}\mathbf{Exp} + \mathit{P(4)}\mathbf{MA(dW\text{-}dprod,2)}$$
$$- \mathit{P(5)}\mathbf{(dlPgdp_{bs}(-1) + dlPgdp_{bs}(-2))/2} + \mathit{P(6)}\mathbf{MA(gap(-1),2)} + \mathit{P(7)}\mathbf{dldol}$$
$$+ \mathit{P(8)}\mathbf{dq_1} - \mathit{P(9)}\mathbf{ECP}$$

The coefficients P(3), P(4) and P(7) measure the relative weight of the firms producing for the domestic market and are forward looking, of their counterparts that are backward looking and of the exporting firms, respectively. In view of the fact that expected inflation is expressed in annualized terms while the two other regressors and the dependent variable are expressed in

[15] See the cointegration regression (3) in Appendix 2.

quarterly terms, the coefficient P(3), has to be adjusted accordingly and the sum of this adjusted coefficient together with P(4) and P(7) should add up to unity, if our classification of types of firms is exhaustive and covers indeed all the business sector. Moreover this condition implies also that the inflation equation is homogeneous of degree one.

From the unconstrained estimation of the regression equation it turns out that P(3) = P(5). This result implies that the relevant regressor in the PC estimation is given by (Exp – ($dlPgdp_{bs}$(-1) + $dlPgdp_{bs}$(-2))/2). We may consider the expression in parenthesis as measuring the forward looking element of the variable measuring expected inflation, Exp, since its backward looking element is measured by the average quarterly inflation during the past two quarters. The expression in parenthesis measures cumulative inflation on a three quarters basis since it has been obtained after subtracting from the annualized rate of expectations, Exp, the average quarterly inflation of the two previous quarters, ($dlPgdp_{bs}$(-1) + $dlPgdp_{bs}$(-2))/2. In order to express this regressor in quarterly terms we have to divide it by three, which implies that the corresponding regression coefficient will be three times greater than the estimated value of P(3). If the relative weight of the different types of firms should add up to unity, then the condition 3*P(3) + P(4) + P(7) = 1 should hold. Indeed the results of the unconstrained estimation of the regression do not allow the rejection of this condition which has been incorporated in the final PC estimation.

We found that the share of the purely tradable sector in the determination of the business sector GDP price inflation has a confidence interval between 2 and 18 percent. Of the remaining firms the 67 per cent, are forward looking and the remaining 23 percent, are backward looking.

The coefficient for the error correction factor was statistically insignificant, indicating that shocks to prices are not corrected over time if they diverge from unit labor costs.

In the vicinity of full employment, a change in the output gap by one percentage point gives rise to a 0.2 change in prices on an annual basis. Our definition of the output-gap in terms of the log-difference between potential and actual output implies that the Phillips curve flattens with the downward deviation of economic activity from its potential. This could indicate that an unexpected fall in prices at an already low level of economic activity is reflected in a further expansion of the output gap, most probably as a result of firms going out of business, a further reduction in prices in reaction to a slack in economic activity being futile.

The GDP price inflation

This is an auxiliary equation linking the quarterly inflation in terms of the deflator of the business sector, to the quarterly inflation with respect to the general GDP deflator, **dlpgdp**.

We examined and found that these two variables are cointegrated in their levels and as a result the estimated regression should be the first difference of the long-run cointegration relationship augmented by an error-correction term, **ECPgdp,** and possibly other variables, like seasonal dummies, relevant in the short-run.

$$\textbf{(4)}\quad \mathbf{dlPgdp} = \mathit{pg(0)} + \mathit{pg(1)}\mathbf{d_{951}} + \mathit{pg(2)}\mathbf{dlPgdp_{bs}} - \mathit{pg(3)}\mathbf{ECPgdp(-1)} + \mathit{pg(4)}\mathbf{dq_2} - \mathit{pg(5)}\mathbf{dq_4}$$

The error correction coefficient is statistically significant but substantially small. Since expression (4) is equal in the long-run to the first difference of the cointegration equation, the coefficient pg(2) should be equal to the coefficient of the gdp deflator of the business sector in the cointegration equation. Indeed pg(2) was equal to 1.03 while the coefficient of the corresponding level variable in the cointegration equation was equal to 1.1 (Appendix 2).

The CP inflation

When consumer good prices are determined competitively, the duality between prices and quantities implies that our assumption, whereby consumption goods are produced using domestic product, GDP, and imported materials, is consistent with the representation of the CPI as a weighted average, in log terms, of the GDP deflator and the price of imported materials in domestic currency. This equation plays the role of a co-integrating relationship between the CPI, the GDP deflator and the price of imported materials. In this equation the

GDP deflator elasticity and the elasticity of the prices of imported materials are identical to those of the corresponding inputs in the production function of consumption goods. [16] This implies that the CP inflation we wish to estimate may be expressed as the first difference of this co-integrating relationship, augmented by an error correction factor**, ECCP**, and by other variables affecting consumer price inflation in the short run.[17]

Under these circumstances a change in the weight of the prices of imported materials relative to that of GDP prices in the cointegrating equation and of their rate of change in the corresponding first difference equation must reflect identical changes, because of the duality principle, in the elasticities of the two production inputs in the corresponding production functions. Absent such a technological change, the change in the relative weights of the prices of the two inputs and hence of their inflation rates in the estimated equation is unjustified.

We have not found empirical evidence supporting such a structural change. As a result the only possible change in the contribution of the price of imported materials and of the change in the exchange rate, in particular, to the CP inflation in the short-run may arise from changes in the lag with which the former affects the latter. Such a change does not affect the long-run specification of the regression and does not imply therefore a similar change in the price cointegration equation and its dual representation - the production function.

$$\textbf{(5)}\quad \mathbf{dP} = p(0) - p(1)\mathbf{d_{973aft}} - p(2)\mathbf{d_{951}} + p(3)\mathbf{dPgdp(\text{-}1)} + p(4)\mathbf{d_{973aft}.dldol}$$

$$+ p(4)\mathbf{d_{973aft}.dlpmi} + p(5)\mathbf{(dldol(\text{-}1) + dlpmi(\text{-}1))} - p(6)\mathbf{d_{973aft}.(dldol(\text{-}1)}$$

$$\mathbf{+ dlpmi(\text{-}1))} + p(7)\mathbf{dq_2} - p(8)\mathbf{dq_3} + p(9)\mathbf{dP(\text{-}1)} + p(10)\mathbf{ECCP(\text{-}1)}$$

The estimated equation includes as regressors, in addition to the GDP price inflation, **dPgdp,** and the imported materials' inflation, **(dldol+dlpmi),** lagged values of these variables

[16] Our hypothesis of the existence of a co-integrating vector among the consumer price index, the GDP deflator and the domestic currency price of imported materials is supported by the results of a unit-root test conducted on the residuals of the co-integrating equation. In spite of the existence of a cointegrating relationship the estimation results of the consumer price inflation equation did not allow for the introduction of an error-correction component because its coefficient was not statistically different from zero.

[17] In the specification of this equation the regression coefficients should be identical to the coefficients of the co-integrating regression. The estimation results gave rise to different estimates. In this way the GDP and imported materials' inflation coefficients are 0.63 and 0.36, respectively, while the corresponding coefficients of the co-integrating equation are equal to 0.83 and 0.17 respectively (see appendix 2). The latter fall, however, within the confidence interval of the former.

and seasonal dummies. It also includes a dummy variable, $\mathbf{d_{973a}}$, to account for changes in the timing with which exchange rate depreciation affects CP inflation prior to and after the transition to a floating exchange rate regime.

The estimated coefficients of the unrestricted regression have the signs assigned to them in the above expression and they fulfill the following equalities:

**p(4) - p(6) = 0** and **p(9) + p(3) + p(5) = 1**

The first equality implies that the effect of a change in the prices of imported materials on consumer price inflation has shortened affecting the CPI inflation contemporaneously after 1997, while prior to this date it did so with a one quarter lag. However since the hypothesis of a structural change in the production function has been rejected, the total exchange rate depreciation effect on CPI inflation should remain the same before and after 1997; that is the coefficients p(4) and p(6) should be equal as it indeed transpires from the unrestricted estimation. The second equality implies a constant-returns-to-scale technology in the production of consumption goods. The estimation results reported in Appendix 3 refer to the constrained version of equation (5).

The insignificance of the error-correction factor, which was omitted from the final estimation, implies that the deviation of consumer prices from the GDP deflator and from the prices of imported materials is not corrected by an adjustment of the former in the direction of the latter. As a resut shocks to consumer prices do not reverse themselves. The elasticities of GDP inflation and of imported materials inflation, after all lagged regressor values have been eliminated are 0.64 and 0.36 respectively. In addition to the existence of the direct exchange rate depreciation effect of the imported materials inflation, the estimation results attest to the existence of an indirect one, through the effect of the change in the exchange rate on the GDP price inflation. This latter effect is equal to 0.064.[18]

[18] The exchange rate depreciation effect of GDP price inflation was found to be equal to 0.1. As a result the fact that the elasticity of CPI inflation with respect to GDP price inflation is equal to 0.64 implies that the indirect exchange rate depreciation effect on CPI inflation is equal to the aforementioned percentage.

The inflation expectations equation

The dependent variable in the estimated regression is the quarterly average of the twelve-months-ahead expected CPI inflation, **exp**, lagged by one month, **exp_1**. The lagged specification of expected inflation derives from the fact that the BoI sets the interest rate for a particular month at the end of the previous month so that the corresponding expected inflation rate is the one available at the month preceding that for which the interest rate is set by the BoI.

The conception behind the specification of the estimated regression equation is that the s.s. inflation rate is determined in the long run by the size of the government budget deficit and by the ratio of the public sector's debt to the GDP measured here by the variable Fiscal Index, **FI**, introduced by Dahan and Strawczynski (1997). Deviations from this long run rate may be the result of shocks or of monetary policy measures which can affect the inflation rate only in the short run. These factors affect expected inflation in the estimated regression through the effect of the lagged value of quarterly consumer price inflation, **dp,** and of the nominal exchange rate depreciation, **DE,** following the transition to a pure float in July 1997. The estimated regression equation is of the form:

$$\textbf{(6)}\quad \mathbf{Exp\_1} = x(0) - x(1)\mathbf{d_{973aft}} + x(3)\mathbf{(FI(-1) + FI((-2))/200} + x(4)\mathbf{dP(-1)*4}$$
$$+ x(5)\mathbf{d_{973aft}dE*4} + x(6)\mathbf{Exp\_1(-1)}$$

The lagged quarterly CPI inflation rate may account for the backward looking component of the inflation expectations when they deviate from their steady state equilibrium level,. The exchange rate depreciation effect after July 1997 may reflect, in its turn, our finding that changes in the nominal exchange rate affect the CPI inflation contemporaneously after 1997 whereas prior to this date they did so with a one quarter lag. This exchange rate effect prior to 1997 was incorporated in the lagged value of the quarterly inflation rate **dp(-1)**. The estimated equation includes also an AR(1) term to guarantee an i.i.d residual.

The estimated coefficients have the sign assigned to them in expression (6) and indicate that a one percentage point reduction in the fiscal index is reflected in a commensurate fall of the long run inflation rate[19]. Moreover a quarterly depreciation of the nominal exchange rate by one percentage point is consistent with a rise of expected inflation by 0.32 percentage points, after the transition to a pure float in 1997.

**b.4 The nominal wage setting equation**

The nominal wage adjustment equation is based on the notion that the workers in the business sector set their wages, based on expected inflation, **exp,** and on the labor market conditions, measured by the level of domestic product, **Y**. Higher inflation expectations support higher wage inflation, **dw,** while lower economic activity decelerates this process. This wage setting can be formally written as follows:

(7.1) $dw = exp + F(y)$

Linearizing F(y) around full employment y* yields the following short-run wage equation:

(7.2) $dw = exp + F(y^*) + F_1(y^*).(y - y^*)$,

In the long-run the rate of change of nominal wages per unit of labor input, **dw,** should be equal to expected inflation augmented by the long run trend of productivity gains, **dprod***. A general specification of this relationship appears in expression (7.3) below.

(7.3) $dW = exp + f_2 dprod^*$, with $f_2$ being a constant to be estimated[20]

Comparison between expressions (7.2) and (7.3) implies that in the long run, when the output-gap equals zero, the term F(y*) in (7.2) should be equal to $f_2.dprod^*$. The estimated regression is an augmented version of expression (7.2). It includes as regressors, in addition to the output gap (y*-y), expected inflation and productivity gains, an error-correction component, **Ecw**, assuring the long-run convergence of real wages in terms of the business sector GDP deflator to a level equal to that of labor productivity.[21]

**(7.4)** $\mathbf{dW = \mathit{w(0)} + \mathit{w(1)}dq_2 - \mathit{w(2)}d951 + \mathit{w(3)}dprod + \mathit{w(4)}exp/4 + \mathit{w(5)}dW(-4)}$

$\mathbf{- \mathit{w(6)}gap(-2) - \mathit{w(7)}Ecw(-1)}$

[19] This calculation constitutes an approximation since the nominal exchange rate depreciation and the consumer price inflation are not necessarily identical in the steady state.
[20] $f_2$ should be equal to unity under perfect competition.
[21] See discussion on the co-integration equation in the section on the business sector GDP-price inflation.

Data on wages per unit of labor input are not available and as a result we had to calculate an estimate for this variable based on some simplifying assumptions (See appendix 4). We allowed additional dynamics in the estimation by including the dependent variable, **dw**, lagged by four quarters and two intercept dummies. The first one, **dq$_2$**, accounts for a seasonal factor present in the second quarter and the second one, **d951**, is set equal to one in the first quarter of 1995 to account for a change in the classification of the wage data. Long-run equilibrium properties of the estimated equation imply restrictions on its coefficients. In particular the long run coefficients of the expected inflation and of the productivity gains should be equal to unity under the assumption of a competitive labor market.

The estimated coefficients have the sign indicated in expression (7.3). The only constraint imposed initially in the estimation of equation (7.3) was the equality between the coefficients w(3) and w(4). The estimation results did not allow in this case the rejection of the additional constraint that w(3) + w(5) = 1, a condition which implies a long run coefficient of unity for inflation expectations and for labor productivity and is consistent with rational expectations in the long run and competitive labor compensation[22]. We found that the coefficient of the error correction factor was negative and significantly different from zero, unlike the estimation of the PC equation. This result implies that the deviation from the long-run relationship between wages, prices and productivity is made through the adjustment of nominal wages while business sector prices remain exogenous to this process according to the estimation results of equation (3).

**b.5 The short-run productivity equation**

This equation was estimated following the 2sls procedure outside our 3sls system The dependent variable, **dprod**, measures the change in the product per unit of labor input in logs.

[22] The estimation results reported here are of the constrained version of the regression after our hypothesis that the coefficients of exp and dprod were found to be equal in the unrestricted version of the estimation.

The regression specification is based on the first difference of the cointegrating relationship among labor productivity, business sector GDP prices and nominal wages and it is augmented by lags of the corresponding variables This statistical specification implies that lagged changes in labor productivity, which serves as the regression's dependent variable, are correlated with lagged changes in real wages in terms of the GDP deflator of the business sector, **($dw - dgdp_{bs}$).** To overcome the multicolinearity involved when lagged values of changes in real wages and of productivity gains are both included in the estimated regression, we regressed first the productivity gain, **dprod,** on the change in real wages and then used the residuals of this regression, **resdprod,** as a regressor in equation (8) below, the coefficient cc(5) measuring, as a result, the effect of past changes in labor productivity. We have excluded from the estimated regression equation the error-correction component because there is no reason to assume that technology fluctuates in tandem with these two variables, being exogenous to them.

$$\textbf{(8)}\quad \mathbf{dprod} = cc(0) + cc(1)\mathbf{dW} - cc(2)\mathbf{dPgdp_{bs}} + cc(3)\mathbf{dW(-4)} - cc(4)\mathbf{dPgdp_{bs}(-4)} - cc(5)\mathbf{resdprod(-4)}$$

The long-run version of the estimated equation obtained, following the elimination of all lags present in it, should give rise to a long-run unit elasticity between changes in productivity and real wages.

The estimation was initially made by imposing the two restrictions **cc(1) = cc(2)** and **cc(3) = cc(4)** which imply a direct correlation between labor productivity and real wages. The estimation results obtained under these two restrictions did not allow the rejection of the hypothesis that the long run value of the real wage coefficient was equal to unity, namely**, cc(1) + cc(3) + cc(5) = 1,** implying a long-run correlation between real wages and labor productivity equal to one. This finding is consistent with the estimation results of the cointegration equation and with competitive labor compensation. The positive sign we obtained for the real contemporaneous wage, may be interpreted as reflecting, at least to some extent, the expectation for higher real wages to reflect higher productivity. This expectation arises from the fact that the optimizing firm is expected to raise the capital/labor ratio in response higher real wages increasing thereby the output per unit of labor input.

### b.6 The Bank of Israel interest rate

During the first four years of the estimation period, 1990-1993, the BOI was mainly concerned with the stability of the foreign exchange market and the growth of the economy. This policy was reflected in a systematically low real short interest rate which was negative during most of the period. The Israeli government and the BoI adopted formally inflation targets in 1994 and the BoI has explicitly used its short-term nominal interest rate for the conduct of monetary policy since September 1994. It thus abandoned the nominal exchange rate as the nominal anchor, and allowing thereby greater exchange rate flexibility, culminating in transition to the pure float in the third quarter of 1997. Taking into consideration these policy changes, we formulated our regression equation so as to allow the testing of the hypothesis of structural breaks in 1994 and in 1997.

We consider the estimated equation as a parsimonious description of the factors affecting the short-run nominal interest rate bearing in mind the criticism of observational equivalence of Christiano et al. (1998), and Minford et al. (2001).

Our specification of the BoI interest rate equation assumes that the setting of the interest rate depends, prior to the adoption of inflation targets, on the output gap, on lagged values of the interest rate (for interest rate smoothing) and on inflation expectations, while after the adoption of inflation targets, in 1994, it depends also on the inflation target.

The purpose of the introduction of inflation expectations in the estimated regression prior to the adoption of the inflation target was designed to reflect the public's expectations concerning the evolution of the nominal exchange rate which served at that time as a nominal anchor (Djivre and Ribon 2000). It is the interdependence between expected inflation and changes in the exchange rate and the use of the interest rate by the BoI to defend the latter's stability prior to 1994 which justifies the specification of the regression equation for this period in equation (9a) below.

**(9a)** $\mathbf{i_m = \mathit{r(0)} + \mathit{r(1)}exp\_1 - \mathit{r(2)}(gap(-1) + gap(-2))/2 + \mathit{r(3)}i_{m(-1)}}$

We tested the hypothesis of the existence of structural breaks by introducing a dummy variable in inflation expectations after 1994. and an additional one for the period after 1997. Accordingly, the interest rate equation (9a) was augmented to become:

**9(b)** $\mathbf{i_m = \mathit{r(0)} + \mathit{r(1)}exp\_1 + \mathit{r(11)}d_{942aft}Exp\_1 + \mathit{r(12)}d_{973aft}Exp\_1}$

$\mathbf{- \mathit{r(2)}(gap(-1)+gap(-2))/2 + \mathit{r(3)}i_{m(-1)} - \mathit{r(4)}d_{942aft}Target}$

Rearranging terms we may rewrite equation (9b) as a Taylor rule:

For 1994 - 1997

**(9c)** $\mathbf{i_m = \mathit{r(0)} + [\mathit{r(1)} + \mathit{r(11)} - \mathit{r(4)}]Target + [\mathit{r(1)} + \mathit{r(11)}][Exp\_1 - Target]}$

$\mathbf{- \mathit{r(2)}(gap(-1)+gap(-2))/2 + \mathit{r(3)}i_{m(-1)}}$

and after 1997

**(9d)** $\mathbf{i^m{}_t = \mathit{r(0)} + [\mathit{r(1)} + \mathit{r(11)} + \mathit{r(12)} - \mathit{r(4)}]Target + [\mathit{r(1)} + \mathit{r(11)} + \mathit{r(12)}][Exp\_1 - Target]}$

$\mathbf{- \mathit{r(2)}(gap(-1)+gap(-2))/2 + \mathit{r(3)}i_{m(-1)}}$

It is evident from the specification of equations (9b) and (9c) that the change in the reaction of the BoI to a change in expectations after 1994 and 1997 affects the coefficient of the deviation of expected from targeted inflation which includes r(11) for the period 1994-1997 and both r(11) and r(12) for the period after 1997. In the long-run, when inflation is on target and the output-gap is equal to zero, the equality between the left and the right hand side of the estimated regression implies that when the Fisher equation is fulfilled, i.e i = exp +Target, then r(11)+r(12)+r(3)-r(4)=1 and expression $\frac{r(0)}{(1 - r(3))}$ stands for the short-term real interest rate at the s.s equilibrium. We assumed that this short-term real interest rate0 is not affected by the stance of monetary policy but by real factors. As a result it should not be affected by changes in the intensity with which the Central Bank reacts to the deviation of inflation expectations from the inflation target. For this reason we did not introduce a dummy variable in the intercept of the estimated regression alongside its introduction in the coefficient of the inflation expectations.

We consider as in Clarida et al. (1998 and 2000) expressions (9b)-(9d) as the reduced form of two equations. The first equation reflects the evolution of a targeted nominal interest rate, $\mathbf{i^T_t}$, and the second one describes the actual nominal BoI interest rate, $\mathbf{i^m_t}$, as a weighted average of the targeted nominal interest rate and of the actual interest rate in the previous period, $\mathbf{i^m_{t-1}}$ namely:

**(9e)** $\mathbf{i^m_t = \mathit{r(3)}i^m_{t-1} + (1 - \mathit{r(3)})i^T_t}$, with $\mathbf{i^T_t}$ being specified as follows:

**(9f)** $\mathbf{i^T_t = \theta(0) + \theta(1)exp\_1 - \theta(2)Target - \theta(3)(gap(-1)+gap(-2))/2}$

We have also included in the estimated version of the equation four intercept dummies, **d1, d2, d3 and** $\mathbf{d_{98q4}}$ to account for short and distinct periods of speculative attacks on the managed exchange rate regime and exchange rate crises such as the one in the last quarter of 1998[23]. The inclusion of these dummies is justified because when the BoI reacted to the exchange rate crises by raising its interest rate, inflation expectations fell back eventually, while the interest rate was kept high. As a result the quarterly average of expected inflation cannot account for the high BoI rate of interest which was reduced afterwards only gradually, requiring the introduction of the aforementioned dummy variables. We also used an additional dummy variable, $\mathbf{d_{02q1}}$, to account for the unanticipated interest rate reduction by the BoI in the first quarter of 2002. The sign of the speculative dummies should be positive while that of the 2002 dummy should be negative.

The estimated coefficients have all the expected positive sign and confirm the hypothesis of a gradual monetary tightening both after 1994 and 1997. The estimation results give rise to the following equations for the targeted nominal interest of the BoI:

<u>1989.4-1994.2</u>

**(9i)** $\mathbf{i^T_t = 0.054 + 0.563Exp^* - 0.188(gap(-1) + gap(-2))/2}$

[23] The other three dummy variables refer to the periods: 1990.1, 1991.4 and 1992.4

1994.3-1997.3

**(9j)** $i^T_t = 0.054 + 0.764\text{Target*} + 2.032(\text{Exp*} - \text{Target*}) - 0.188(\text{gap}(-1) + \text{gap}(-2))/2$

1997.3 2002.2

**(9k)** $i^T_t = 0.054 + 1.362\text{Target*} + 2.630(\text{Exp*} - \text{Target*}) - 0.188(\text{gap}(-1) + \text{gap}(-2))/2$

An interpretation of the estimated regression as a Taylor rule allows us to consider its intercept as an estimate of the long run short-term real interest rate which after taking into consideration the lagged interest rate effect is equal to 5.4 percent.

Expressions (9j) and (9k) indicate that after 1994 a rise in inflation expectations is accompanied by interest rate increases that overcompensate for the rise in expected inflation leading to higher short term real interest rates. The Wald tests we performed on the coefficient of the inflation target indicate that the hypothesis it is equal to one can be reject at a five percent confidence level only for the last sub-period in favor of the hypothesis that it is greater than one. For the sub-period between 1994 and 1997 the same hypothesis is rejected only at a significance level of 6.6 percent in favor of the hypothesis that the inflation target coefficient in expression (9j) is smaller than one. As a result the estimation results reported above are not consistent in the long-run with the Fisher equation at least for the last sub-period of our sample. It is possible to reconcile the data with the deviation from conventional wisdom and economic theory by rearranging terms in expression (9k) allowing the equilibrium real interest rate, which is the first right-hand side component in parenthesis in the expression below, to vary across policy regimes:

**(9l)** $i^T_t = (0.054 + 0.362\text{Target*}) + \text{Target*} + 2.630(\text{Exp*} - \text{Target*})$
$- 0.188(\text{gap}(-1) + \text{gap}(-2))/2$

The interpretation to be given in this version of the estimation results is that the monetary policy followed by the BoI after 1997 aimed at a real interest rate higher than its s.s level, by a factor equal to **0.362.Target*.**

Our estimation results are within the range found by Clarida et al. (1998). They report a coefficient for the deviation of expected from targeted inflation ranging from 0.90 for the Bank of Italy between 1981 and 1989 to 2.04 for the Bank of Japan between 1979 and 1994 , the Bundesbank having a coefficient of 1.31 between 1979 and 1993 and the Banks of England and France being around unity for the periods 1979-1993 and 1983-1989, respectively. For the same periods the corresponding coefficients of the output-gap were equal to: 0.22, 0.08, 0.25, 0.19 and 0.88, respectively.[24]

To conclude we may state that monetary policy after 1997 was tighter than between 1990 and 1994, being more aggressive with respect to deviations of inflation expectations from the inflation target and targeting a higher equilibrium real interest rate.

**b.7 The debit short term interest rate**

Commercial banks in Israel set the interest rate they charge on loans using the BoI interest rate as a benchmark. Commercial banks add a constant mark-up to this benchmark, which reflects their monopoly power in the market for loanable funds, and is supplemented by a risk premium. This pricing policy stands behind the specification of the estimated regression whose dependent variable is the short-term commercial bank nominal interest rate on lines of credit in which the regression intercept measures the aforementioned mark-up

**(10)** $$\mathbf{i_{hhd}} = ih(0) - ih(1)\mathbf{d_{91aft}} + ih(2)\mathbf{i_m} + ih(3)\mathbf{i_{hhd}(-1)} + ih(4)\mathbf{AR(1)}$$

The estimated regression includes also an intercept dummy variable to account for the period following 1991, during which capital flows to and from Israel were gradually liberalized, starting with foreign currency indexed and denominated credit. The estimation results indicate that the dummy coefficient is negative and of a considerable magnitude in the long run 7.1 percentage points. This finding implies that the access to alternative credit markets apparently weakened the commercial bank monopolistic power through market contestability as a result of the liberalization of the capital account of the balance of payments after 1991.

[24] These estimation results are not completely comparable to ours in view of the fact that the output-gap relevant for the estimation in Clarida et al(1998) refers to the level of expected future activity while in our estimation the output-gap is backward looking and entirely demand determined..

The pricing policy we stipulated requires that the specification of the estimated regression should give rise in the long run to a coefficient for the BoI interest rate which is equal to unity, a condition fulfilled when ih(2) + ih(3) = 1. Contrary to the pricing policy we stipulated, the unconstrained estimation of the regression equation gave rise to a long run coefficient for the BoI interest rate which is close but significantly greater than unity. The estimation results reported in Appendix 3 refer to the constrained estimation to ensure convergence.

**C. Summary and Implications of the estimation results**

Our main empirical finding is that the data allow us to differentiate among three different monetary policy regimes the first one prior to the adoption of formal inflation targets before 1994, the second between 1994 and 1997 and the third one after 1997 and the transition to a pure float. We also found that the real and nominal exchange rates became more sensitive to the interest rate differential on domestic currency credit and on foreign currency credit and that the lag with which changes in the nominal exchange rate affect the CPI inflation rate shortened. This shortening of the lag is also reflected in the introduction of the contemporaneous quarterly nominal exchange depreciation rate in the inflation expectations regression.

A shift of the economy along the Phillips Curve implies a shift of the curve itself over time in the inflation-output-gap plane because nominal exchange rate depreciation, expected inflation and hence nominal wage inflation, which affect the location of the PC in this plane, are themselves affected by changes in the inflation rate. This observation implies that while the Phillips curve did not undergo structural changes during the estimation period, the coefficients of its regressors remaining unchanged, the output-gap-inflation relationship did. The reason for this is that most of the regressors of the PC underwent structural changes as a result of the policy regime changes, affecting thereby the extent of the aforementioned shift of the PC in the inflation-output-gap plane. This observation is important with respect to the evaluation of the anti-inflation stance of monetary policy because it implies that the sacrifice ratio cannot be considered as the inverse of the coefficient of the output gap in the estimated PC equation.

## III. Goodness of fit and Impulse response functions.

### a. The goodness of fit

To assess the goodness of fit of our model we performed a within the sample dynamic simulation. Had the regressor coefficients changed considerably during the period under consideration, we would have expected long horizon forecasts to deviate considerably from actual values as a result of the aforementioned hypothesized structural breaks. This implies of course that the goodness of fit reflected in the residuals of the estimated regressions would have been also rather poor. Indeed the information included and revealed by such a dynamic simulation is identical to the information conveyed by the estimation residuals.[25] In this respect it may be said that the dynamic simulation constitutes just a more illustrative and illuminating method of examining the goodness of fit of the estimated model (Figure 3). In spite of the relative good fit of the dynamic simulation a few remarks are still in order.

a) Our model performs rather poorly in the case of nominal wages. This may be attributed mainly to the poor performance of the productivity equation.

b) The forecasts for inflation and inflation expectations for the years 1992-1994 are high relatively to the actual evolution of these two variables and they imply that our model does not account satisfactorily for the fall in inflation rate after 1991. This deviation affects also the values of the ex-post real interest rate which are relatively low to their actual value giving rise to relatively low output-gap forecasts for the same years.

The conclusion to be drawn from this exercise is that our model exhibits in general a good fit and that an effort should be made to account for the drop in inflation after 1991 and to improve our measure of labor productivity. A direct estimation of employment and of the

[25] Pagan (1989).

business-sector GDP could serve to calculate the business sector GDP per unit of labor input, improving the model's performance.

**b. Characterization of the Monetary Policy Transmission**

In this section we present the impulse response function to shocks in the interest rate of the BoI. The objective is to trace the sequence of changes observed in the economy from the change in the BoI interest rate until its reflection in prices and in economic activity.

In view of the structural breaks described in previous sections we present here the impulse response function under the monetary regime which prevailed after 1997 (Figure 4). A one percentage point initial increase of the interest rates by the BoI leads on impact to higher nominal short term credit interest rates inducing a nominal exchange rate appreciation, lower GDP price inflation and higher real interest rates and real wages. The nominal exchange rate appreciation is also reflected in lower CP inflation, which is enhanced in the subsequent period by the mitigating effect of lower Business sector GDP inflation, and in lower inflation expectations (effect non-existent before 1997). Because of the partial transmission of the nominal exchange rate appreciation to prices, the nominal exchange rate appreciation induces a real exchange rate appreciation. In the subsequent quarters the higher real interest rate and the appreciated real exchange rate affect adversely economic activity. In its peak the output gap is approximately equal to forty percent of the initial interest rate shock (in percentage points). At this stage the central bank is in a process of reducing gradually the interest rate, a policy which supports a gradual process of deceleration of the nominal and real exchange rate appreciation and of the price deflation. However the rising output-gap, because of the lagged effect of the higher real interest rate and the appreciated real exchange rate, exerts downward pressure on business sector GDP which slide to a second trough (double dip), 9-10 quarters after the initial interest rate shock. This second trough is 10 quarters long. A similar double dip is also experienced by the four quarter moving average of CPI inflation (Figure 4). The second inflation trough is 50% of the first trough in the case of CPI inflation and 75% in the case of business sector GDP price inflation[26]. The delay with which real activity affects inflation in Israel puts the Israeli economy relative to other economies, at the higher end of the domain regarding the lag with which the real activity channel becomes effective.

The delayed output-gap effect mitigating GDP inflation is amplified by a process of real and nominal exchange rate appreciation, reflecting the convergence of the real exchange rate to equilibrium after its depreciation and triggered by the lower economic activity that followed the tightening of monetary policy. After the output-gap has been almost eliminated, 13 quarters after the positive interest rate shock shock, the real exchange rate experiences a process of appreciation which is reflected also in the evolution of the nominal exchange rate., so that at a time economic activity starts picking-up, inflation is still pushed into negative territory, firstly because of the aforementioned lagged effect of the positive output-gap and secondly because of the exchange rate appreciation. The CPI inflation is characterized by a similar but more protracted process because of the autoregressive component in the corresponding regression equation.

We may therefore differentiate between two stages in the process of inflation deceleration following an interest rate increase. The immediate effect of nominal origin is characteristic of small and open economies, it is due to the nominal exchange rate appreciation and is active for the first eight quarters after the interest rate shock. The origin of the second round effect is mainly in the real sector and arises from the inflation mitigating effect of the positive output gap brought about by the higher real interest rate and the real exchange rate appreciation triggered by monetary tightening. While the real interest rate component of the output-gap channel is characteristic of large and relatively closed economies, the real exchange rate component of this channel is particular to open economies only.

The protracted adjustment process of the output-gap is due to its autoregressive nature. A lower coefficient for the lagged output gap by fifty percent shortens the length of the

[26] The amplitude of the inflation oscillation is bigger when the impulse response is in terms of a four-quarter MA of inflation.

downturn in economic activity by two quarters, almost eliminates the oscillation of the output gap and reduces its amplitude from 0.45 percentage points to 0.28 percentage points.

**IV. Output-gap vs. Inflation under different policy regimes.**

a. **Dynamic Forecasts**

The first exercise consists of tracing the evolution of the economy by performing dynamic forecasts under the three different policy regime we, identified in our estimation, over a given time period assuming that these regimes remain unaltered during this period. This exercise allows us to compare inflation-output-gap pairs at given dates under different policy regimes. This comparison is instrumental to answering the question of where would the Israeli economy have been at the end of the estimation period, in terms of inflation and of the output-gap under each one of the three different policy regimes, had they been implemented continuously since 1994. This exercise is not however equivalent to the calculation of the conventional sacrifice ratio. Here we consider the inflation-output trade-off conditional on the evolution of the exogenous variables of the model during the estimation period while in the conventional calculation of the sacrifice ratio this trade–off is unconditional.[27]

In the exercise we performed the dynamic simulations under the three policy regimes share the same exogenous variables. The results of this exercise indicate that the policy regime adopted after 1997 allows a much more substantial reduction of the inflation rate at the cost of a higher output-gap relatively to the two previous regimes (Figure 5). The inflation rate would have dropped from around 15 percent in 1994 to around zero at the end of the estimation period had the 1997 policy regime been implemented in 1994. The corresponding annual inflation rates at the end of the simulation period are 8.5 and 10 percent respectively for the 1994 and the 1990 policy regimes.

[27] This exercise does not suffer from Lucas critique since it cannot be claimed that the initial values of the endogenous variables and the exogenous variables on which the forecasts are based, were affected by the policy regimes changes. This comment applies also, but to a lesser extent in the case of the Fiscal Index, in view of the fact that the concept of fiscal consolidation was first introduced (1991) long before the adoption of inflation targets and the transition to a pure float.

The policy of 1994 looks relatively inefficient since it is consistent with a path for the output-gap not substantially different from that under the 1997 policy regime, but with an inflation path which is much higher than that of the 1997 and quite close to that of the 1990 regime. In other words while the output loss under the 1994 regime is close to that of the more austere 1997 regime the gain in terms of lower inflation is smaller. However in terms of cumulative output loss the 1994 regime indicates a loss of 2.4 percentage points of output for every unit of inflation reduction while the corresponding loss under the 1997 regime is 3.8.

It is worth noting that the dynamic simulations performed give rise to an increase in the output-gap at the end of the simulation period, regardless of the monetary policy stance, most probably as a result of changes in the exogenous variables. To eliminate to some extent the contribution of the exogenous variables, common to all three simulations, to the widening of the output gap we calculated the marginal cost of inflation in terms of output loss under the 1994 and the 1997 policy regimes relative to the 1990 regime. This comparison was based on the calculation of the additional cost in terms of output loss involved in the reduction of inflation under the 1994 and the 1997 regimes beyond the reduction already observed under the 1990 regime. This calculation indicates that this marginal output loss is equal to 60 under the 1994 policy regime and 13 under the 1997 regime, attesting to the relative inefficiency of the 1994 policy, implying a less costly monetary policy in the margin after 1997.

**b. The effects of the regime changes on the impulse responses to shocks**

In this section we examine the effects of the monetary policy and exchange rate regime changes on the impulse responses of the CPI inflation and of the output-gap to shocks augmenting the nominal (and real) exchange rates, the output-gap and the CPI inflation rate. We also discuss, when necessary, the evolution of additional endogenous variables following these shocks in order to understand the inflation and the output gap dynamics. In Figure 6 we present the impulse response functions to the various shocks and in Figure 7 we display the relative volatility of the CPI inflation and of the output-gap between the 1997 and the 1994 regimes.[28] The results of this exercise may be summarized as follows:

1) There exists a similarity in the impulse response of the CPI inflation and of the output-gap to shocks, especially those to the output-gap and to exchange rate between the 1990 and the 1994 regimes which is not shared by the 1997 policy regime. This finding confirms the one in the previous exercise, that the major structural break in the transmission of monetary policy occurred after 1997 with the transition to a floating exchange rate regime and not in 1994 after the formal adoption of inflation targets.

2) The BoI nominal interest rate displays a rise in its volatility across policy regimes in response to all three shocks (Figures 6.1.g, 6.2.f and 6.3.c).

3) The long-run CPI inflation volatility, measured by the cumulative deviation of the CPI inflation from its unperturbed level, remained constant or fell under the 1997 policy regime. This fall was concentrated in periods distant from the initial shocks, whereas during periods immediately after the shocks the picture is exactly the inverse. Namely the relative CPI inflation volatility remained constant or increased after 1997. (Figures 6.1.e, 6.2.d, 6.3.b and 7.1).

4) The output-gap volatility increased across policy regimes with the exception of the response to shocks to the exchange rate (Figures 6.1.a,6.2.e, 6.3.f and 7.2).

We analyze below the factors which triggered the aforementioned changes.

The BoI interest rate volatility

The BoI interest rate volatility is higher under the 1997 regime than under the two previous regimes because of the BoI more vigorous reaction to deviations of expected from targeted inflation, the higher sensitivity of the nominal exchange rate to changes in the nominal interest

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[28] We have calculated here the cumulative deviation of the CPI inflation and of the output-gap from their unperturbed level as the sum of the absolute values of the deviations in the IRF of these variables because of the inflicted shocks. This sum may be also considered as the volatility of the endogenous variables due to uniform positive shocks at time t and in previous periods.

rate and the higher speed with which changes in the exchange rate affect prices and expected inflation. These factors imply a rise in the efficacy of monetary policy after 1997. As a result of this higher efficacy the interest rate changed direction faster and to a more substantial degree, becoming thus more volatile after 1997.[29]

The nominal exchange rate depreciation effect on expected inflation and thereby on the nominal interest rate response after 1997 is most apparent in the case of shocks to the output-gap (Figure 6.1). A negative shock to economic activity gives rise to a real exchange rate depreciation (Figures 6.1.b and 6.1.c), since aggregate demand lower than potential output is consistent with a real exchange rate lower than its s.s value. The lower GDP prices (Figure 6.1.d), because of the fall in demand, are not enough to engineer the required real exchange rate depreciation which gives rise to a nominal exchange rate depreciation. While GDP prices fall after the shock, CPI prices increase (Figure 6.1.e) because the inflationary effect of the nominal exchange rate depreciation prevails over the inflation mitigating effect of lower GDP prices. This effect is faster and more substantial in the short-run after 1997 because of the shortening of the lag with which changes in the exchange rate affect CPI inflation. These developments which affect expected inflation with a lag together with the direct effect of the nominal exchange rate depreciation on expected inflation are reflected in a more significant deviation of the latter from targeted inflation under the 1997 regime (Figure 6.1.f). This more substantial deviation together with the stronger reaction of the BoI to such deviations after 1997, allow the inflation effect of the nominal exchange rate depreciation to dominate the interest rate mitigating effect of the expanding output-gap in the determination of the BoI interest rate. As a result the BoI interest rate is raised following the shock to the output-gap after 1997 instead of being lowered as under the previous policy regimes (Figure 6.1.g).

[29] The derivation of the BoI feedback rule from optimization principles could have allowed the derivation of the coefficient of the deviation of expected from targeted inflation as a function of variables which reflect the efficacy of the transmission mechanism of the monetary policy from interest rates to inflation. Our specification of the interest rate equation as an ad-hoc Taylor rule did not allow such a formulation of the interest rate equation.

The CPI inflation volatility

The cumulative long-run deviation of the CPI inflation from its unperturbed level remains constant or decreases under the 1997 policy regime in response to the three different shocks in the context of the present exercise (Figure 7.1). This is the result of the combined effect of three factors, the greater sensitivity of the exchange rate to changes in the domestic interest rate, the shortening of the lag with which changes in the exchange rate affect CPI prices and expected inflation and the increased vigor of the BoI interest rate reaction after 1997 to changes in the latter. Why is it then that in the short run the picture is reversed?

Shocks to the output-gap and to the nominal (and real) exchange rate are accompanied by a nominal exchange rate depreciation[30] (Figures 6.1.a and 6.2.a). The short-run inflationary effect of this nominal exchange rate depreciation is amplified after 1997 because of the shortening of the lag with which changes in the nominal exchange rate affect the CPI inflation and the stronger reaction of the latter to the former (equation 5) on impact. Why is it then that this mechanism is not active in the case of shocks to the CPI inflation?

While the effect of the change in the nominal exchange rate on actual inflation has been amplified after 1997 becoming contemporaneous to the latter, the exchange rate effect on inflation expectations is of a relatively small magnitude. It is however the deviation of expected and not of actual inflation which affects the setting of the interest rate by the BoI. In other words while the interest rate reaction of the BoI is commensurate after 1997 to the change in expected inflation it falls short, on impact, from the amplified change in CPI inflation allowing thereby an increase in the inflation rate volatility.

The main contribution to the increase in expected inflation and to its deviation from targeted inflation in the case of a shock to the CPI inflation rate (figure 6.3.a), is made by the CPI inflation itself with a one quarter lag (figure 6.3b). While the extent of this contribution did not change across policy regimes, the BoI reaction to it became more aggressive after 1997

[30] The shocks inflicted to the real exchange depreciation rate under the three policy regimes are not of the same magnitude. Their size has been determined so as to ensure a nominal exchange rate depreciation of one percentage point prior to the effect of the change in the interest rate on the nominal exchange rate.

(Figure 6.3.c) causing a more substantial nominal exchange rate appreciation (6.3.d) compared to the two previous regimes. Inflation and its cumulative deviations from its unperturbed level were thus mitigated.

The Output-gap volatility

The fact that shocks to the CPI inflation rate destabilize the output gap and the real exchange rate under the 1997 regime relative to the two previous regimes while the opposite is true for shocks to the exchange rate depreciation results from the different patterns in the evolution of the output gap and the real exchange rate under the two shocks. More precisely, following both shocks the real interest rate is eroded by inflation (Figures 6.2.c, 6.2.d and 6.3.e. 6.3.b) supporting the expansion of economic activity and leading to a negative output gap in the periods following the shock (Figures 6.2.e and 6.3.f). In the case of shocks to the exchange rate this activity enhancing effect is strengthened further by the real exchange rate depreciation (Figures 6.2.b). The expansion of economic activity sets forth a process of real appreciation which is also supported by the rise in the nominal interest rates in reaction to inflationary pressures (Figure 6.2.f and 6.3.c). In the case of shocks to the exchange rate, the real appreciation brings the real exchange rate (Figure 6.2.b) closer to its unperturbed level at a time when the negative output-gap (Figure 6.2.e) is narrowing due to its lagged reaction to the tighter monetary policy (Figure 6.2.c).

The closing of the gap, because of the earlier real interest rate increase, brought about by the relatively higher nominal interest rates and the fall in inflation, stops the process of the real exchange rate appreciation. The real exchange rate is thus prevented from falling excessively below its unperturbed level, in contrast to the case of inflation shocks, limiting thereby the upward deviations of the output-gap in future periods. This process is even more pronounced under the 1997 regime. More precisely when the real exchange rate is close to its unperturbed level, following its appreciation, the output-gap is still negative similarly to the two previous policy regimes but to a smaller extent because of the earlier and more substantial real interest rate increase (Figures 6.2.c and 6.2.e). The higher real interest rates after 1997 are the outcome of the more aggressive reaction of the BoI to inflation pressures after 1997 and of the relatively quick fall in inflation. The latter is brought about by the higher sensitivity of the nominal exchange rate to changes in the domestic interest rate and its immediate effect on CPI inflation after 1997. The smaller negative output-gap, after 1997, mitigates the process of real exchange rate appreciation, keeping the exchange rate even closer to its unperturbed level. It thus limits even further, relative to the two previous policy regimes, the exchange rate's downward deviation, which affects adversely the output-gap in subsequent periods (Figure 6.2.b), and reduces thereby the output-gap volatility.

In the case of the inflation shocks the aforementioned process of real exchange rate appreciation, triggered by the negative output-gap, destabilizes the real exchange rate**,** pushing it away from its unperturbed level (Figure 6.3.g) and not closer to it as was the case with shocks to the exchange rate. This process is more extreme under the 1997 policy regime because of a more aggressive monetary tightening supported by a faster fall in inflation and a more substantial real exchange rate appreciation. As a result by the time the output gap has narrowed, the real exchange rate is far below its unperturbed level and increasingly so under the 1997 regime. This implies a greater potential of destabilization of the output-gap because of the too low level of the real exchange rate, which materializes a few quarters later and leads to a relatively higher cumulative deviation of the output-gap from its unperturbed level after 1997 (Figure 6.3.f).

The rise in the cumulative deviations of the output-gap from its unperturbed level, under the 1997 policy regime, after its experiencing positive shocks, can be also explained by examining the interdependence in the evolution of the output-gap and the real exchange rate (Figure 7.2.b).

More precisely, the rise in the output-gap following the positive shock it experiences gives rise to a real exchange rate depreciation which supports the gap's gradual convergence to its unperturbed level, after the shock, while pushing the real exchange rate away from its unperturbed level. When the gap is close to be eliminated, the real exchange rate is close to its peak starting its gradual appreciation in its convergence to its unperturbed level. This real exchange rate appreciation is accompanied by a nominal exchange appreciation (Figures 6.1.b –6.1.c). The nominal exchange rate appreciation pushes actual and expected inflation below their unperturbed levels (Figures 6.1.e and 6.1.f) and since the output-gap is close to zero the central bank responds by reducing its interest rate (Figure 6.1.g). The lower nominal interest rate mitigates the process of exchange rate appreciation keeping the real exchange rate above its unperturbed level and allowing thereby output to remain above potential during the following periods. The greater direct and indirect sensitivity of actual and expected inflation to changes in the exchange rate after 1997 is reflected in a more substantial fall in actual and expected inflation which support a relatively more substantial interest rate reduction (Figure 6.1.g). This relatively substantial interest rate reduction under the 1997 policy regime decelerates the process of the real exchange rate appreciation which becomes, as a result, more protracted under the 1997 policy regime relatively to the two previous regimes. This implies that the real exchange rate remains above its unperturbed level for a longer period under the 1997 regime (figure 6.1.b) and by the same token the output-gap stays longer in negative territory with output above potential (figure 6.1.a). This relatively protracted deviation of the output-gap from its unperturbed level leads to its observed greater cumulative deviation from its unperturbed level (Figure 7.2.b).

## V. Conclusions

We presented in this paper a small open economy macro-economic model under a floating exchange rate regime including a Taylor-rule in which output is demand determined in the short run. The model is characterized by a real exchange rate overshooting, following a temporary increase in the foreign interest rate, and the initial depreciation of the real exchange rate is followed by a process of real exchange appreciation along the convergence path to the steady state equilibrium. Along this path aggregate demand is greater than potential output, inflation is above target and the real interest rate is higher than its s.s level. Similar dynamics are consistent with a negative shock to domestic interest rates and they replicate the evolution patterns of inflation and the real interest rate following the two percent interest rate reduction by the BoI at the end of 2001. Along this path aggregate demand is greater than potential output, inflation is above target and the real interest rate is higher than its s.s level. We used this model as a base for the estimation of a 3sls quarterly model of the Israeli economy between 1990 and 2002. In this model monetary policy affects real activity in the short run mainly through its effect on the real exchange rate and on the short-term ex-post real interest rate. The estimation results imply the existence of two major transmission channels of the monetary policy to prices, a nominal and a real activity channel. As a result the monetary policy effect on prices is characterized by a double dip (peak). The first dip, in the case of monetary tightening, can be attributed to the nominal exchange rate channel. This channel is characteristic of small and open economies like Israel ( Ball(1999) and Djivre and Ribon (2003)). The second dip can be attributed mainly to the delayed effect of real interest and exchange rate changes on economic activity, 8 -16 quarters after the change in interest rates, and through it on inflation. The delay with which real activity affects inflation in Israel puts the Israeli economy relative to other economies, at the higher end of the domain regarding the lag with which the real activity channel becomes effective. While the real interest rate effect of the output-gap channel, following the tightening of monetary policy, constitutes the conventional channel of monetary policy transmission characterizing closed economies (Mankiw (2000) and Vinals & Valles (1999)), the real exchange rate effect of the output-gap channel is particular to open economies only.

The estimation results allowed us to identify structural breaks in 1994.II and in 1997.III both in the BoI interest rate equation and in the structural equations of the economy related to the nominal exchange rate. The structural breaks observed consist in a gradual tightening of the monetary policy after 1994 and 1997 and a greater exchange rate flexibility. The observed tightening of monetary policy had two aspects. First it was more aggressive with respect to deviations of inflation expectations from the inflation target and second it targeted a higher equilibrium short-term real interest rate after 1997. The changes in capital flows and in the exchange rate regime affected the transmission mechanism, according to the estimation results, mainly after 1997 with the transition to a free float. These changes were reflected in a higher sensitivity of the real and the nominal exchange rate to changes in the domestic and foreign interest rates, in the shortening of the lag with which nominal exchange rate depreciation affects CPI inflation, alongside the strengthening of this effect, and in the contribution of the nominal exchange rate depreciation in the formation of inflation expectations. The estimation results indicate also that monetary policy was characterized by interest rate smoothing and that the deviation from the long-run relationship between wages, prices and productivity is made through the adjustment of nominal wages while business sector prices remain exogenous to this process.

The results of the dynamic simulation we performed indicate that in most cases our model succeeds in replicating the actual changes in the direction of the evolution of the endogenous variables. It performs however rather poorly in the case of nominal wages as a result of the poor performance of the productivity equation. The forecasts for inflation and inflation expectations for the years 1992-1994 are high relatively to the actual evolution of these two variables and they imply that our model does not account satisfactorily for the fall in inflation rate after 1991. An effort should be made therefore in future research to account for the drop in inflation after 1991 and an alternative approach for the calculation of productivity and of changes thereof could improve the model's performance in the case of wages.

We also performed dynamic forecasts under the aforementioned different policy regimes and compared inflation-output-gap pairs at given dates. The results of this exercise indicate that the policy regime adopted after 1997 allowed for a relatively substantial reduction of the inflation rate at the cost of a higher output-gap (Figure 4). The fundamental structural break in monetary policy which occurred after 1997, finds also support in the impulse response functions to shocks to the output gap, the CPI inflation rate and the real and nominal exchange depreciation rate.

It also transpires from the impulse response functions analysis that the transition to the 1997 policy regime was characterized by a higher interest rate volatility. A similar result was obtained for the CPI inflation volatility under shocks to the output-gap and to the exchange rate and for the output-gap volatility under shocks to the output-gap and to the CPI inflation.

The higher nominal interest rate volatility, after 1997, can be attributed to the higher efficacy of the monetary policy especially after 1997 which allowed a faster and more substantial change in the direction of the interest rate which becomes thus more volatile.

The change in interest rates by the BoI while being commensurate to the change in expected inflation, after shocks to the output-gap and to the exchange rate under the 1997 policy regime, fell short of the rise in inflation, allowing thereby an increase in its volatility under the 1997 regime. This is not the case under shocks to the CPI inflation rate. While the effect of these shocks on expected inflation and its deviation from targeted inflation has not changed across policy regimes, the BoI reaction to such deviations became more aggressive after 1997 giving rise to a more substantial nominal exchange rate appreciation, mitigating thus inflation and its volatility.

The rise in the output-gap volatility under the 1997 policy regime, in response to inflation shocks, and its fall in response to exchange rate shocks reflect the fact that, as the output-gap closes, in the first case, the real exchange rate shifts away from its unperturbed level and much more so under the 1997 regime, while exactly the opposite is true in the second case. As a result by the time the output gap has narrowed, after shocks to the inflation rate, the real exchange rate is far below its unperturbed level and increasingly so under the 1997 regime. This implies a more substantial deviation of the output-gap from its unperturbed level in future periods, and hence a higher output-gap volatility than under the two previous policy regimes. In the case of shocks to the exchange rate the faster closure of the gap after 1997, because of the relatively higher nominal and real interest rates, puts an end to the real exchange rate appreciation when the output-gap is even closer to its unperturbed level. The greater proximity of the output-gap to its unperturbed level after 1997 weakens the appreciation effect of the negative output-gap on the real exchange rate, preventing it from entering deep into positive territory and destabilizing thereby economic activity in future periods and the output-gap volatility is as a result reduced.

## References


Andres, J., R. Mestre and J. Valles (1997), "A Structural Model for the Analysis of the Impact of Monetary Policy on Output and Inflation," in *Monetary Policy and the Inflation Process*, Conference Papers Volume 4 BIS, Basle.

Artstein Y., L. Meridor, Z. Sussman and F. Wieder (1978), "An Econometric Model of the Israeli Economy," Research Department, Bank of Israel.

Aviran O. (1998), "The Impact of Monetary Policy on Inflation and Output in Israel 1988-1996," Discussion paper 98.04, The Maurice Falk Institute for Economic Research, Jerusalem.

Azoulay, E. and D. Elkayam (1997), "The Short-Term Effect of the Interest and Exchange Rates on Inflation in Israel 1990-96," *The Economic Quarterly* 1, pp. 76-85 (Hebrew).

________________________ (1999), "A Model to Determine the Influence of Monetary Policy on Activity and Prices in Israel 1988-1996," Bank of Israel Monetary Department Discussion Papers Series No. 99.01. (Hebrew).

Ball, L. (1999), "Policy Rules for Open Economies," in Taylor J. ed., *Monetary Policy Rules,* The University of Chicago Press, Chicago.

Bank of England (1999), "*Economic Models at the Bank of England*", Bank of England.

Beenstock, M., Y. Lavi and A. Offenbacher, (1994) "A Macroeconomic Model for Israel, 1962-1990: A Market Equilibrium Approach to Aggregate Demand and Supply," *Economic Modelling*, 11(4), pp. 413-462.

Bufman, G. and L. Leiderman (1995), "Israel's Stabilization: Some Important Policy Lessons," *The Economic Quarterly,* 4. (Hebrew).

------------------------------------ (1998), "*Monetary Policy and Inflation in Israel*," Discussion Paper No. 98.04, Research Department, Bank of Israel.

Ceccetti, S. G. (1998), "Policy Rules and Targets: Framing the Central Bank's Problem," *Federal Reserve Bank of New-York Policy Review* (June), pp.1-14.

Christiano L. J., M. Eichenbaum and C. L. Evans (1998), "Monetary Policy Shocks: What Have We Learned and to What End?", NBER Working Paper Series No. 6400, February 1998.

Clarida R., J. Gali and M. Gertler (1998), "Monetary Policy Rules in Practice Some International Evidence," *European Economic Review* 2, pp. 1033-1067.

____________________ (1999), "The Science of Monetary Policy: A New Keynesian Perspective, " *Journal of Economic Literature,37,*pp.1661-1707

____________________ (2000), " Monetary Policy Rules and Macroeconomic Stability: Evidence and some Theory," *The Quarterly Journal of Economics February 2000,* pp. 147-180.

Condor, Y. (1983), "An Annual Econometric Model for the Israeli Economy," Discussion Paper 10-83, The Pinhas Sapir Center for Development, Tel-Aviv University. December (Hebrew).

Cukeirman, A., E.A. Pazner, and A. Razin (1977), "A Macroeconometric Model of the Israeli Economy," *Bank of Israel Economic Review* 44, pp. 29-64.

Dahan, M. and M. Strawczynski (1997), "Fiscal Policy and Inflation in Israel", Bank of Israel Research Department Discussion Paper Series No. 97.04 (Hebrew).

De Fiore F. (1998), "The Transmission of Monetary Policy in Israel," IMF Working Paper, Aug. 1998, WP/98/114.

De Gregorio, J., A. Giovannini, and Wolf, H.C. (1994), "International Evidence on Tradables and Nontradables Inflation," *European Economic Review* 38, pp.1225-1244.

Djivre, J. and S. Ribon (2000), "Monetary Policy, the Output_Gap and Inflation: A Closer Look at the Monetary Policy Transmission Mechanism in Israel 1989-1999,"Bank of Israel Research Department Discussion Paper Series No. 2000.09.

Djivre, J and D.Tsiddon (2002), "A Monetary Labyrinth: Instruments and the Conduct of Monetary Policy in Israel: 1987-1998" in Ben Bassat. A ed *in The Israeli Economy1985-1998: From Government Intervention to Market Econom,.M.I.T Press, Cambridge.MA.*

Drachman, R. And B.-Z. Zilberfarb (1987), "An Econometric Model of the Real Sector in Israel," *Economic Modelling* 4(3), July, pp.370-376.

Duguay, P. (1994), "Empirical Evidence on the Strength of the Monetary Transmission Mechanism in Canada: An Aggregate Approach," *Journal of Monetary Economics* 33(1), pp. 39-61.

Elkayam, D. (2001), "Inflation Targets and Monetary Policy: A Model for Analysis and Forecast," Bank of Israel, Monetary Department, Discussion Paper Series No. 2001.01.

Evans M. K. (1970), "An Econometric Model of the Israeli Economy," *Econometrica,* 38(5), Sept., pp.624-659.

Fuhrer, J., (1995), "The Phillips Curve Is Alive and Well," *New England Economic Review*, pp. 51-56.

Fuhrer, J., (1997a), " The (Un)Importance of Forward-Looking Behavior in Price Specifications," *Journal of Money Credit and Banking,29,* pp. 338-350.

Fuhrer, J., (1997b), " Towards a Compact Empirically-Verified Rational Expectations Model for Monetary Policy Analysis, "*Carnegie-Rochester Conference on Public Policy, 47,*pp.197-230.

Fuhrer, J., and Moore, G., (1995), " Monetary Policy Trade-offs and the Correlation between Nominal Interest Rates and Real Output, " *The American Economic Review,85,*pp. 219-239.

Gertler, M. and Gilchrist S. (1993), "The Role of Credit Market Imperfections in the Monetary Transmision Mechanism: Arguments and Evidence," *Scandinavian Journal of Economics*, 95(1), pp.43-64.

Gottlieb, D. and S. Ribon (1999), "Capital Flows of the Private Sector and Monetary Policy in Israel - October 1988 - March 1997," *The Economic Quarterly* 136-174*,* (Hebrew)

Gruen, D., A. Pagan, and Ch. Thomson (1999), "The Phillips Curve in Australia," *Journal of Monetary Economics* 44, pp. 222-258.

Haldane, A. (1995), "Targeting Inflation," presented at the Conference of Central Banks on the Use of Inflation Targets organized by the Bank of England, pp. 170-201.

Hercowitz Z., Y. Lavi, Melnick R. and O. Eshchar (1997), "A Framework for a Macro-Economic Analysis of the Israeli Economy," Research Department, Bank of Israel, Working paper (not published, Hebrew).

King, R.G. and M.W. Watson (1994), "The Post-War U.S. Phillips Curve: A Revisionist Econometric History," *Carnegie-Rochester Conference Series on Public Policy* 41, pp. 157-219.

Lavi, Y. and N. Sussman, (1997) "Policy-Induced Shifts in Phillips Curve Tradeoffs," presented at the Conference on Inflation and Disinflation in Israel, June 22-23, 1997 (Hebrew).

Mankiw, N.G. (2001), "The Inexorable and Mysterious Tradeoff between Inflation and Unemployment," *Economic Journal* 111(471), May 2001,pp.C45-C61.

Mc Callum,B. and Nelson, Ed., (2001), " Monetary Policy for an Open Economy: An Alternative with Optimizing Agents and Sticky Prices," CEPR Discussion Paper No. 2756, April.

Melnick, R. (2000), "Disinflation with Inflation Targeting in a Small Open Economy," unpublished.

Minford, P., F. Perugini, and N. Srinivasan, (2001), "The Observational Equivalence of Taylor Rule and Taylor-Type Rules," CEPR Discussion Paper No. 2959, September.

Mualem, Y. and M. Strawczynski (1998), "The Utilization of Production Factors: Quarterly Computation," Research Department, Bank of Israel, unpublished.

Rogoff, K. (1996), "The Purchasing Power Parity Puzzle," *Journal of Economic Literature* 34, June, pp. 647.

Rudebusch, G. D. and L.E.O. Svensson (1998), "Policy Rules For Inflation Targeting," NBER Working Paper 6512.

Svensson, L.E.O. (2000), " Open Economy Inflation Targeting, "*Journal of International Economics,50,*pp.155-183.

Taylor, J.B. (1993), "Discretion versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy,*39, pp. 195-214.

------------- (1994), "The Inflation/Output Variability Trade-off Revisited," in Fuhrer J. Ed. *Goals, Guidelines and Constraints Facing Monetary Policymakers*, Federal Reserve Bank of Boston.

Watanabe, T. (1997), "Output Gap and Inflation: The Case of Japan," in *Monetary Policy and the Inflation Process*, Conference Papers Volume 4 BIS, Basle.

Vinals and Valles, J. (1999), "On the Real Effects of Monetary Policy: A Central Banker's View, CEPR Discussion Paper Series No. 2241, September.

Zussman A. (1998), *"The Real Exchange Rate - Israel 1960-1996, The Long Run and the Short Run",* Bank of Israel Research Department Working Paper Series No. 98.05 (Hebrew).

## Figure 3: Dynamic Simulation:1990.1-2002.2

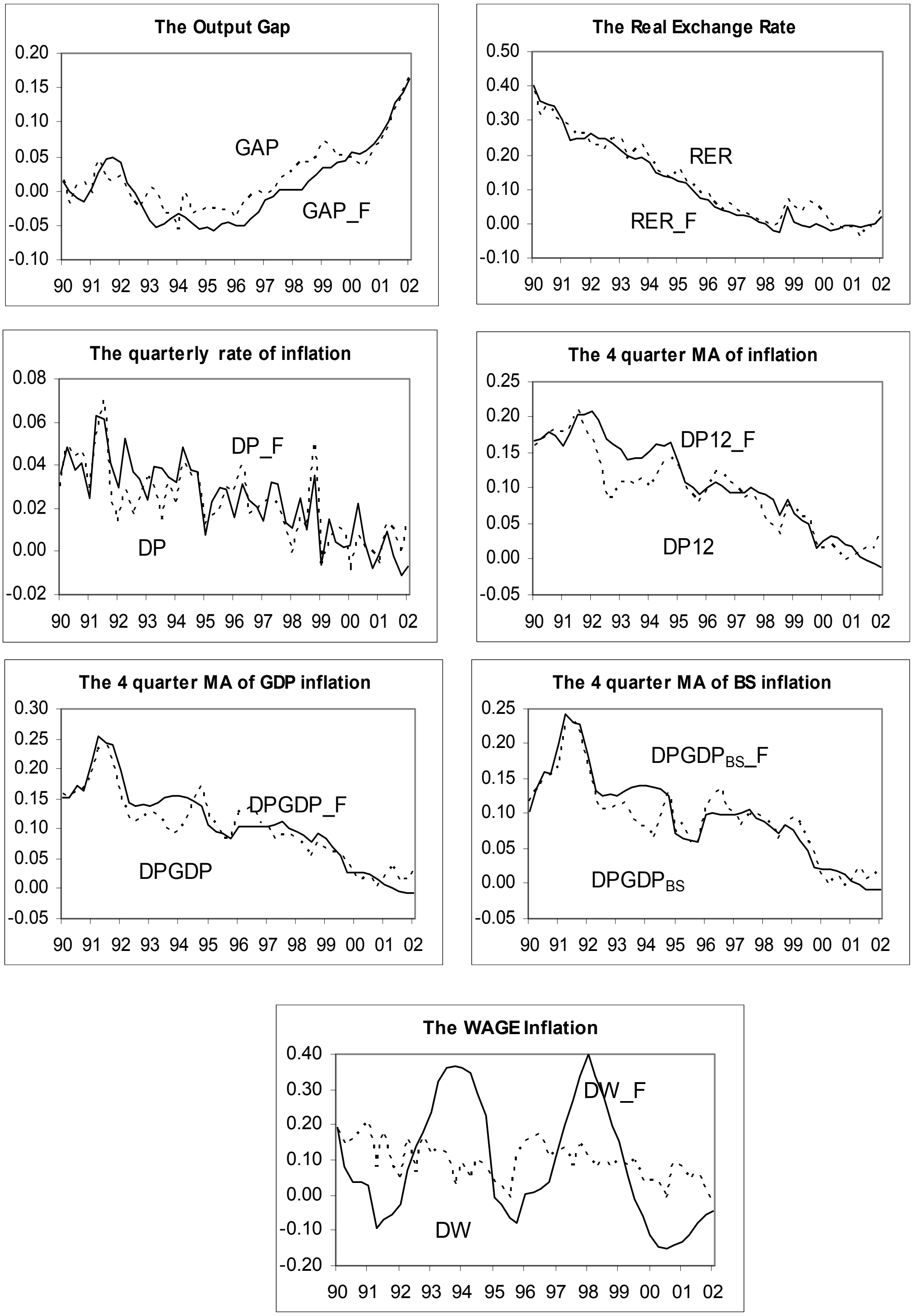


**Figure 3** (con'd)

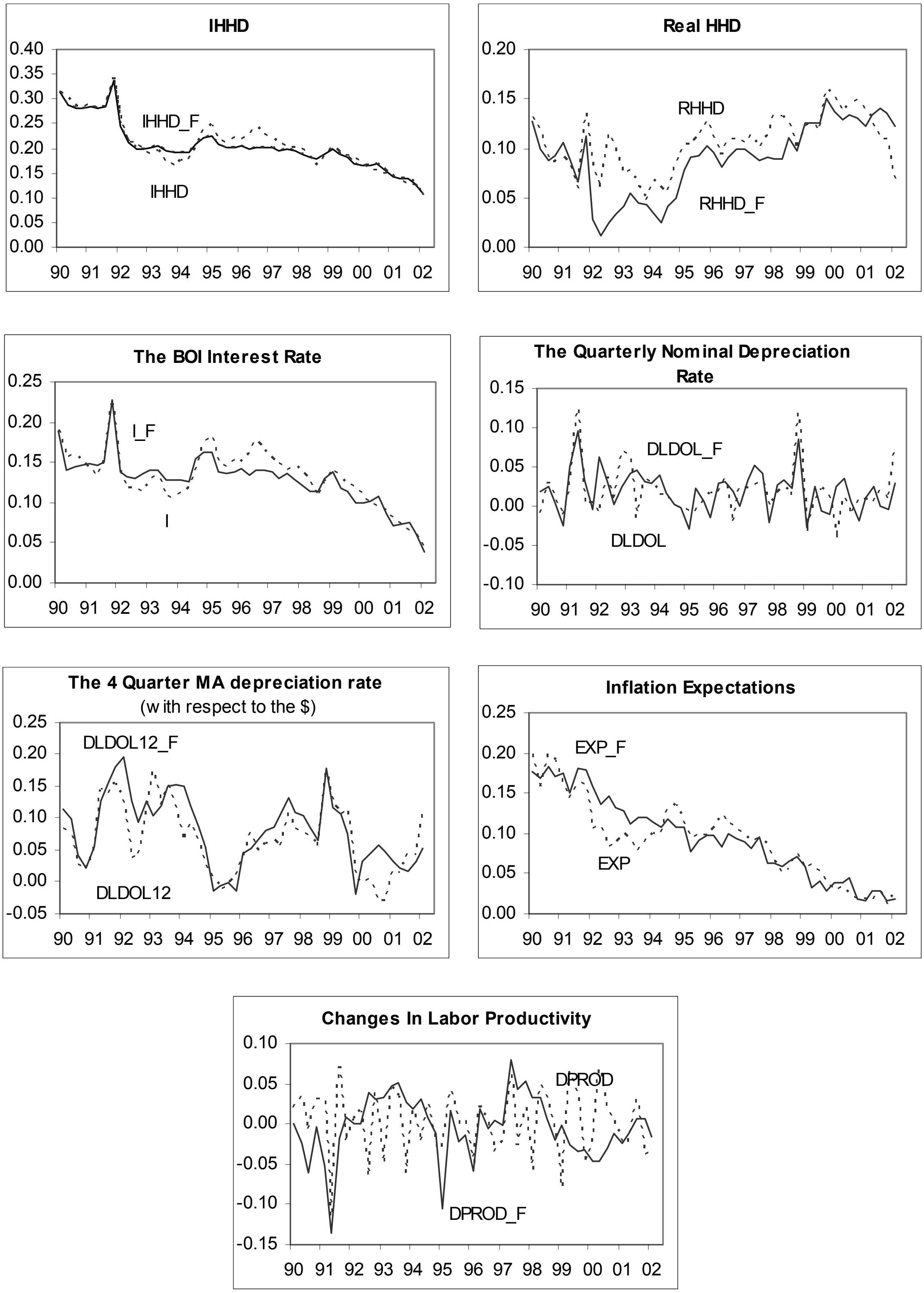


**Figure 4: Characterization of Monetary Policy IRF to a 1% shocks in the BOI Interest Rate**

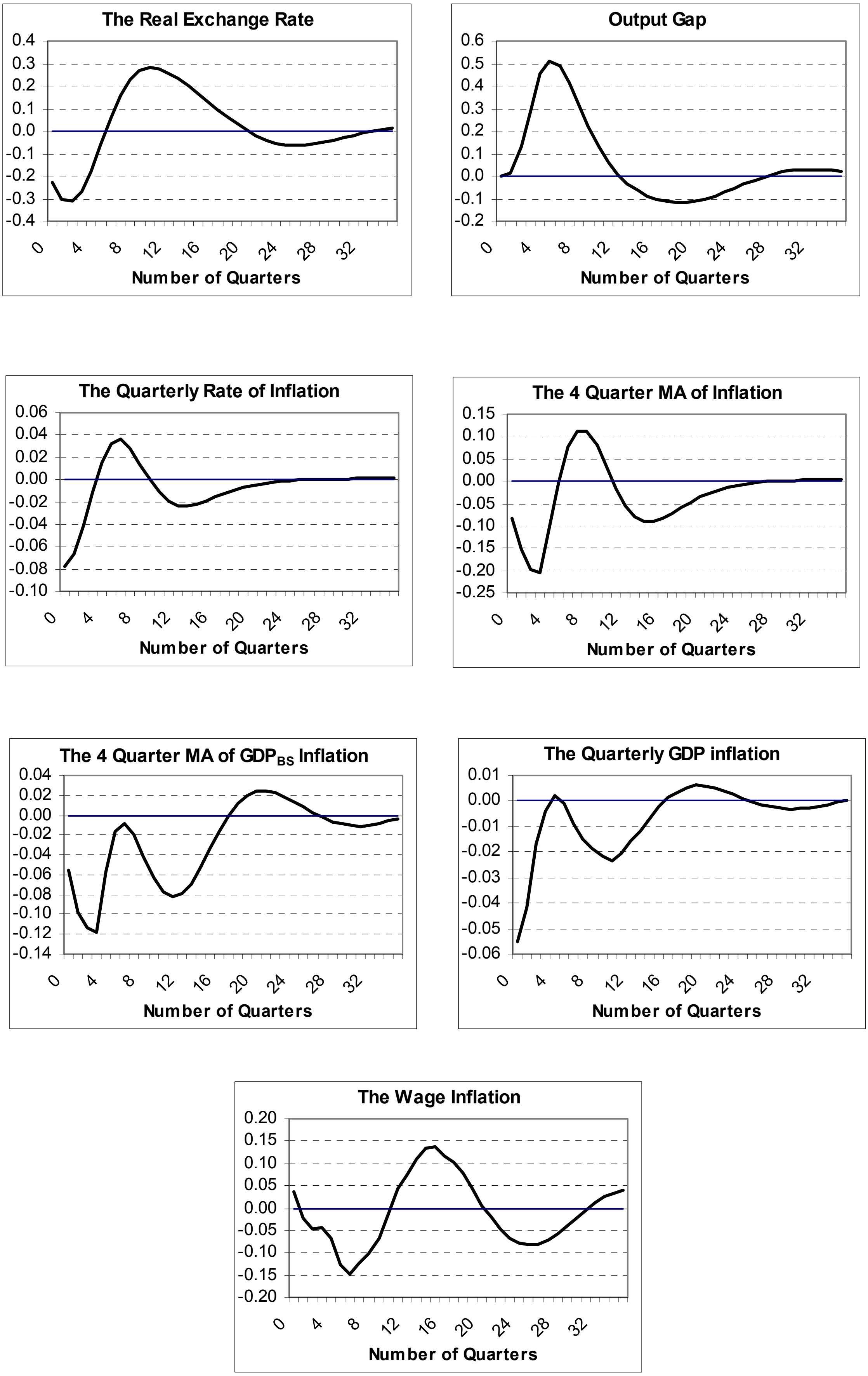


**Figure 4:** (con'd)

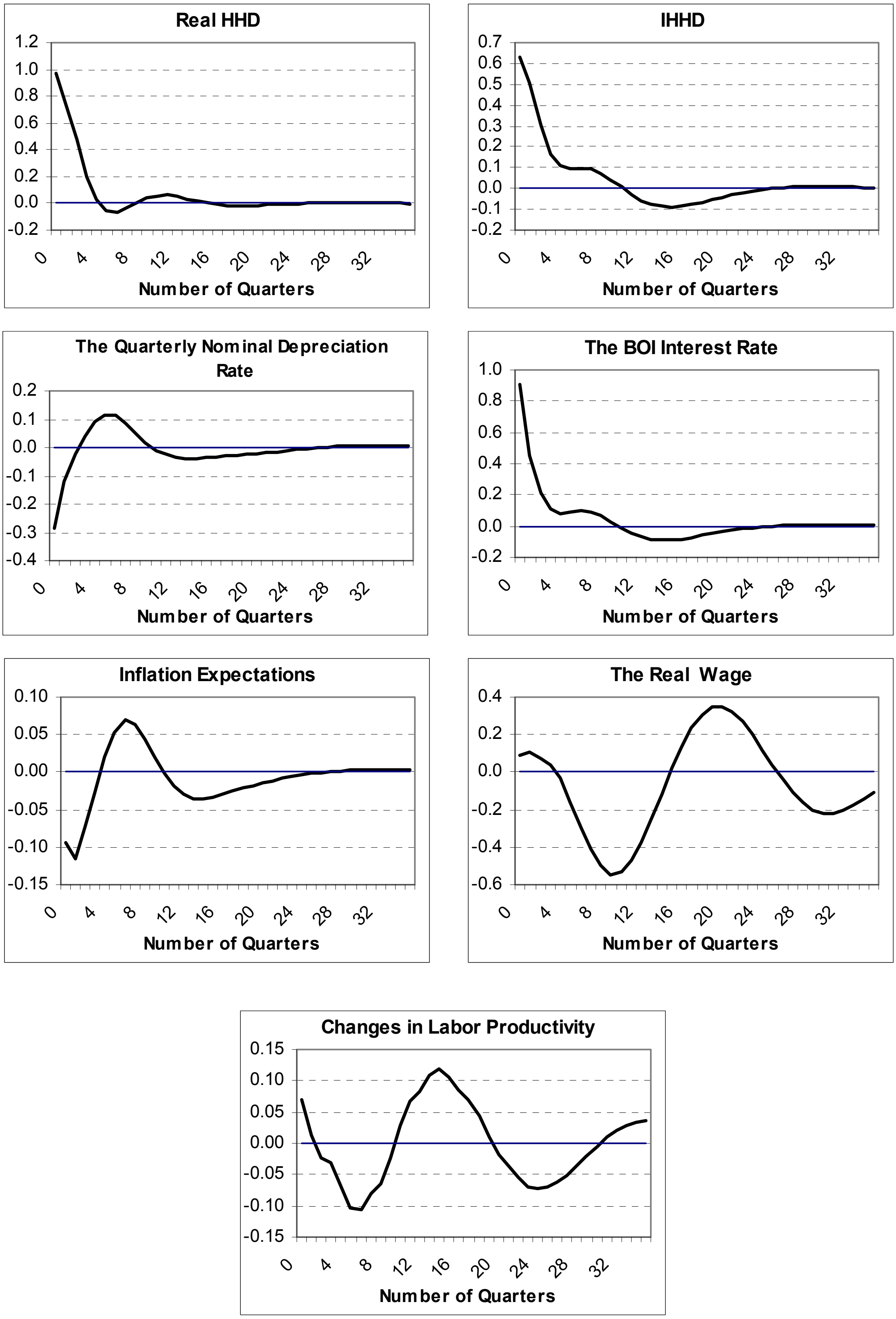
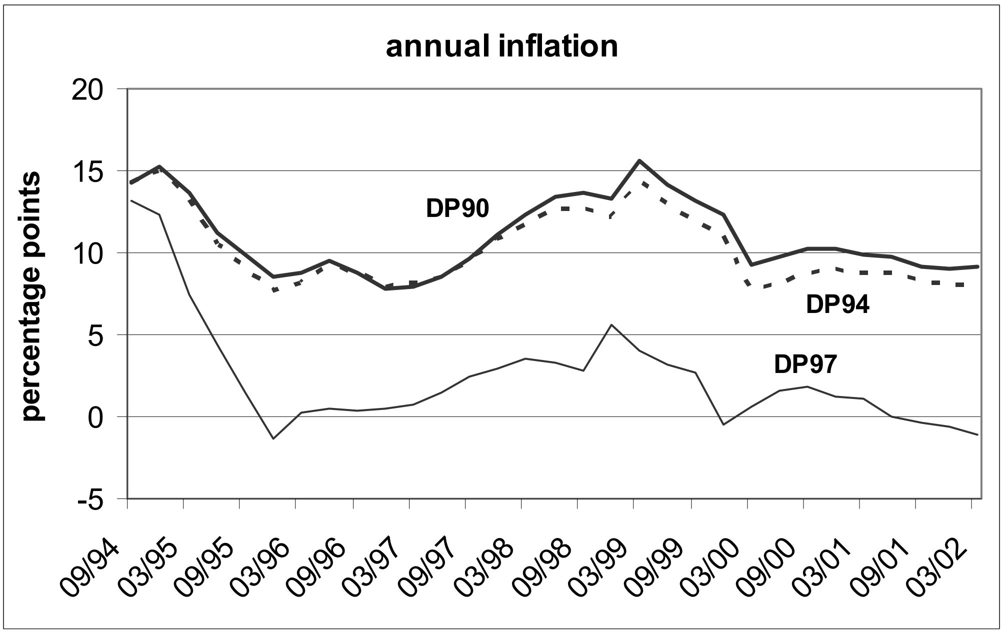
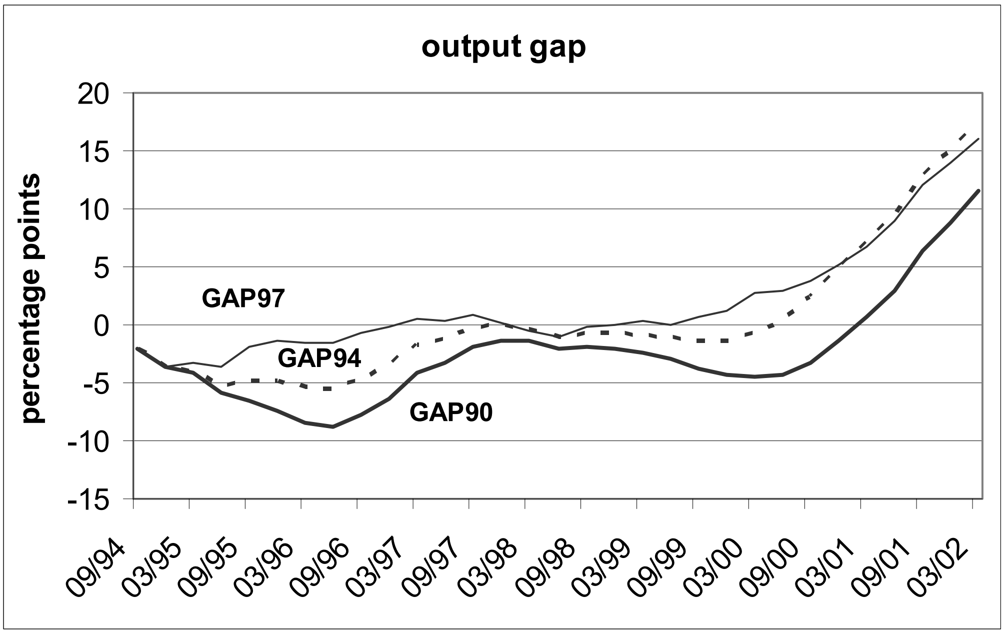


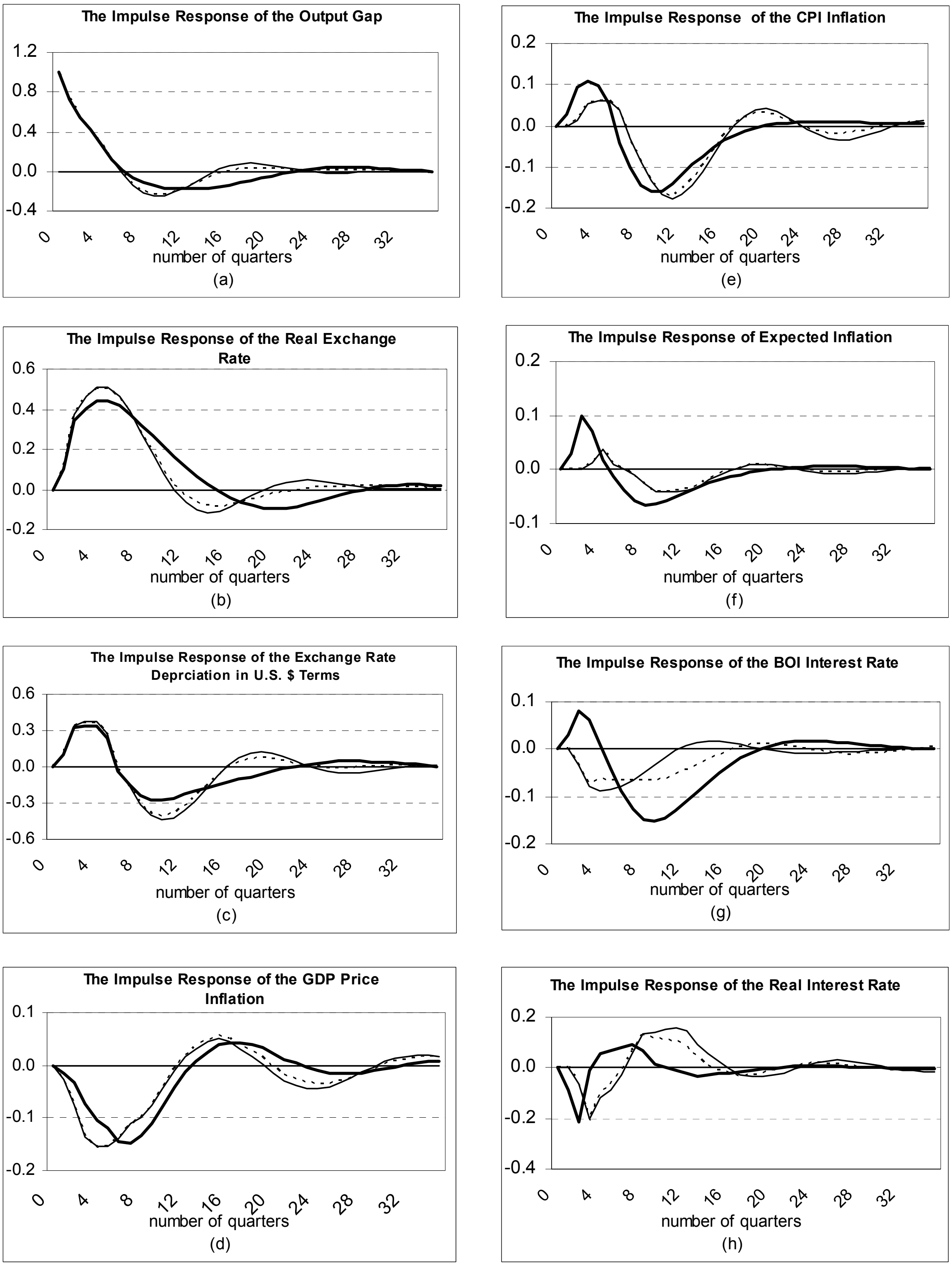
**Figure 5: Dynamic simulations under different policy regimes, 1994:3 – 2002:1**



## Figure 6.1: A percentage point shock to the output gap

1990 regime ——— 1994 regime ------ 1997 regime ━━━



## Figure 6.2: A percentage point shock to the exchange rate depreciation

1990 regime ——— 1994 regime - - - - - - 1997 regime ▬▬▬

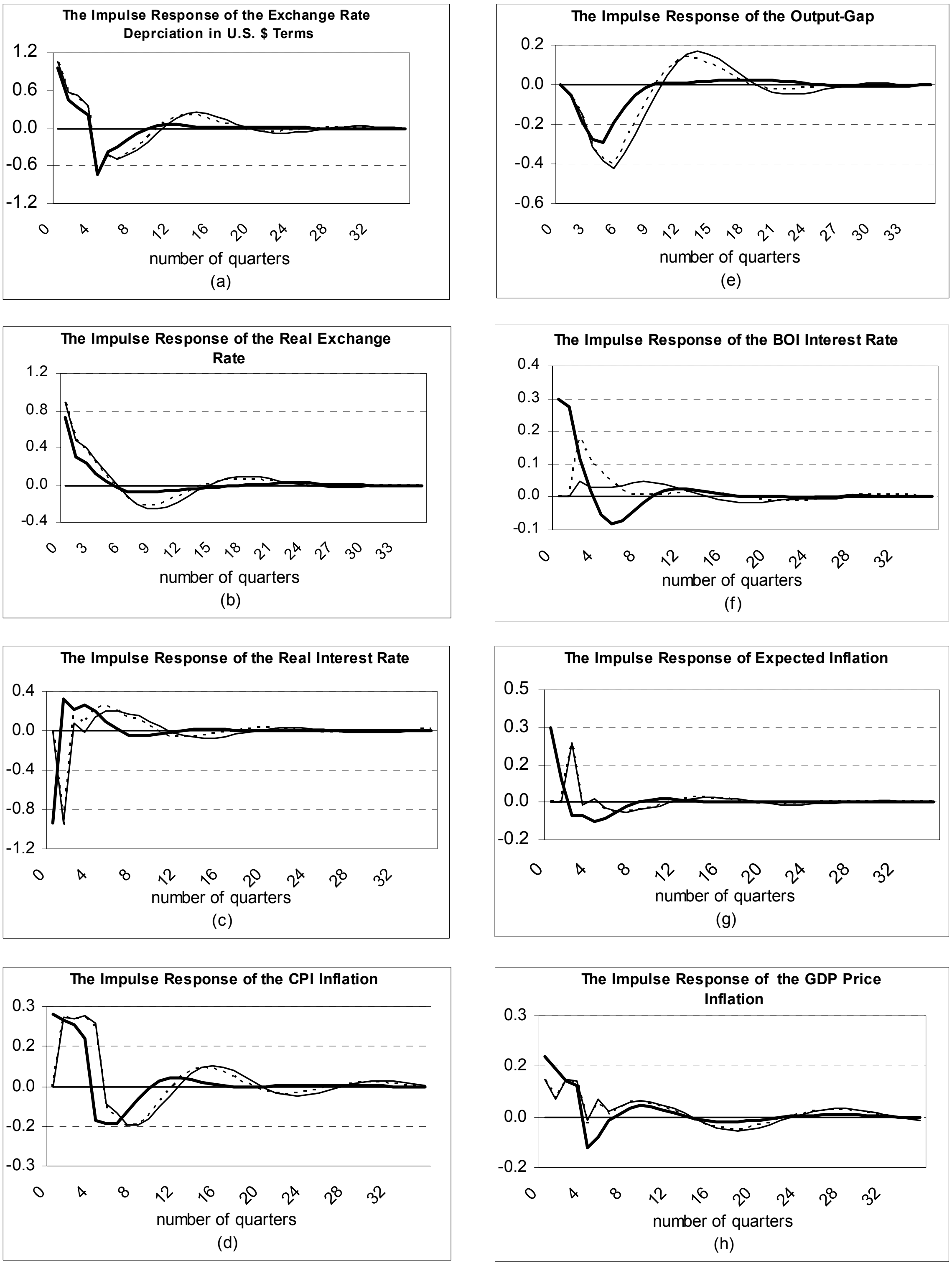
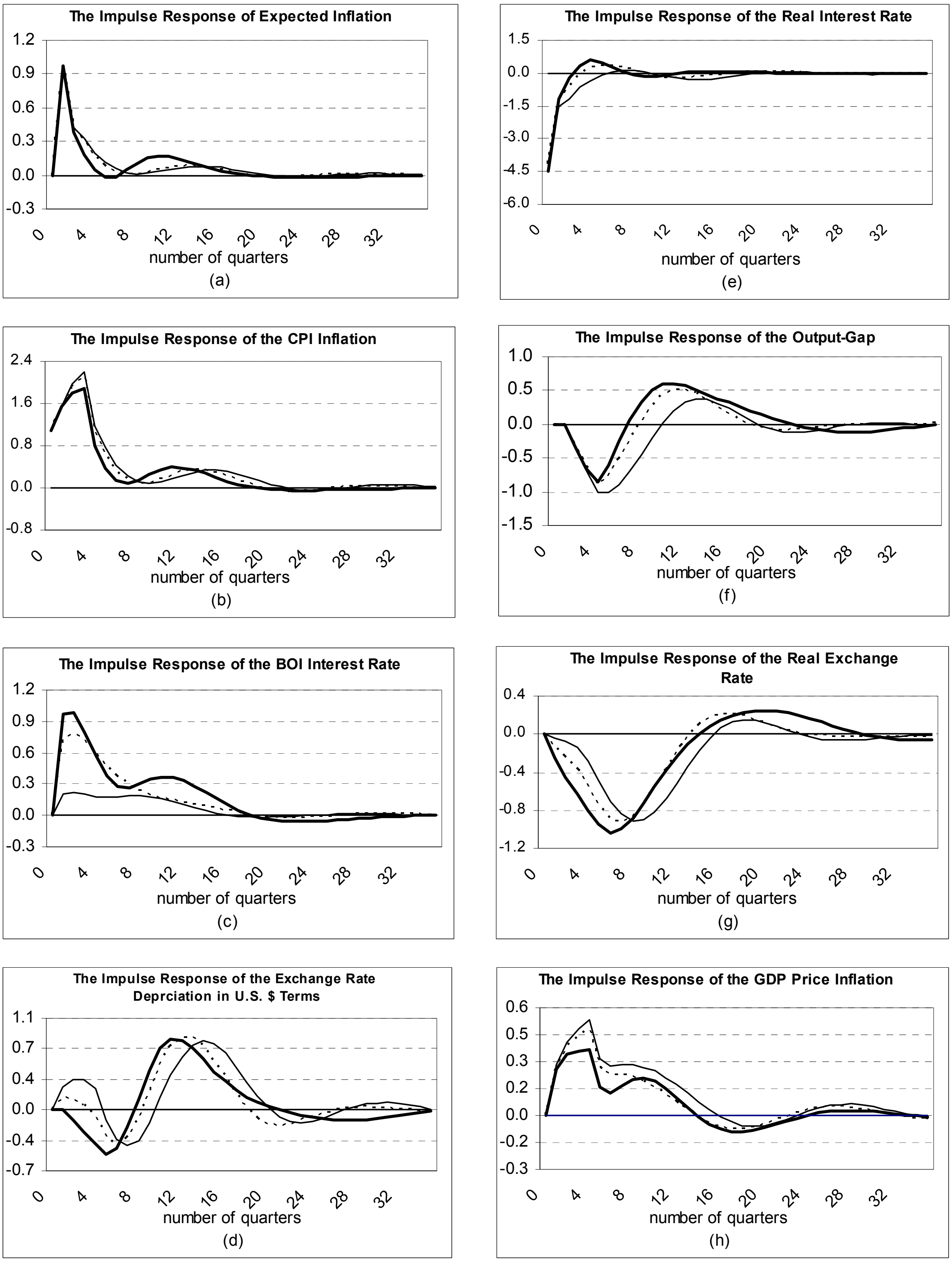
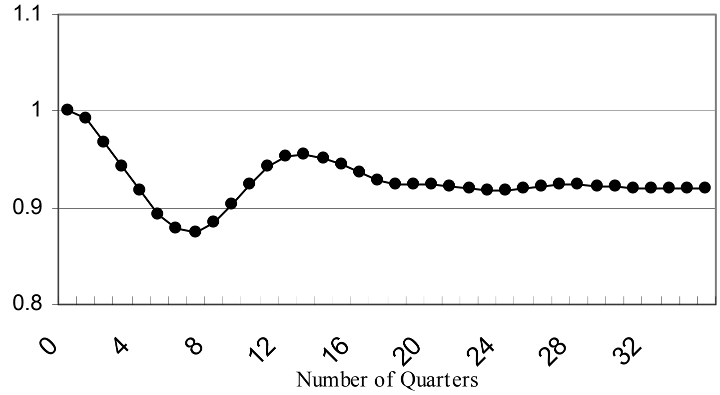


**Figure 6.3: A percentage point shock to the CPI inflation**

1990 regime —— 1994 regime - - - - - 1997 regime ▬▬

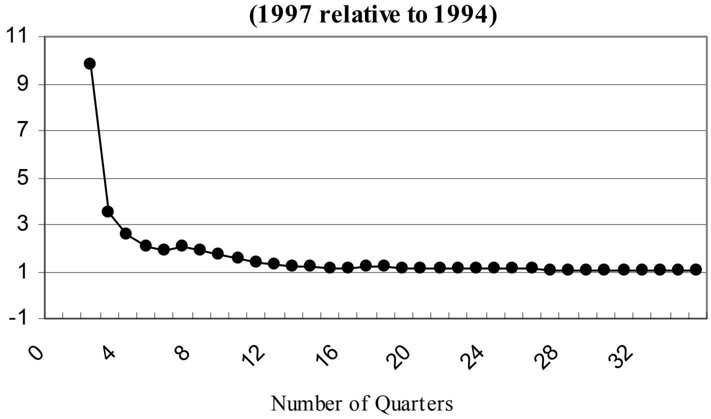


**Figures 7.1:**
**Cumulative absolute values deviations of CPI inflation following a-one-percent shock to the CPI inflation (1997 relative to 1994)**



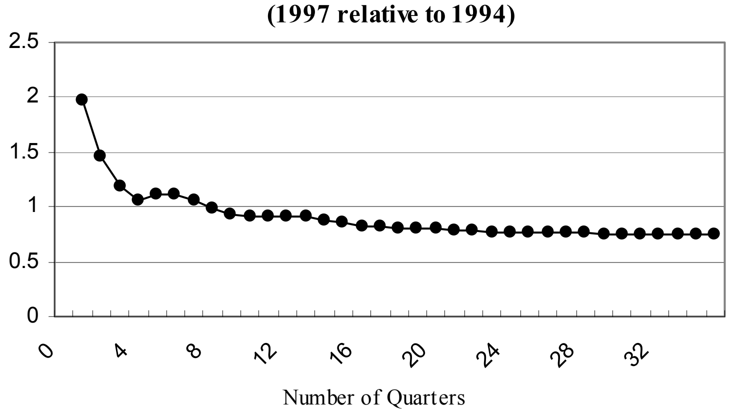

(a)

**Cumulative absolute values deviations of CPI inflation following a-one-percent shock to the Output Gap (1997 relative to 1994)**



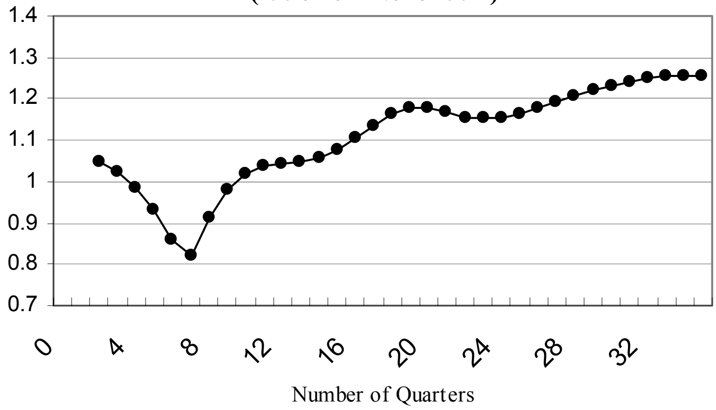

(b)

**Cumulative absolute values deviations of CPI inflation following a-one-percent shock to the exchange rate (1997 relative to 1994)**



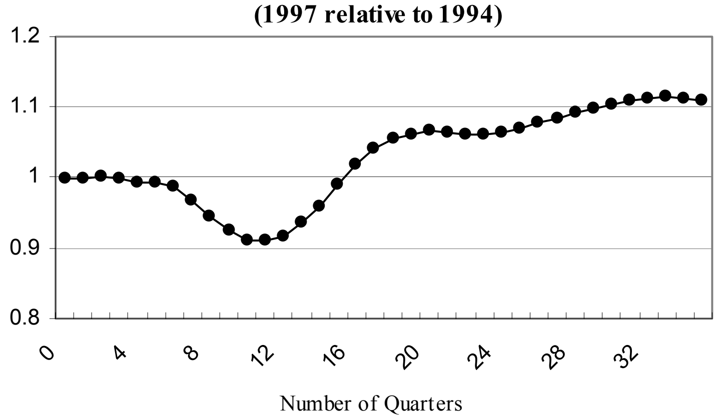

(c)

**Figures 7.2:**
**Cumulative absolute values deviations of Output Gap following a-one-percent shock to the CPI inflation (1997 relative to 1994)**



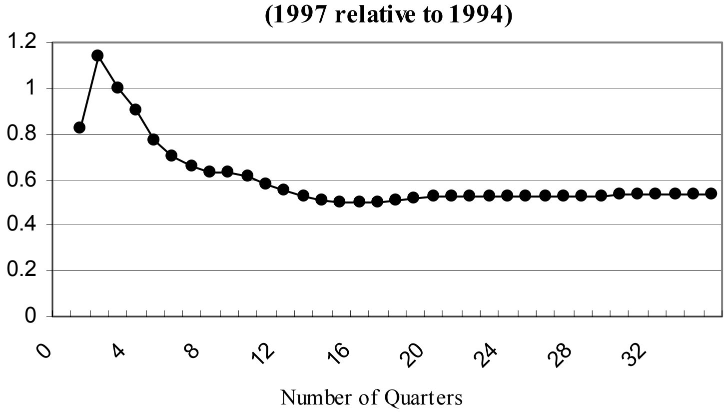

(a)

**Cumulative absolute values deviations of Output Gap following a-one-percent shock to the Output Gap (1997 relative to 1994)**




(b)

**Cumulative absolute values deviations of Output Gap following a-one-percent shock to the exchange rate (1997 relative to 1994)**




(c)

## Appendix 1

In this appendix we derive analytically the reaction of the real exchange rate, $q_t$ , to a positive shock in the foreign interest rate. Consider the benchmark economy described by equations (1) – (5) in section II. Suppose there is an (unexpected) increase in the foreign interest rate i* in period t that is known to persist for a few periods ahead disappearing thereafter. Solving simultaneously equations (1), (2) and (3') for $Gap_t$ and $(\pi^e_t - \pi^T)$ as functions of $q_t - \bar{q}$ and of $\varepsilon$ we get:

(A:1) $$\pi_t^e - \pi^T = -\frac{a_2}{\Delta}(1 + a_1 b_2 + f_1 b_2)(q_t - \bar{q}) + \frac{f_1(1 + a_1 b_2)}{\Delta}\varepsilon$$

(A:2) $$Gap_t = -\frac{a_2}{\Delta}(f_1(1 + b_1) + a_1 b_1)(q_t - \bar{q}) + \frac{f_1 a_1 b_1}{\Delta}\varepsilon$$

Where $\Delta = f_1(1+b_1+a_1b_2) > 0$.

Applying the expectations operator to (A.1) and comparing the obtained expression for $_{t-}q_t^e$ and $q_t$ allows us to get that:

(A:3) $$q_t - {}_{t-}q_t^e = \frac{f_1(1 + a_1 b_2)}{a_2(1 + a_1 b_2 + f_1 b_2)}\varepsilon > 0.$$

As a result of our assumption of RE, of the unexpected nature of the shock on impact and of the economy being at the s.s equilibrium prior to the shock, it is also true that $\bar{q} = {}_{t-}q_t^e$ and as a result:

(A.4) $$q_t - \bar{q} = \frac{f_1(1 + a_1 b_2)}{a_2(1 + a_1 b_2 + f_1 b_2)}\varepsilon > 0.$$

so that the real exchange rate increases on impact in reaction to the shock to the foreign interest rate. The same result may be also reached through the following reasoning: Expected inflation is equal to the inflation target on impact since the shock to the foreign interest rate was unexpected. According to expression (A.1) this observation implies that:

(A.5) $$0 = -\frac{a_2}{\Delta}(1 + a_1 b_2 + f_1 b_2)(q_t - \bar{q}) + \frac{f_1(1 + a_1 b_2)}{\Delta}\varepsilon$$ which gives rise to (A.4) above.

Our assumption that the shock persists for a few periods after it occurs with perfect certainty allows us to write that at period t+1 $\pi_{t+1} = \pi^e_{t+1}$.Solving simultaneously expressions (4) and (5) in the text we get:

$$\text{(A.6)} \quad q_{t+1} - q_t = -\frac{\phi_1 + \lambda\phi_2}{1-\lambda}\frac{1}{\Delta}\left(\frac{f_1^2(1+b_1) + f_1^2 a_1 b_2}{1 + a_1 b_2 + f_1 b_2}\right)\varepsilon < 0.$$

According to (A.6) the real exchange rate appreciates in period t+1 indicating that the economy has experienced an overshooting on impact. This kind of dynamics are consistent with our model only if the economy shifts to a point like c in Figure 2 in the text and implies also that aggregate demand exceeds potential output as it is evident from expression (A.7) below.

$$\text{(A:7)} \quad Gap_t = \frac{1-\lambda}{\phi_1 + \lambda\phi_2}(q_{t+1} - q_t) < 0$$

At this point we address the issue of the level of inflation, actual and expected following the impact effect. According to (A.1):

$$\text{(A.8)} \ \pi^e_{t+1} - \pi^T = -\frac{a_2}{\Delta}(1 + a_1 b_2 + f_1 b_2)(q_{t+1} - \bar{q}) + \frac{f_1(1 + a_1 b_2)}{\Delta}\varepsilon$$

We have proved that following the impact effect the real exchange rate appreciates. This implies that $q_{t+1}$ can be written as being equal to $q_t$-δ, δ being a positive number. Inserting the latter expression in (A.8) we get that:

$$\text{(A.9)} \ \pi^e_{t+1} - \pi^T = -\frac{a_2}{\Delta}(1 + a_1 b_2 + f_1 b_2)(q_t - \delta - \bar{q}) + \frac{f_1(1 + a_1 b_2)}{\Delta}\varepsilon \ or$$

$$\pi^e_{t+1} - \pi^T = -\frac{a_2}{\Delta}(1 + a_1 b_2 + f_1 b_2)(q_t - \bar{q}) + \frac{f_1(1 + a_1 b_2)}{\Delta}\varepsilon + \delta \cdot \frac{a_2}{\Delta}(1 + a_1 b_2 + f_1 b_2) \Rightarrow in \text{ line with (A.6) that :}$$

$$\pi^e_{t+1} - \pi^T = 0 + \delta \cdot \frac{a_2}{\Delta}(1 + a_1 b_2 + f_1 b_2) > 0$$

This result indicates that expected inflation remains higher than the inflation target after the impact effect and so does the actual inflation rate since the interest rate shock is perfectly anticipated during the following periods. Since economic activity at this point in time is also higher than at full employment, according to expression (A.8), then the real interest rate should be also higher than its s.s value according to the CB reaction function in equation (2).

## Appendix 2

We report below the estimation results for the three cointegration equations from which we have derived the error correction components used in the regression equations of the estimated system.

**1. The GDP equation**

$$\underset{}{LPGDP} = \underset{(.0062)}{4.618} + \underset{(.0067)}{1.098} * LPGDP\_BS\_HT$$

DW: 0.63

Sample period: 1988.1 – 2002.2

LPGDP _BS_HT = The business sector gdp deflator including start-up companies.

The residual of this equation lagged by one quarter serves as the error-correction component in the GDP price inflation equation.

**2. The real exchange rate equation**

$$LPXNPGDP = \underset{(.5688)}{2.346} - \underset{(.1874)}{1.027} * TFP\_DIF - \underset{(.1552)}{1.209} * \log(RGDP/POP)$$

$$- \underset{(.0687)}{0.643} * \log(RGOGDS/RGDP)$$

DW: 1.23

Sample period: 1988.2 – 2002.1

The residual of this equation lagged by one quarter serves as the error-correction component in the Real exchange rate depreciation equation..

TFP_DIF= Productivity differential between the tradable and the non-tradable goods sectors.

RGDP/POP = Real Income per capita.

RGOGDS/RGDP = The ratio of public sector civilian purchases to GDP

### 3. The wage-price-productivity equation

$$LHRWPRV2 = \underset{(.0112)}{3.807} + \underset{(.1094)}{0.845}*PROD + \underset{(.0174)}{1.061}*LPGDP\_BS\_HT - \underset{(.0110)}{0.072}*D9196$$

DW: 1.37

Sample period: 1989.4 – 2002.2

The residual of this equation lagged by one quarter serves as the error-correction component in the nominal wage inflation equation.

Prod = business sector product per unit of labor input.

LPGDP_BS_HT= The business sector gdp deflator including start-up companies.

D9196 = 1 if 19992.1<t<1997.1 and 0 otherwise.

The residuals obtained in the regression estimation without the dummy variable, d9196, exhibited a U-shape pattern and were not white noise. We attributed this behaviour of the residuals to the influx of foreign workers not properly registered. As a result of the improper registration of foreign workers the measured output to whose production they have contributed is taken into consideration while their labor input is not. The obtained labor productivity obtained in this way is too high or nominal wages which reflect the influx of foreign workers are too low giving rise to the observed negative residuals. To neutralize the effect of the afore mentioned influx given the small number of observations we used as a regressor the dummy variable for the years this influx was on the rise and had not yet stabilized.

### 4. The cointegration equation among CP prices ,business sector GDP prices and prices of imported raw materials.

$$Log(CP) = -\underset{(0.017)}{0.205} + \underset{(0.012)}{0.829}*LPGDP + (1-0.829)*(LDOL+LPMI)$$

DW: 1.12

Sample period: 1988.1 – 2002.2

The residual of this equation lagged by one quarter served as the error-correction factor in the consumer price inflation equation, but it was found statistically insignificant.

# Appendix 3

## I. List of Variables

* prefix L for natural log
* prefix D for difference
* suffix _S for seasonal adjustment

* suffix _MAx moving average for x quarters.

| | | |
|---|---|---|
| CP | - | Consumer prices. |
| DP | - | Quarterly CPI inflation rate. |
| DPGDP | - | Quarterly GDP price inflation rate. |
| DPTAR | - | Inflation target for current year. |
| DP12 | - | Inflation rate in past 12 months. |
| DLOL | - | Dollar/Shekel exchange rate depreciation |
| Dlpmi | - | The change in the price of intermediate goods in dollar terms. |
| $Dpgdp_{bs}$ | - | Quarterly business sector GDP inflation rate. |
| Dprod | - | Change in Labor productivity. |
| DUMQq | - | Dummy variable for q quarter. |
| D91aft | - | Dummy variable =1 starting from 1992Q1. |
| dw | - | Nominal wage rate of change. |
| Dyyq | - | Dummy variable =1 for year yy quarter q. |
| Dyyqaft | - | Dummy variable=1 after year yy quarter q. |
| ECx | - | Error correction factor of variable x. |
| Eurosal | - | Lending rate on foreign currency denominated credit. |
| Exp | - | Expected inflation 12-months ahead. |
| Exp1 | - | DPE lagged one month. |
| FI | - | Fiscal index: average of fiscal stance index (according to potential output) and public debt, averaged for past 3 years (see Dahan and Strawczynski (1997)) |
| GAP | - | The output gap. The ratio between potential output of the business sector and actual output. |
| Ihhd | - | The nominal interest rate on short term credit. |
| Pdefgdp | - | Government local budget deficit (percentage of GDP). |
| RGOGDS/RGDP | - | Real Government civilian purchases over Real gdp |
| $i_m$ | - | BoI interest rate. |
| LPMI | - | The price of imported intermediate goods in dollar terms. |
| POP | - | population |
| $P^*_{iexp}$ | - | Export prices (in dollar terms). |
| PGDP | - | GDP deflator. |
| Pgexp | - | dollar prices |
| Prod | - | Labor productivity: GDP per labor input |
| rhhd | - | Real interest rate on short-term credit. |

| | | |
|---|---|---|
| RER | - | Real exchange rate |
| Target | - | The inflation Target |
| Tfpres1 | - | The residuals from the long run cointegration equation of the real exchange rate.. |
| Tour_entry | - | Number of tourist entries in Israel. |
| Tour_us | - | Tourists in USA. |
| WT | - | The volume of world trade. |

## II. The Estimation Results

Standard errors appear in parenthesis below the regression coefficients.

1. The Output-gap Equation

$$\mathbf{gap} = -\underset{(0.035)}{0.216} - \underset{(0.053)}{0.219}MA(tfpres1(-1),3) + \underset{(0.052)}{0.238}MA(rhhd(-2),3)$$

$$- \underset{(0.100)}{0.166}MA(\log(wt(-1)) - Lwt\_hp(-1),3) - \underset{(0.009)}{0.056}MA((\log(tour\_entry)$$

$$- \log(tour\_us)),4) - \underset{(0.112)}{0.532}MA(pdefgdp(-2),4) + \underset{(0.069)}{0.694}gap(-1) - \underset{(0.111)}{0.282}AR(1)$$

**Adjusted $R^2$ : 0.87** **D.W. = 2.09**

2. The Real Exchange Rate Depreciation Equation

$$\mathbf{dRER} = \underset{(0.013)}{0.031} - \underset{(0.081)}{0.189}Rer(-1) - \underset{(0.055)}{0.279}tfpres1(-1) - \underset{(0.071)}{0.255}i_{hhd} + \underset{(0.071)}{0.255}eurosal$$

$$- \underset{(0.054)}{0.107}d_{973aft}\, i_{hhd} + \underset{(0.054)}{0.107}d_{973aft}eurosal + \underset{(0.096)}{0.460}D(\log(pgexp))*(1+1/\log(T))$$

$$+ \underset{(0.077)}{0.208}gap(-2) + \underset{(0.015)}{0.077}d_{98q4}$$

**Adjusted $R^2$ : 0.50** **D.W. = 2.18**

3. The Business-Sector Price Inflation Equation

$$\mathbf{dPgdp_{bs}} = -\underset{(0.002)}{0.003} + \underset{(0.006)}{0.031}d_{9112} - \underset{(0.010)}{0.032}d_{951} + \underset{(0.020)}{0.223}Exp$$

$$+ \underset{(0.053)}{0.230}MA(dW\text{-}dprod,2) - \underset{(0.020)}{0.223}(dPgdp_{bs}(-1) + dPgdp_{bs}(-2))/2$$

$$- \underset{(0.032)}{0.056}MA(gap(-1),2) + (1\text{-}3*\underset{(0.020)}{0.223} - \underset{(0.053)}{0.230}))dldol + \underset{(0.002)}{0.008}dq_1$$

**Adjusted $R^2$ : 0.68** **D.W. = 2.39**

4. The GDP Price Inflation Equation

$$dPgdp = \underset{(0.002)}{-0.001} + \underset{(0.008)}{0.021}d_{951} + \underset{(0.082)}{1.027}dPgdp_{bs} - \underset{(0.051)}{0.097}ECPgdp(-1)$$

$$+ \underset{(0.002)}{0.017}dq_2 - \underset{(0.002)}{0.009}dq_4$$

**Adjusted $R^2$ : 0.84 D.W. = 1.93**

5.The CP Price inflation Equation

$$dP = \underset{(0.002)}{0.003} - \underset{(0.002)}{0.005}d_{973aft} - \underset{(0.008)}{0.026}d_{951} + \underset{(0.082)}{0.364}dPgdp(-1) + \underset{(0.031)}{0.276}d_{973aft}dldol$$

$$+ \underset{(0.031)}{0.276}d_{973aft}dlpmi + \underset{(0.044)}{0.204}(dldol(-1) + dlpmi(-1))$$

$$- \underset{(0.031)}{0.276}d_{973aft}(dldol(-1) + dlpmi(-1)) + \underset{(0.003)}{0.010}dq_2 - \underset{(0.003)}{0.009}dq_3$$

$$+ (1-\underset{(0.082)}{0.364} - \underset{(0.044)}{0.204})dP(-1)$$

**Adjusted $R^2$: 0.72 D.W. = 2.41**

6. The Lagged Inflation Expectations Equation

$$Exp\_1 = \underset{(0.112)}{-0.623} - \underset{(0.008)}{0.025}d_{973aft} + \underset{(0.121)}{0.733}(FI(-1) + FI(-2))/200 + \underset{(0.030)}{0.246}dP(-1)*4$$

$$+ \underset{(0.83)}{0.083}d_{973aft}dE*4 + \underset{(0.089)}{0.504}\,Exp\_1(-1)$$

**Adjusted $R^2$ : 0.90 D.W. = 2.08**

7. The Nominal Wage Inflation Equation

$$dW = \underset{(0.004)}{0.002} - \underset{(0.026)}{0.087}d951 + \underset{(0.067)}{0.762}dprod + \underset{(0.067)}{0.762}exp/4 + (1 - \underset{(0.067)}{0.762})dW(-4)$$

$$- \underset{(0.102)}{0.168}gap(-2) - \underset{(0.122)}{0.479}\,Ecw(-1)$$

**Adjusted $R^2$ : 0.66 D.W. = 2.05**

8. The Labor Productivity Equation

$$dprod = \underset{(0003}{-0.001} + \underset{(0.091)}{0.787}dW - 0.787dPgdp_{bs} - \underset{(0.083)}{0.248}dW(-4) + 0.248dPgdp_{bs}(-4)$$

$$+ (1 - 0.787 + 0.248)resdprod(-4)$$

**Adjusted $R^2$ : 0.53 D.W. = 2.49**

9. The BoI Interest Rate Equation

$$\mathbf{i_m = \underset{(0.005)}{0.020} + \underset{(0.004)}{0.031}d_1 + \underset{(0.008)}{0.055}d_2 + \underset{(0.003)}{0.008}d_3 + \underset{(0.009)}{0.022}d_{91q4} - \underset{(0.006)}{0.018}d_{02q1} + \underset{(0.043)}{0.210}Exp}$$

$$\mathbf{+ \underset{(0.069)}{0.548}d_{942aft}Exp + \underset{(0.052)}{0.223}d_{973aft}Exp - \underset{(0.086)}{0.473}d_{942aft}Target}$$

$$\mathbf{- \underset{(0.020)}{0.035}gap(-2) - \underset{(0.020)}{0.035}gap(-3) + \underset{(0.061)}{0.627}\, i_m(-1)}$$

**Adjusted $R^2$ : 0.95** **D.W. = 2.22**

<u>10. The Debitory Interest Rate Equation</u>

$$\mathbf{i_{hhd} = \underset{(0.004)}{0.093} - \underset{(0.003)}{0.049}d_{91aft} + \underset{(0.031)}{0.695}i_m + 0.305i_{hhd}(-1) + \underset{(0.113)}{0.507}AR(1)}$$

**Adjusted $R^2$ : 0.99** **D.W. = 2.01**

**<u>Appendix 4</u>**

The data on business sector wages per unit of labor input are not available and as a result we calculate them here based on some simplifying assumptions. The data we use for this calculation include the monthly wage per working position, the number of working positions per employee and the number of hours worked per week per employee in the business sector The monthly wage per working position, which is available, can be thought as being equal to the following expression:

**w/position=(w/hour)*(hours/employee)/(Positions/employee).**

The only variable which is unknown in this expression is the w/hour which is also the variable we are interested in calculating. While the labor cost per unit of labor input which we estimate should also include foreign workers, the number of weekly hours by foreign workers is unknown, so that the data of hours/employee worked per week refer to Israeli workers in the business sector only. The same is true for the data on Positions/employee which refer to Israeli workers in the business sector only**.** We based our calculations on the following simplifying assumptions:

a) the number of weekly hours worked by foreign workers in the business sector is proportional to that of local workers and constant over time.
b) the number of jobs per worker of foreign workers in the business sector is proportional to that of local workers and constant over time.
c) A month is made-up of 52/12 weeks.

In the regression estimation the data are expressed in log terms so that the proportionality coefficients which have been assumed to be constant are accounted for by the regression intercept of both the long-run and the short-run equations.