Bank of Israel Research Department

Monetary Policy, the Output Gap and Inflation:

A Closer Look at the Monetary Policy Transmission Mechanism in Israel 1989-1999

by

Joseph Djivre and Sigal Ribon

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

Abstract

This paper presents a quarterly structural model of the Israeli economy which delineates the transmission mechanism of the monetary policy during the years 1989-1999 and allows to evaluate the short run consequences of various exogenous shocks on both the nominal and the real sectors of the economy.

The main endogenous variables of the model are the business sector output gap, the real exchange rate, the inflation rate, the Bank of Israel (BoI) short-term nominal interest rate and the rate of change of the business sector nominal wages.

The estimated model is stable and exhibits to a large extent the expected properties in response to supply and demand shocks.

The model specification and the estimation results give rise to a nominal transmission channel and a real activity transmission channel of the monetary policy to prices. Unlike large and relatively closed economies in which monetary policy affects prices through its effect on economic activity, in the case of Israel, the evolution of prices is affected first, through the nominal exchange rate channel, and only at a later stage is their effect felt on economic activity.

The estimation results of the BoI nominal interest rate equation suggest a decreasing weight of short run economic activity in the interest rate evolution and a rising output and inflation volatility over time following supply side shocks.

I. Introduction and Main Results

This paper presents a quarterly structural model of the Israeli economy which delineates the transmission mechanism of the monetary policy during the years 1989-1999 and allows to evaluate the short run consequences of various exogenous shocks on both the nominal and the real sectors of the economy.

The main endogenous variables of the model are the business sector output gap, the real exchange rate, the inflation rate, the Bank of Israel (BoI) short term nominal interest rate and the rate of change of the business sector nominal wages. Our model which is estimated following the iterative 3SLS procedure does also include some additional auxiliary equations and identities, which are transformation equations, instrumental in the transition from one variable into another.

The BoI short term nominal interest rate serves as a measure of the monetary policy stance and it is estimated in the context of a reaction function a la Taylor (1993). We preferred to use the short run nominal interest rate of the BoI as the unique measure of the monetary policy stance even in the period during which the nominal exchange rate served as the unique nominal anchor (1986-1992). The use of the interest rate allows for a quantification of the monetary policy stance while the lack of a declared predetermined exchange rate path during most of the period under consideration renders unobservable the exact exchange rate target. Moreover the short term BoI interest rate does also reflect to a large extent the exchange rate policy followed at that time even when the interest rate did not serve as the main short term target of monetary policy.

Since one of the aims of the paper is the determination of the relative importance of the various transmission channels of monetary policy we avoided a detailed estimation of the real sector similar to that in 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)). Still our work shares in some respects concepts developed in these models, as it will be seen later on, as well as in other empirical work on the Israeli economy concerning components of our model[1]. Aviran (1998) estimated the effect of monetary policy on inflation and on economic activity through independent equation estimation, which did not include however the evolution of the real and of the nominal exchange rate preventing thus the independent equations from being integrated in a single model for the calculation of dynamic multipliers.

From the viewpoint of its objectives and its time horizon (short -medium term) our paper has affinities with the quarterly small macroeconomic model of the Israeli economy estimated by Azoulai and Elkayam (1999), in which the BoI interest rate and the rate of nominal exchange rate depreciation were used simultaneously as measures of economic policy without specifying and estimating econometrically their interdependence.

Empirical work similar to the present paper has been undertaken in other countries including Great Britain (see Haldane (1995), Bank of England (1999)), Spain (Andres et al. (1997)) and Canada (Duguay (1994))[2] to mention only a few out of a much longer list of empirical work.

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1 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).

2 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

The estimation of our model is based on about forty quarterly observations. The reason for this lies in the drastic changes experienced during the last fifteen years by the Israeli economy as a result of which it is almost impossible to isolate a relatively long enough homogeneous period allowing for meaningful estimation results. During the period surveyed the changes undergone by the Israeli economy were so substantial that the specification of the regression equations had to be, sometimes, rather complicated to account for major regime changes. The most important of these changes, which affected the transmission mechanism of monetary policy, were the gradual liberalization of capital movements and in particular of capital inflows, the gradual convergence to a floating exchange rate regime within a widening exchange rate band and the adoption of an inflation target regime. Moreover, the weakening of the government's monopolistic position in the capital market after an end was put to its involvement in the allocation of credit and the reduction of its budget deficit, which led to a decreasing need of raising capital in the domestic capital market, did also affect the transmission of changes in the Bank of Israel interest rate to the market interest rates, by enhancing competition in financial intermediation.

Our main contributions in this paper relatively to previous empirical work on the Israeli economy is the short run modeling of the real exchange rate evolution, which together with the estimation of the inflation rate allows us to derive the evolution of the nominal exchange rate and the evolution of the central bank short term interest rate. Another contribution is the introduction of a fiscal policy index, which affects the

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Inflationary Process", B.I.S, 1997.

determination of the steady state rate of inflation, in line with Dahan and Strewchinski (1997) and captures the transition of the Israeli economy to lower inflation plateaux, implying that monetary policy cannot bring single handedly a permenent reduction in the level of long run inflation.

The estimated model is stable and exhibits to a large extent the expected properties of real exchange rate appreciation, output contraction and inflation and monetary tightening following negative supply shocks, and output expansion, real exchange rate appreciation, inflation and monetary tightening following a positive demand shock.

The model specification and the estimation results give rise to two major transmission channels of the monetary policy to prices - a nominal and a real activity channel. The nominal channel includes in its turn the nominal exchange rate, the expectations and the nominal wage channels, while the real activity channel incorporates the real exchange rate and the real interest rate channels. The nominal and the real activity channels are interdependent because monetary policy is found to affect the real exchange and interest rates, and hence economic activity, through the nominal exchange and interest rates because of nominal. Real activity in its turn affects, according to the estimated model, the evolution of the nominal wage determination and the evolution of prices. Unlike large and relatively closed economies in which monetary policy affects prices through its effect on economic activity so that changes in the level of economic activity precede the reaction of prices to changes in monetary policy, in the case of Israel the latter affect first the evolution of prices, through the nominal exchange rate channel, and only at a later stage is their effect felt on economic activity.

The estimation results of the BoI nominal interest rate equation suggest a decreasing weight of short run economic activity in the interest rate evolution and a rising output and inflation volatility over time following supply side shocks. Inflation rate volatility, because of demand side shocks, rises also but this is not the case of output volatility which, falls over time.

The paper includes three additional parts: The second part contains a brief description of the model and the results of its econometric estimation including a dynamic simulation to test its stability. The third part traces out in some detail the transmission mechanism and the last part concludes. Technical derivations and descriptions appear in the appendices.

II. The System of Equations

A. An overview

Our model was estimated using the iterative three stage least squares estimation procedure[3]. The estimation, whose results appear in appendix 2, is based on quarterly data for the period between 1989:I and 1999:IV[4]. The estimated model consists of five basic regression equations for the GDP gap of the business sector, the short term evolution of the real exchange rate, the quarterly rate of inflation and the evolution of the BoI short term interest rate and of the rate of change of nominal wages in the business sector. The estimated regressions are reduced form equations and as a result our model does not secure full identification of the structural coefficients. Furthermore our model does not relate

[3] Both coefficients and the weighting matrix are updated each iteration until they converge.

[4] Some of the equations are estimated starting from mid 1989 due to absence of data.

directly to balance of payments issues and it does so only indirectly through the estimation of the real exchange rate evolution

The model does also include identities specified in appendix 3 and four additional auxiliary regression equations which are instrumental for running dynamic simulations and for deriving the evolution of the nominal exchange rate from that of the real exchange rate. These regressions describe the determination of the lending interest rate as a function of the BoI interest rate, the evolution of the inflation expectations index and the links between the GDP price inflation and the CPI inflation and between export prices in domestic currency, in terms of National Accounts Statistics and export prices according to Balance of Payments Statistics.

B. The Specification of the Regression Equations and the Estimation Results

B.1 The Output Gap Equation

The business sector GDP gap equation may be considered as a reduced form equation in the context of an AS-AD model. Suppose that aggregate demand is described by expression (1) below:

$$(1)\quad Y^{D} = D\left(\frac{e_{t-i}.P^{*}_{t-i}}{GDPP_{t-i}}, r_{t-i}, G_{t-i,} W_{t-i}, WT_{t-i}, Y_{t-i-1}\right), \qquad i = 0,1 \ldots.$$

And Aggregate supply by expression (2),

$$(2)\ \ Y^s = S(\frac{w_t}{p_t}, \frac{e_{t-i}..P_{t-i}}{GDPP_{t-i}} A), \quad i = 0,1....$$

and that *e, P*, GDPP, r, G,W, WT , p , Y, and w* in (1) and (2) stand for the nominal exchange rate, foreign prices, the GDP deflator, the real interest rate, government expenditure, real wealth of the private sector, the price level of consumer goods, domestic product and nominal wages, respectively[5].

We may obtain domestic output (the product of the business sector) by solving (1) and (2) simultaneously for Y_t , and for the real exchange rate, $e_{t*}P_t/GDPP_t$. In general the solution is in the form of expression (3) below, with output being in the short run a function of its own lagged values and of lagged values of the real exchange and other variables appearing in expressions (1) and (2).

$$(3)\ \ Y = Y(\frac{e_{t-i}.P^*_{t-i}}{GDPP_{t-i}}, r_t, r_{t-i}, G_{t,} G_{t-i,} W_{t,} W_{t-i}, WT_t, WT_{t-i}, Y_{t-i}, \frac{w_t}{p_t}, \frac{w_{t-i}}{p_{t-i}}, A),\ \ i = 1,2,...$$

The introduction of the lagged values of the various variables in the specification of these two expressions is not imposed by theoretical but by empirical considerations and reflects the possibility of a gradual adjustment of aggregate supply and aggregate demand to changes in the variables which determine them, the exact lag structure, if it exists, being defined by the estimation results.

The stock of wealth, the volume of world trade and government expenditures are defined in the context of the estimated model as exogenous variables while the real

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5 See Cukierman et al (1977) and Hercowitz et al (1997) for the introduction of the price of

exchange and interest rates, and the real wages are endogenous variables in the estimated system. Expression (3) bears witness to the interdependence between the real and the nominal side of the economy. In this way the evolution of real wages depends on the evolution of nominal wages which is modeled in the estimated model and by the evolution of prices as the latter is defined in the inflation equation which is also estimated in the model. In a similar way the real interest rate is affected in the short-run by the evolution of the nominal interest rate, which is determined by the evolution of the Bank of Israel nominal interest rate and by inflation. The short run evolution of the real exchange rate is estimated and described by a separate dynamic equation. In the aggregate supply specification the real exchange rate, which is negatively correlated with output stands for the relative price of imported intermediate goods, while the real exchange rate appearing in the aggregate demand specification should reflect the relative price of exports or that of finished imported goods. This implies that the econometric estimation should include at least two different definitions of foreign prices.

Expression (3) expressed in deviations from equilibrium serves as the basis for the estimation of the business sector output gap regression. As a proxy for government expenditure we have used a lagged four quarter moving average of the government budget deficit-GDP ratio on a cash flow basis. The remaining regressors, with the exception of the real interest rate, have been detrended using their moving average or have been expressed in deviations from their equilibrium value. We have not calculated the equilibrium real interest rate and have introduced instead in the estimated regression the level of the real

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intermediate good in the aggregate supply function of GDP (not of output).

interest rate assuming that the effect of the equilibrium real interest rate will be captured by the estimated intercept.

The real interest rate coefficient should be positive since it adversely affects aggregate demand, widening thereby the output gap. By the same token the wealth, government expenditure, and world trade terms should have negative coefficients while the real wage term should have a positive coefficient.

The estimation results: The signs of the regressor coefficients were in line with expectations. The only supply side variable which was positively correlated, as expected, with the output gap was the deviation of the two quarter lagged real wage of Israeli workers from its moving average trend. The relative price of imported intermediate goods was not statistically different from zero and was as a result excluded from the regression. The deviation of the real exchange rate, measured as the price of exports relatively to the GDP deflator, from its long run value was found to affect negatively the gap with a lag of five to six quarters, implying that a real exchange rate higher than its long run value is consistent with a rise in aggregate demand and a fall in the output gap. Changes in wealth, in the world trade and in the government budget deficit,on a cash basis, with respect to gdp were found to affect the gap with a four, three and two quarters lag respectively.

The only real interest rate which was found to affect the output gap in the expected direction and in a statistically significant manner was the lagged (3-5 quarters) ex-post short term interest rate on overdraft credit. A similar result has been also obtained by Beenstock et al. (1994). In addition to the usual interpretation of this finding that the short term interest rate affects the timing of investment, this result does also allude to imperfect capital markets and the credit channel. In particular the ex-post nature of this interest rate is in line with the financial accelerator version of the credit channel theory [Gertler and Gilchrist (1993 **)**] according to which higher interest rates adversely affect the cash flow of borrowers because of higher interest rate payments, which are related to the ex-post real interest rates erode by the internal funds available for investment and the net wealth of firms and leading thereby to a credit contraction and a fall in investment.

B.2 The Real Exchange Rate Equation

The estimation of the short run real exchange rate evolution is based on an error correction equation with the first difference of the real exchange rate as the dependent variable. The real exchange rate was defined as the ratio between export and gdp prices so that a real exchange rate depreciation is consistent with a higher real exchange rate. The estimated equation is based on a variation of the standard error-correction specification derived from a long run cointegrating regression that has been augmented by variables which in the presence of short run rigidities may affect the short run evolution of the real exchange rate. The long run cointegration equation is based on the Balassa (1964) –Samuelson (1964) approach. (see appendix 3) According to this approach a perfect long run supply elasticity of the factors of production implies that the long run real exchange rate is determined by the productivity differential between the tradable and the non-tradable sector. Under less than perfect supply elasticity, demand factors may also affect the long run determination of the real exchange rate. Following this latter less binding assumption we have used income per capita and the civilian government expenditure – GDP ratio as the demand factors which may affect the long run determination of the real exchange rate.[6]

The variables in the specification of the error correction equation include also the lagged first differences of the variables of the long run cointegration regression. In addition to these variables we have included the distance of the nominal exchange rate from the lower bound of the exchange rate band and the interest rate differential between the domestic and the foreign currency sectors. We used these variables to capture the nominal exchange rate effect on the short run evolution of the real exchange rate in the presence of rigidities. More precisely, a higher interest rate differential in favour of the domestic currency reduces, ceteris paribus, demand for foreign currency leading thereby to a lower rate of nominal exchange rate depreciation, i.e to a relative appreciation, implying a negative coefficient for the corresponding regressor. Moreover the gradually growing importance of market forces in the determination of the nominal exchange rate, in light of the liberalization of capital flows and of the diminishing intervention of the BoI in the foreign exchange market, is consistent with a higher sensitivity over time of the nominal exchange rate to the interest rate spread between domestic and foreign currency interest rate. This implies an increasing coefficient over time for the interest rate spread term, provided changes in the nominal exchange rate do indeed affect in the short run the determination of the real exchange rate.

The nominal exchange rate distance from the lower bound of the band captures to

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6 In the estimation of the cointegration equation we differ from Zussman (1998) in two aspects. The first is that we have used a different sample period 1987:1 1999:3 instead of 1980-1997. We chose this period in order to exclude the pre-stabilization observations. The second difference lies in our including the government civilian expenditure-gdp ratio instead of the terms of trade which were used

some extent the non-linear relationship between interest and exchange rates inside the band. As the distance of the nominal exchange rate from the lower bound decreases, the nominal exchange rate depreciation expectations increase so that the coefficient of the corresponding regressor should be negative. The increasing contribution of market forces in the determination of the nominal exchange rate should be reflected in this case in weaker exchange rate depreciation expectations for a given distance from the lower bound of the band implying a decreasing, in absolute terms, regression coefficient over time. The weakening of the depreciation expectations over time reflects the positive probability of further nominal exchange rate appreciation as long as the nominal exchange rate has not reached yet the lower bound of the band, unlike the period of the managed float during which this appreciation probability was practically equal to zero in view of the determination of the nominal exchange rate within a undeclared narrow band.

In order to account for possible rigidities in the short run determination of the real exchange rate we have also used as a regressor the rate of change of export prices in dollars, whose coefficient is expected to be positive implying that a higher rate of increase of export prices is consistent in the short run with higher real exchange rate rate of depreciation. For a similar reason we introduced also as a regressor the GDP price inflation during the period of the managed exchange rate regime (until the first quarter of 1996) in view of the fact that short run adjustments of the real exchange rate through changes in the nominal exchange rate were limited at that time due to the policy of managed floating before 1996. For obvious reasons the corresponding coefficient should be negative. In

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by Zussman and which were not statistically significant in our estimation.

addition we have included a dummy for the last quarter of 1998 which represents the exceptional rate of depreciation in the exchange rate, on the background of the global financial crisis at that time.

The influence of a change in the output gap on the change of the real exchange rate depends on whether this change arises from aggregate demand or aggregate supply factors. To differentiate between aggregate demand and aggregate supply effects the aggregate supply regressor, which was introduced in the output gap regression - real wages - was also introduced in this regression as a regressor, in first differences. In this way the change in the output gap picked up the changes in aggregate demand while the first difference of the rate of wage expansion picked up the aggregate supply effects. Under this specification the sign of the aggregate supply variable coefficient is expected to be negative indicating that a wage acceleration accelerates real appreciation while the sign of the output gap coefficient should be positive indicating that the opposite is true when aggregate demand falls.

The estimation results: Out of the lagged first differences of the variables in the long run cointegrating equation only the coefficient of the government expenditure-GDP ratio was (almost) significant. The coefficient of the gdp inflation was insignificant, and the remaining coefficients were significant (at a level of significance of at least 94 percent) their sign being in the expected direction. The estimation results indicate that the interest rate spread has an immediate effect on the nominal and hence on the real exchange rate as it is expected by the rather fast reaction of asset markets to changes in interest rates, while the changes in the output gap and in the real wage rates affect the real exchange rate with a lag shorter than a year. The estimation results confirm a) the existence of nominal rigidities, as a result of which the real exchange rate constitutes one of the transmission channels of monetary policy, b) the rising sensitivity of the nominal exchange rate to the interest rate spread between domestic and foreign currency following the liberalization of capital flows and the diminishing intervention of the BoI in the foreign exchange market and c) the existence of non-linearities in the determination of the nominal exchange rate within the band. In view however of the substantial BoI intervention inside the band during the sample period it is probable that such an effect may reflect the intraband intervention effect in line with Lewis (19…) and not necessarily the "honeymoon" effect of Krugman (19….).

B.3. The Inflation Equation

The estimated inflation equation constitutes the reduced form of an expectations augmented Phillips curve with inflation expectations which have both forward and backward looking characteristics.

(4) $\pi = f(\pi^{e}) + a.GDPGap + Supply\ \ factors$

Inflation expectations deviate from actual inflation because of deviations of economic activity from its full capacity level, measured by the output-gap, because of supply-side factors and because their partially backward looking character protracts their adjustment to changes in the inflation environment in general and in the steady state rate of inflation, π^*, in particular. This implies that the fit of the estimated regression equation should improve if the latter includes variables which are expected to be highly correlated with the steady state inflation level (plateau) and with future values of these inflation expectations, given their partially backward looking character. These considerations led us to introduce in the inflation equation as regressors the fiscal index, which constitutes a determining factor of the steady state inflation rate, according to economic theory (see section II), and the central bank nominal interest rate, whose lagged value was found to affect negatively the formation of inflation expectations in Israel. The latter are extracted by comparing yields on nominal and indexed bonds with a twelve month maturity and have a substantial backward looking character.

The supply side factors include the nominal wage rate of growth and the rates of change of the dollar prices of intermediate goods and of the exchange rate. The estimated regression does also include seasonal dummies. As a result of the inclusion of the supply side cost factors in the estimated regression, the output gap measures the inflation pressures originating in the demand side of the economy which are in excess of those consistent with a full employment equilibrium. These pressures do not reflect the inflation contribution of the wage channel which has been directly introduced in the regression specification but the fact that during periods, say, of slack firms do not adjust prices in tandem with increases in production costs. In line with this reasoning the output gap regression coefficient should be negative while the coefficients of the supply side factors should be of a positive sign.

The estimation results: The regression coefficient signs were as expected. The testing for asymmetries between positive and negative gaps with respect to the output gap effect on inflation led to statistically insignificant results. The output gap affects inflation with a two and a three quarter lag similarly to the nominal wage growth rate, while changes in the dollar price of imported intermediate goods and in the nominal exchange rate with respect to the US. dollar affect inflation with shorter lags (0 to 2 quarters). The exchange rate nominal depreciation coefficient hovers around .20, a level which is somewhat lower than the one obtained in other models of the Israeli economy. Moreover it is impossible to reject the hypothesis that the sum of the supply side coefficients and that of inflation expectations add up to 1, a fact implying long run homogeneity between cpi inflation on the one hand, and inflation expectations, exchange rate depreciation and wage and import price inflation on the other.

The nominal interest rate lag in the inflation equation is shorter (one to three lags) than the corresponding lag of the real interest rate in the output gap regression equation (three to five quarters) supporting the hypothesis that they represent inflation expectations. The coefficient of the fiscal policy index was significant supporting our hypothesis that the fiscal policy stance affects the long-run inflation rate. However the coefficient of a dummy variable for 1997 splitting the sample period into two sub-periods before and after the third quarter of 1997, when an additional inflation break seems to have taken place, was found to be highly significant. These results suggest that further research is required on this issue requiring, perhaps, the construction of a more precise fiscal index and the examination of other variables which may affect the long-run rate of inflation

B.4 The Wage Evolution Equation

$$(5)\quad \hat{W} = d_1 \hat{p}_{t-i} + (1-d_1)\hat{p}_t^e + d_2 GDPgap + d_3 Supplyshocks + d_4((w/p)_{t-i} - (w/p)^*)$$

We have specified the rate of change as a function of past and expected inflation of the deviation of output from its full employment level and of changes in productivity.

However since such a specification such a specification of the nominal wage evolution allows for a pemanent change in real wages as a result of a disparity between expected and realized inflation, which is inconsistent with economic reality, we included also in the estimated regression an error correction component measuring the deviation of real wages from their long run level whose regression coefficient must be negative.[7] The long run wage level *w** was measured in this case as the marginal product of Israeli workers which is consistent with the potential output used to construct the output gap. This marginal product does also include, by construction, a labour productivity component, which has been as a result omitted from the regression specification. In addition to these variables we have also included the lagged dependent variable to deal with the seasonality which is present in the quarterly rate of change of nominal wages.

The willingness of workers to accept real wage erosion in the face of a slowdown in economic activity is measured by the coefficient d_2 which is expected to be negative in the estimated regression. A rise in labour market flexibility is reflected in a higher value of this coefficient, in absolute value, indicating that for the same output gap workers are willing to accept, other things equal, a relatively greater erosion in their real wages. The coefficient d_1 measures the backward looking character of wage setting, originating, among other factors, in the indexation arrangements prevailing in the israeli labour market. The value of this coefficient lies between zero - for completely forward looking wage setting - and unity for full indexation to past inflation.

The estimation results: Inflation during the past twelve months, lagged by two quarters,

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[7] Melnick (2000) uses a similar specification in a calibrated model.

was found to affect positively the rate of change of nominal wages. The simultaneous inclusion of past and expected inflation did not give rise to significant results and as a result expected inflation was excluded from the estimated regression. The two quarter lagged inflation coefficient is about 0.6[8], and its long run value is 0.40 implying that the existing indexation arrangements do not prevent real wage erosion by inflation, a fact which emphasizes the stabilizing role of the error correction factor. The significance of the coefficient of the error correction term in the context of a two tailed test though was relatively low, 85percent, supporting only weakly our hypothesis that deviations of real wages from their long run level give rise to compensating nominal wage changes.

The output gap affects with a one year lag the evolution of nominal wages. No structural breaks were detected in the corresponding coefficient, a finding which does not support the hypothesis of structural changes in the labour market during the

B.5 The Bank of Israel Nominal Interest Rate Equation

Our nominal interest rate equation is an ad hoc specification of the nominal BoI interest rate evolution, which does not necessarily reflect a targeting rule derived from the minimization of a loss function by the central bank [Cecchetti (1998) and Rudebusch and Svensson (1998)]. In this respect we have followed Taylor(1993 and 1994) and Clarida et al. (1998). As a result the regressor coefficients in the interest rate equation may not reflect only the preferences of the central banker among various targeted variables but also the

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8 The estimated coefficient 0.144 is the effect of the annual inflation rate on the quarterly rate of change of nominal wages.

underlying structure of the Israeli economy.[9] This issue has been also raised by Christiano et al. (1998) who claim that the interest rate reaction functions suffer from the observational equivalence problem, a criticism which implies that such equations may be considered at best as econometric specifications of the evolution of central bank short-term interest rates. Bearing this criticism in mind we have avoided considering the estimated equation as a central bank reaction function in the strict sense of the term and interpreting the estimated coefficients of the regressors as measures of the cenral banker's preferences.

The equation regressors include dummy variables, the lagged central bank interest rate, which allows to test the hypothesis of interest rate smoothing, the annual rate of past inflation, the output gap and the deviation of inflation expectations from the inflation target, which may serve as a regressor only after the adoption of inflation targets in Israel. Such targets were initially implied in the slope specification of the crawling exchange rate band, which was first introduced at the end of 1991. This slope was defined as being equal to the inflation differential between Israel and its main trading partners. This definition allowed the public to derive the implied inflation target and created on the part of the Bank of Israel the obligation to implement a monetary policy consistent with the exchange rate band. Still this inflation target was more of an inflation forecast than a strict target. In our specification we considered nevertheless 1992 as the year in which inflation targets were adopted for the first time and not 1994, when they were formally introduced, differentiating with a dummy variable between the period before and after 1992 both in the intercept and in the regressor coefficient. In this way according to our specification the

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9 For the determination of the central bank interest rate in Israel as a function of the unemployment rate

determination of the BoI interest rate prior to 1992 depends on inflation expectations and on past inflation only and following this date it depends on the deviations of inflation expectations from the inflation target. Because of the lags characterizing the transmission of the monetary policy we assumed that the inflation target used in determining the deviation of inflation expectations from the targeted level was the one quarter ahead inflation target. Such a specification reflects the policymaker's awareness of the fact that monetary policy measures taken during a certain quarter are expected to affect prices some quarters ahead, a fact which is especially true at the fourth quarter when inflation targets are set for the following calendar year and at a level which is usually lower than that of the previous year. During the surveyed period the inflation targets alternated between point targets and inflation rate bands. In the latter case (1995-1998) we considered as the inflation target the inflation rate at the center of the inflation target band.

Our specification does also allow for a gradually decreasing weight of the output gap in the determination of the BoI nominal interest rate. It also includes a dummy variable at the intercept for the last quarter of 1991 accounting for the interest rate hike which accompanied the crisis in the exchange rate market during that period and an intercept dummy for the period after 1991, following the introduction of such a dummy variable in the regression coefficients of past inflation and of inflation expectation deviations from the inflation target. A third dummy variable for the period of monetary policy tightening (second half of 1994 and thereafter) was also used to test for the hypothesis of a shift to higher real interest rates after this date.

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and the deviation of inflation from its targeted level see also Gottlieb and Ribon (1999).

We chose as the BoI short-term interest rate the effective nominal interest rate on the highest discount window of the monetary loan. The monetary loan at the discount window is the only policy instrument which has been used without any interruption since 1989 and makes as a result possible the estimation of our model for the whole period under consideration.

The estimated coefficients for past inflation and for inflation expectations must be positive implying that higher inflation is followed by higher nominal central bank interest rates while that of the output gap should be negative indicating a lower nominal interest rate when economic activity slows down.

The rather complicated specification of the interest rate regression equation reflects the need to accommodate the changes which the conduct and the targets of monetary policy underwent over time in view of the fact that the limited number of observations at our disposal does not allow us the luxury of estimating the model separately for different sub-periods.

The estimation results: All the regression coefficients were statistically significant and their signs were in the expected direction. The estimation results do indicate that the deviation expectations from the inflation target become a significant factor in the determination of the short term interest rate evolution after 1991. The coefficient of a three quarter moving average of the output gap, lagged by one quarter, decreases through time and the coefficient of the lagged dependent variable is significant and positive, a fact which may be considered as an indication of interest rate smoothing.

The intercept dummy splitting the sample period into two subperiods one before the second quarter of 1994 and one after this quarter was negative but not significant (significance level of 83 percent in a two tailed test). However the coefficient of past inflation regained its significance after 1994, suppoorting our hypothesis of monetary tightening after 1994 in spite of the lack of significance of the intercept dummy. This hypothesis does find also support in the dynamic multiplier analysis, as it will shown later on, which indicates that the monetary policy reacted more aggressively to inflation shocks after 1994.

D. Simulation and Model Stability

The aim of the static simulation is to check the goodness of fit of our system of equations. This is done by simulating the system using actual values of lagged endogenous variables. Generally, values of the major variables are very close to actual values and succeed in following their path over time. (Diagram 1). In order to check the robustness of our estimation we performed also an in sample dynamic simulation of our model as a result of the fact that the limited number of observations renders impossible the performance of stability tests. Had the regressor coefficients changed considerably during the period under consideration, then we would have expected long horizon forecasts to deviate considerably from actual values as a result of the aforementioned hypothesized structural break.

To perform the dynamic simulation we included 14 additional equations (regressions and identities) which serve as a basis for the transformation of endogenous and exogenous variables in the system (See appendix 2 for a more detailed description). The identities allow, for instance, the transition from levels to first (log) differences, while the auxiliary regressions are instrumental in the forecast of certain endogenous variables used in the dynamic simulation: Commercial bank interest rates enter, for example, the output gap regression and real wages enter the output gap regression and the real exchange rate error correction regression. While the regressions estimating these two variables are not required for the estimation of the output gap and the real exchange rate regression they are necessary for the dynamic simulation of the model because they allow us to obtain forecasts of these variables. For the same reason we have included an equation that extracts the (change in) the nominal exchange rate from the estimated change in the real exchange rate and inflation. This nominal exchange rate change serves with a lag in determining the evolution of inflation in later periods.

In spite of the long forecast horizon (8 years) the results of the dynamic simulation suggest that our model is stable and has succeeded in following the evolution of most of the main endogenous variables, (Diagram 2) even though it deviated from their exact path in various periods.

The reason for which the dynamic simulation does not replicate the inflation path during the mid 90's is apparently due to the fluctuations at that time in the prices of fruits and vegetables, which were not the result of macro developments, and have not been modeled as a result. The dynamic simulation provides also overestimates for the BoI interest rate in 1992-1994 which are however economically consistent with the overestimation of the inflation rate and the underestimation of the output gap during the same period. This result may also imply that the monetary policy implemented during this period was particularly expansionary an interpretation which is consistent with the excessive expansion of monetary aggregates during this period.

III. The Transmission Mechanism and the Dynamic Multipliers

In this section we report the results of additional exercises whose objective is the identification and the characterization of the transmission mechanism of monetary policy and the estimation of the reaction of the Israeli economy to inflation, nominal wages, government expenditures (budget deficit) and world trade shocks. Focusing on the evolution of the economy following inflation shocks we tried to identify the changes in monetary policy after 1994. For this reason we examined the evolution of the economy subsequently to inflation shocks before and after 1994. (Diagram 3).

The transmission mechanism: The identification of the transmission mechanism of the monetary policy is made by identifying the evolution of the economy following shocks to the nominal interest rate. The results of this exercise appear in Diagram 3A. According to them a one time interest rate increase leads to an immediate nominal and real exchange rate appreciation in spite of the fall in the domestic price level. The reason lies in the fact that the fall in prices is itself due to the nominal exchange rate appreciation. The fall in prices triggers a rise in the real interest rate and in real wages. These two factors together with the real exchange rate appreciation lead to an output contraction, the real wage and interest rate changes affecting output first, after two and three quarters respectively, to be followed by the real exchange rate with a five quarter lag.

While the impact effect of the interest rate increase on the nominal exchange rate and through it on prices is immediate, its effect is short lived since the nominal exchange rate tends to return quite fast to its equilibrium level. However the period of lower inflation is relatively more protracted. This is due to the real activity channel, which is affected by the real exchange and interest rates, to the slowdown of the nominal wage expansion, as a result of the real wage deviation from its long run equilibrium level and to the expectations channel, through the effect of the short term real interest rate on inflation, whose influence extends in the longer run. The increasing importance of the real activity channel in the longer run transmission mechanism of the monetary policy is due both to the fact that the effects of monetary policy on the real side of the economy are more protracted, because of nominal rigidities, and due to the lag with which monetary policy starts affecting prices through the real activity channel (5 quarters).

These results differentiate the transmission mechanism of Israel as a small and open economy from that of larger and rather more closed economies in two aspects. The first is the immediate effect that monetary policy has on inflation through the nominal exchange rate, in contrast to larger economies. The second difference aspect lies in the relatively quick reaction of prices to changes in monetary policy through the real activity channel, 5 quarters, in contrast to the longer lags reported by Vinals and Valles (1999), 8-12 quarters.

Inflation Rate Shocks: The inflation shock leads to an output augmenting real wage erosion and to a real exchange rate appreciation as a result of the nominal rigidities, which affect the short run determination of the real exchange rate, and of the development of a negative output gap. The shock is followed by a higher short term nominal interest rate. The nominal interest rate increase is not however commensurate with the rise in prices and as a result the real interest rate is also eroded. The lower real wages and the lower real interest rate sustain the initial expansion of economic activity triggered by the real wage erosion strengthening the real appreciation process.

The higher inflation rate falls relatively quickly reflecting at the following stages only the inflationary pressures arising from the negative output gap and the nominal wage growth as real wages gradually converge to their higher long run level. The nominal interest rate is reduced gradually leading to a rise in the real interest rate in light of the relatively more substantial fall in prices.

In this exercise the economic forces controlling the evolution of the economy after the impact effect of the inflation shock are the negative output gap and the real exchange rate appreciation. The negative output gap prolongs the real exchange rate appreciation process, which leads eventually to a change in the direction of economic activity. Because of the relatively slow convergence of the nominal interest rate to its equilibrium level the real interest rate rises above its equilibrium level. Moreover, the protracted higher nominal interest rate differential between the domestic and the foreign currency sectors keeps the nominal exchange rate depreciation at relatively low levels so that the convergence of the real exchange rate to its equilibrium level is also protracted, leading to the aforementioned change in the direction of economic activity. This in spite of the fact that the level of real wages remains below its long run equilibrium level during the convergence process.

This exercise was performed during two different periods, the first time in 1991, and the second time in 1997. The main difference in the evolution of the economy during these two periods, in response to the same inflation shock, lies in the faster convergence of the real exchange rate to its long run equilibrium level. This finding is apparently due to the fact that during the second period endogenous changes of the domestic prices do not affect directly the real exchange rate because of the rise in the nominal exchange rate flexibility.

Indeed a comparison between diagrams 3B1 and 3B2 reveals a higher nominal exchange rate depreciation following the inflation shock.

Nominal Wage Shocks: A nominal wage increase leads on impact to a higher level of real wages which triggers at the subsequent period higher inflation, a slowdown in economic activity with a positive output gap, a real appreciation of the exchange rate and a fall in the real interest rate eroded by inflation. These dynamic effects replicate the standard text-book reaction of an economy to negative supply shocks. The relatively high levels of the real exchange rate and of real wages keep output below its full capacity potential in spite of the lower real interest rates. In its turn the output gap reduces inflationary pressures bringing about a rise in real interest rates.

In both the present and the previous exercise the central bank is revealed as hesitant to change the short-term interest lagging behind inflation both on the upside and the downside. In this way inflationary shocks are accompanied at the initial stages by an erosion of the real interest rate and later on by an overshooting of real interest rates as the reduction of the nominal interest rate lags behind the fall in inflation. (Diagram 3C).

A one period rise in the government budget deficit-gdp ratio[10]: In this case too our model succeeds in replicating the theory based predictions. The simulation results indicate that a demand shock leads in the short run to an expansion of economic activity, a lower output gap, a real exchange appreciation and higher inflation in response to which the central bank raises nominal interest rates. Because of the fact that an aggregate demand shock

10 We emphasize in this context the transitory character of the shock because a permanent change should also require an adjustment of the fiscal index.

affects prices with a lag, the initial tightening of the monetary policy, because of the rise in economic activity, and the nominal exchange rate appreciation which follows are initially reflected in a lower inflation rate which is temporary since it picks later on in view of the continued strong economic activity. The nominal interest rate increase leads to higher real interest rates, a process which is strengthened further by the initial price fall and which crowds out other components of aggregate demand such as investment. (Diagram 3D).

This exercise is representative of the dynamics of any aggregate demand shock. In this way a shock to the volume of international trade gives rise to similar results. This is due to the fact that we have not modeled foreign trade and as a result the dynamic effects of the two shocks are identical. (Diagram 3E).

IV. Conclusions

In this paper we estimated a small macroeconomic model of the Israeli economy focusing on the identification and characterization of the monetary policy transmission mechanism in Israel during the years 1989-1999. We traced the transmission mechanism by observing the evolution of the economy following transitory shocks to the central bank short-term interest rate. The results suggest that the nominal exchange rate constitutes the main short run transmission channel of the monetary policy to prices in the short run unlike larger and relatively closed economies in which the nominal exchange rate channel is of minor importance in the transmission mechanism. The dynamic passthrough coefficient from the nominal exchange rate depreciation to inflation is however rather low and hovers around twenty percent, a level which is rather low compared to other empirical results on the Israeli economy. While the impact effect of changes in monetary policy on the nominal exchange rate and through it on prices is immediate, its effect is short lived since the nominal exchange rate adjustment to changes in monetary policy is rather fast. However the period of lower inflation is relatively more protracted. This is due to the real activity channel, which is affected by the real exchange and interest rates, to the real interest rate through the expectations channel and to the slowdown of the nominal wage expansion, as a result of the deviation of the real wage from its long run equilibrium level, whose influence extends in the longer run. The increase in the importance of the real activity channel in the monetary policy transmission mechanism in longer time horizons is due both to the fact that the effects of monetary policy on the real side of the economy are more protracted, because of nominal rigidities, and to the relatively long lag with which monetary policy starts affecting prices through the real activity channel (5 quarters). This lag is however shorter than the one reported on larger and relatively closed economies. The real activity and the nominal channels of the transmission mechanism are interdependent as a result of nominal rigidities in the real wage and real exchange rate determination. on the one hand and the output gap influence on the setting of nominal wages.

Our model exhibits to a large extent the expected properties of real exchange rate appreciation, output contraction and inflation and monetary tightening following negative supply shocks, and output expansion, real exchange rate appreciation, inflation and monetary tightening following a positive demand shock.

The estimation results do also suggest a decreasing contribution of the output gap in the evolution of the central bank nominal interest rate and an increasing influence of the interest rate spread between domestic and foreign currency interest rate over time in the nominal and real exchange rate determination. These results are consistent respectively with the gradually increasing emphasis on inflation targeting and with the gradual liberalization of the Israeli foreign exchange market and its integration in the international economy.

Our model estimates the rate of inflation in the context of an expectations augmented Phillips curve with inflation fluctuating around its long run steady state level. We have partially succeeded in estimating this long run inflation rate using a composite fiscal index, which measures the business cycle adjusted government budget deficit and the government debt GDP ratios. This finding implies, that monetary policy cannot bring about by its own a permanent reduction in the level of long run inflation. Our partial success in this direction suggests however that further research is still required on this issue requiring, perhaps, the construction of a more precise fiscal index and the examination of other variables which may affect the long-run rate of inflation.

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Appendix 1: List of Variables

* prefix L for natural log
* prefix D for difference
* suffix _S for seasonal adjustment
* suffix _MAx for x quarters moving average

CP	- CPI index
DP	- Quarterly inflation rate.
DPE	- Expected inflation 12-months ahead (derived from the financial market).
DPE1	- DPE lagged one month.
DPTAR	- Inflation target for current year.
DP12	- Inflation rate in past 12 months.
DOL	- Dollar/Shekel exchange rate
DUMQq	- Dummy variable for q quarter.
D91aft	- Dummy variable =1 starting from 1992Q1.
DyyQq	- Dummy variable =1 for year yy quarter q.
Dyyqaft	- Dummy variable=1 after year yy quarter q.
EURO	- Foreign creditory nominal interest rate.
FISC	- 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.
GDEF	- Government local budget deficit (percentage of GDP).
GP	- Government purchases
ib	- BoI interest rate - The instrument of the monetary policy.
ic	- Nominal interest rate on time deposits.

id	- Nominal interst rate on over-night credit.
LBAND	- Lower bound of exchange rate band.
MPL	- Long-run marginal productivity of labor. Derived from the long-run production function (of potential output). See Appendix 4.
PMI	- Price index of imported intermediate goods.
POP	- population
PX	- Export prices (in dollar terms).
PY	- GDP deflator.
RAT_SAL	- Ratio between exchange rate vs. basket and exchange vs. dollar.
RB	- Real BoI interest rate (nominal interest rate defalted by 12 months CPI inflation rate).
RD	- Real interest rate on short-term credit (nominal interest rate defalted by 12 months CPI inflation rate).
RER	- Real exchange rate (nominal exchange rate of the shekel vs. The basket relative to GDP deflator).
RER_res	- The residuals from the long-term trend of the real exchange rate.
RWGB	- Real wages in the business sector.
SAL	- Exchange rate of the Shekel vs. the basket.
SALBAND	- Distance of exchange rate from the lower bound of the exchange rate band (SAL/BAND-1).
T	- Time
TFP_DIF	- Difference in productivity between tradable and non-tradable sectors.
W	- Real net wealth.
WGB	- Nominal wages in the business sector.
WT	- World trade.
Y	- GDP
YB	- Business sector product.
YB_POT	- Potential business sector output.
YG	- Services of general government.

Appendix 2[11]

1.The gdp gap equation

$$\mathbf{LGAP\_S} = \underset{(0.025)}{0.066} - \underset{(0.120)}{0.233}\,(RER\_res(-5)+RER\_res(-6))/2 + \underset{(0.050)}{0.116}\,(RD(-3)+RD(-4)+RD(-5))/3$$

$$- \underset{(0.094)}{0.164}\,(LW(-4)-LW\_MA8(-4)) - \underset{(0.202)}{0.686}\,(LWT(-3)-LWT\_MA8(-3))$$

$$+ \underset{(0.146)}{0.339}\,(LRWGB(-2)-LRWGB\_MA8(-2)) - \underset{(0.284)}{0.765}\,GDEF\_MA4(-2) + \underset{(0.092)}{0.499}\,LGAP\_S(-1)$$

Adj. $R^2 = 0.585$ D.W. = 2.23

2. The real exchange rate equation

$$\mathbf{DLRER} = \underset{(0.020)}{0.049} - \underset{(0.115)}{0.284}\,RER\_res(-1) + \underset{(0.045)}{0.069}\,DL(GP(-1)/Y(-1)) - \underset{(0.0003)}{0.0007}\,(id\text{-}euro)*\log(T)$$

$$- \underset{(3.516)}{9.218}\,SALBAND(-1)*\log(1+1/T) + \underset{(0.131)}{0.518}\,DPX - \underset{(0.121)}{0.148}\,DPY(1-d961aft)$$

$$+ \underset{(0.180)}{0.333}\,(LGAP\_S(-1)-LGAP\_S(-3))/2 - \underset{(0.216)}{0.416}\,(LRWGB(-2)-LRWGB(-4))/2 + \underset{(0.015)}{0.046}\,D98q4$$

Adj. R^2 =0.428 D.W. = 2.08

Instrumental variables for DPY are the exogenous variables in the equation plus DPY(-1), DPY(-2),DUMQ1, and DUMQ2. Instrumental variable for id is id(-1).

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[11] Values in parantheses are standard errors.

3. The inflation equation

$$DP = -\underset{(0.081)}{0.244} - \underset{(0.041)}{0.128}\,(LGAP\_S(-2)+LGAP\_S(-3))/2 + \underset{(0.085)}{0.163}\,(DLWGB(-2)+DLWGB(-3))/2 -$$

$$\underset{(0.061)}{0.241}\,(ib(-1)+ib(-2)+ib(-3))/3 + \underset{(0.198)}{0.407}\,DPE(-1)/4 + \underset{(0.057)}{0.192}\,(DLDOL+DLDOL(-1))$$

$$+ \underset{(0.033)}{0.119}\,DLPMI(-2) + \underset{(0.092)}{0.299}\,FISC + \underset{(0.002)}{0.0048}\,DUMQ2 + \underset{(0.006)}{0.024}\,D98q4 - \underset{(0.003)}{0.011}\,D973aft$$

Adj. R^2 =0.550 D.W. = 1.64

Instrumental variables for DLDOL are the exogenous variables in the equation plus DLOL(-2) DP(-1) ib(-1)-EUROSAL(-1).

4. The BoI interest rate equation

$$ib = \underset{(0.038)}{0.041} + \underset{(0.061)}{0.115}\,ib(-1) + \underset{(0.071)}{0.263}\,(DPE1-DPTAR(+1)*D91aft) + \underset{(0.179)}{0.308}\,DP12(-1)*(1-D91aft)$$

$$+ \underset{(0.09)}{0.259}\,DP12(-1)*D942aft - \underset{(0.332)}{7.050}\,(LGAP\_S(-1)+LGAP\_S(-2)+LGAP\_S(-3))/3*\log(1+1/T)$$

$$+ \underset{(0.008)}{0.059}\,D91Q4 + \underset{(0.035)}{0.067}\,D91aft - \underset{(0.007)}{0.009}\,D942aft$$

Adj. R^2 =0.888 D.W. = 1.28

Instrumental variables for DPE1 are the exogenous variables in the equation plus DPE_1(-1) and DPE(-1).

5. The nominal wage equation

$$DLWGB = 0.359 - 0.500\ DLWGB(-1) + 0.194\ DP12(-2)$$

(0.233) (0.096) (0.044)

$$-\ 0.192\ LGAP\_S(-4) - 0.067\ (LWGBR(-1)-LMPL(-1)) - 0.013\ DUMQ1$$

(0.082) (0.046) (0.004)

Adj. R^2 =0.455 D.W. = 1.84

6. Additional equations

$$DPE1 = 0.048 + 0.902\ DPE\_1(-1) - 0.425\ ib(-1) + 0.187\ DP12(-1)$$

(0.016) (0.134) (0.132) (0.096)

Adj. R^2 =0.807 D.W. = 1.86

$$id = -0.060 + 1.151\ ib + 0.336\ id(-1) + 1.564\ \log(1+1/T)$$

(0.010) (0.081) (0.041) (0.220)

Adj. R^2 =0.947 D.W. = 0.72

Instrumental variables for ib are the exogenous variables in the equation plus ib(-1) and d91aft.

In order to extract nominal exchange rate from the change in the log of real exchange rate we need to link between the estimated DP to the GDP deflator:

$$DPY = -0.011 + 0.874\ D\log(CP) + 0.019\ DUMQ1 + 0.026\ DUMQ2 + 0.009\ DUMQ3$$

(0.004) (0.075) (0.003) (0.004) (0.003)

Adj. R^2 =0.676 D.W. = 2.11

Linking between Business sector GDP and GDP:

$$LY = 1.695 + 0.677\ LYB\_S + 0.202\ LYB\_S(-1) - 0.011\ DUMQ1 - 0.010\ DUMQ2$$

(0.070) (0.060) (0.059) (0.004) (0.004)

Adj. R^2 =0.996 D.W. = 1.97

Extracting nominal depreciation of Shekel vs. dollar from real exchange rate change equation

$$DLDOL = (1/1.017)*(DLRER + DLPY - 0.006 - 0.643\ D(LOG(PX))$$

(0.066) (0.002) (0.171)

Adj. R^2 =0.859 D.W. = 2.25

<u>Appendix 3</u>

The long-run real exchange rate equation

$$LRER = 1.804 - 1.172\ \log(TFP\_DIF) - 1.025\ \log(Y/POP) - 0.493\ \log(GP/Y)$$

(0.398) (0.211) (0133) (0.037)

Adj. R^2 = 0.963 D.W. = 1.72

<u>Identites and transformation equations</u>

(1) LDOL = LDOL(-1) + DLDOL

(2) DOL = exp(LDOL)

(3) LSAL = LDOL + LOG(RAT_SAL)

(4) DLSAL = D(LSAL)

(5) SALBAND = exp(LSAL)/LBAND - 1

We endogenize the residuals (shifts) from the long term trend of the real exchange rate by:

(6) LER = LER(-1)+DLER

(7) RER_res =LRER –LRER_fit * * see equation above

Real and nominal business GDP are extracted from the GAP estimaton

(8) LYB_S = LYB_POT_S - LGAP_S

(9) DLYB_S = D(LYB_S)

(10) Y = exp(LY)

(11) DP12 = (1+DP)*(1+DP(-1))*(1+DP(-2))*(1+DP(-3)) - 1

(12) RB = ((1+ib/100)/(1+DP12)-1)*100

(13) RD = ((1+id/100)/(1+DP12)-1)*100

Real wages:

(14) DLRWGB = DLWG – log(1+DP)

(15) LRWGB = LRWGB(-1) + D(LWGB)

Appendix 4

Computing the Output Gap

The variable we use to describe economic activity is the gap between potential output (to be precise, product) and actual output in the business sector. The potential output is unobservable, and it must be computed. Our approach is to compute the potential output by plugging in a conventional production function the potential supply of labor and capital, as will be described below (Watanabe (1997)).

Labor: Total labor input in the business sector is the product of the number of employees and hours (per week) per employee. We divided employees into three groups according to their origin: Israelis, Palestinians from the West Bank and Gaza (wbg) and other foreign workers.

Israeli workers' labor input: In order to compute the potential number of Israeli employees we estimated separately the trend of the participation ratio for veteran Israelis and for newcomers (Olim) ($RLFI_{trnd}$ and $RLFO_{trnd}$, respectively). Supply of workers was attained by multiplication with the relevant population. Because we believe that the effective supply of newcomers to the labor market is smaller during the process of absorption and adaptation of their human capital to the local conditions, the supply of new immigrants was corrected by a factor of their unemployment in excess to that of veteran israelis. Therefore:

$$SUPI = RLFI_{trnd} * POPI + RLFO_{trnd} * POPO (1-(UO-UI))$$

Where RLF_ is rate of participation, POP_ is working-age population and U_ is the rate of unemployment. Suffixes I and O stand for israelis and new immigrants respectively.

Since we are dealing only with the product of business sector we deflated SUPI by the average proportion of employees in the business sector (0.703) in the years 1985-1997. Assuming the natural rate as being the minimum value of unemployment during that period (UN=5.8%).

SUPIB = SUPI * 0.703 * (1-UN)

Potential input is the multiplication of number of potential workers calculated above with the trend of hours-per-worker.

$LHSUPB = SUPIB * HOURSB_{trnd}$

WBG workers' and foreign workers' labor input: We assume the supply of these workers labor input is totally elastic. Therefore potential labor input is equal to actual labor input.

Capital: The potential capital included in the production function (KBV) is the stock of non-residential buildings as measured (KBB) and the stock of machinery corrected for vintages[12] (KBMV). The vintage correction for machinery is as follows:corrected stock of machinery is:

$$KBMV = KBMV_{-1} + IM^* (1.03^{1/4})^{T} - DSCRD^*(1.03^{1/4})^{T-16}$$

IM is investment in machinery in the quarter considered and DSCRD is the discard. We assume the rate of growth in machinery productivity between consecutive vintages is 3% and average life length of the machinery - 16 years**.**

Actual stock of capital which is included in the estimated production function equation is corrected for the rate of utilization (of machinery)[13].

12 The computation is similiar to the one appearing in Beenstock, Lavi anf Offenbacher (1994).

13 As computed by Mualem and Strawczynski (1998).

KBVU = KBMV * util + KBB

The Production Function: The production function was estimated for quarterly data from 1986 I until 1997 IV (48 observations). The inputs included are the corrected actual stock of capital, the sum of Israeli and WBG labor input and the labor input of foreign workers. All variables are I(1). We added a time trend to express the total productivity growth. All coefficients are statistically significant at 1%. An attempt to include the stock of infrastructure (roads) was not successful. The (log of) business sector product is estimated as:

LYB_S = (-0.264+0.054 logT)+0.275 log KBVU+0.483 log(L+LHBS)+0.0081 log LHBF

$R^2 = 0.990$ S.E. = 0.021 D.W = 1.94

The sum of coefficients of production inputs is smaller than unity, and not significantly smaller than 0.85. For an similar equation estimated for a shorter period beginning in 1990 (without a time trend) the sum of coefficients is very close to unity (not significantly smaller than 0.98). It may be that the slowdown in productivity growth in recent years is the reason for the bias in the coefficients when estimating the production function over a longer period.

The Output gap

Potential output is computed by substituting the potential stock of labor and capital in the estimated production function and the output gap is the difference between the computed potential output (of the business sector) and the actual output. This difference represents the rate of utilization of capital, unemployment above its natural rate, deviations of actual rate of participation and hours per worker from their trend and noise.

Diagram 1 – Static Simulation

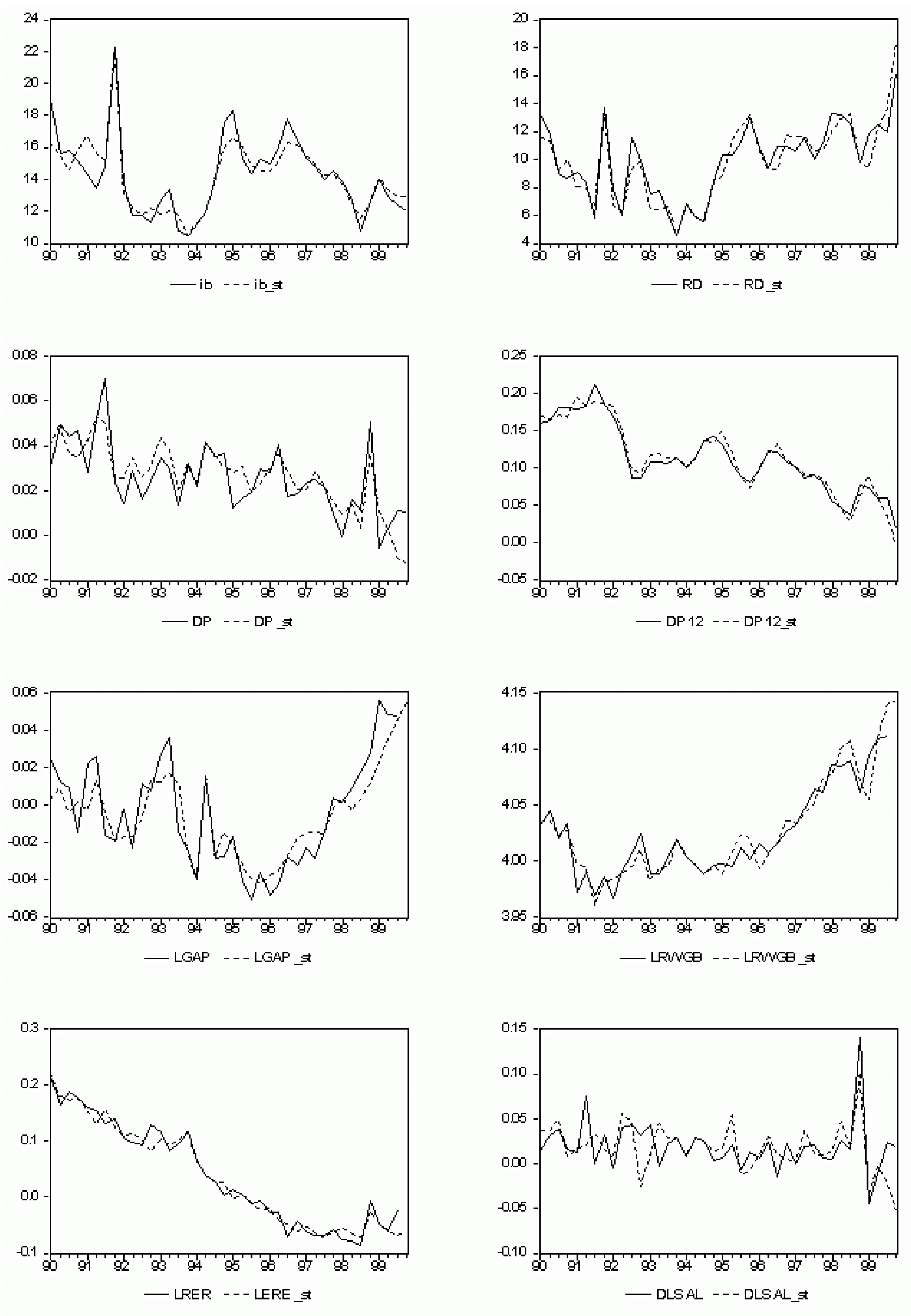

Diagram 2- Dynamic Simulation

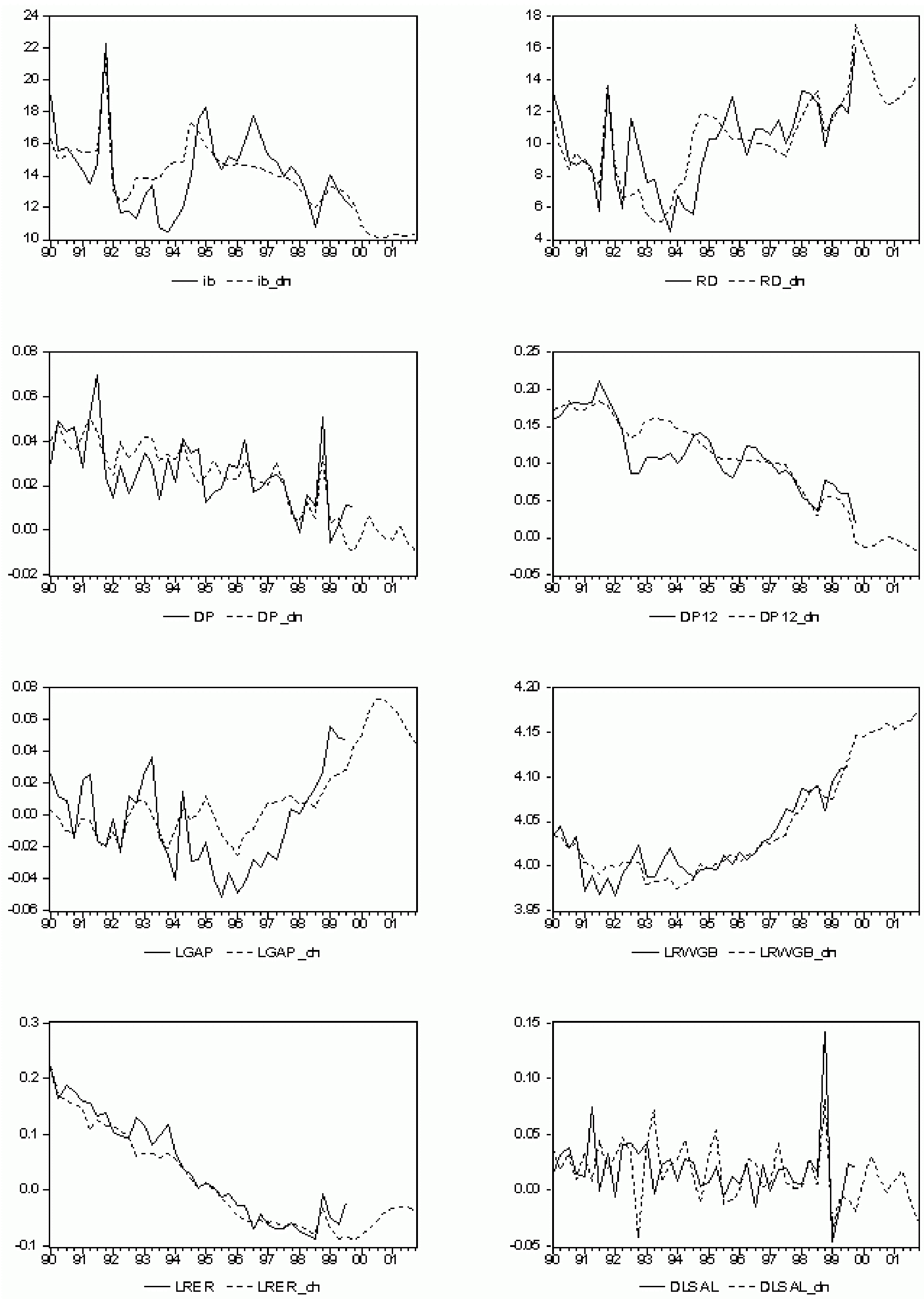

Diagram 3 – Dynamic Multipliers

A: a 1 p.p. shock to BoI interest rate in 90Q1

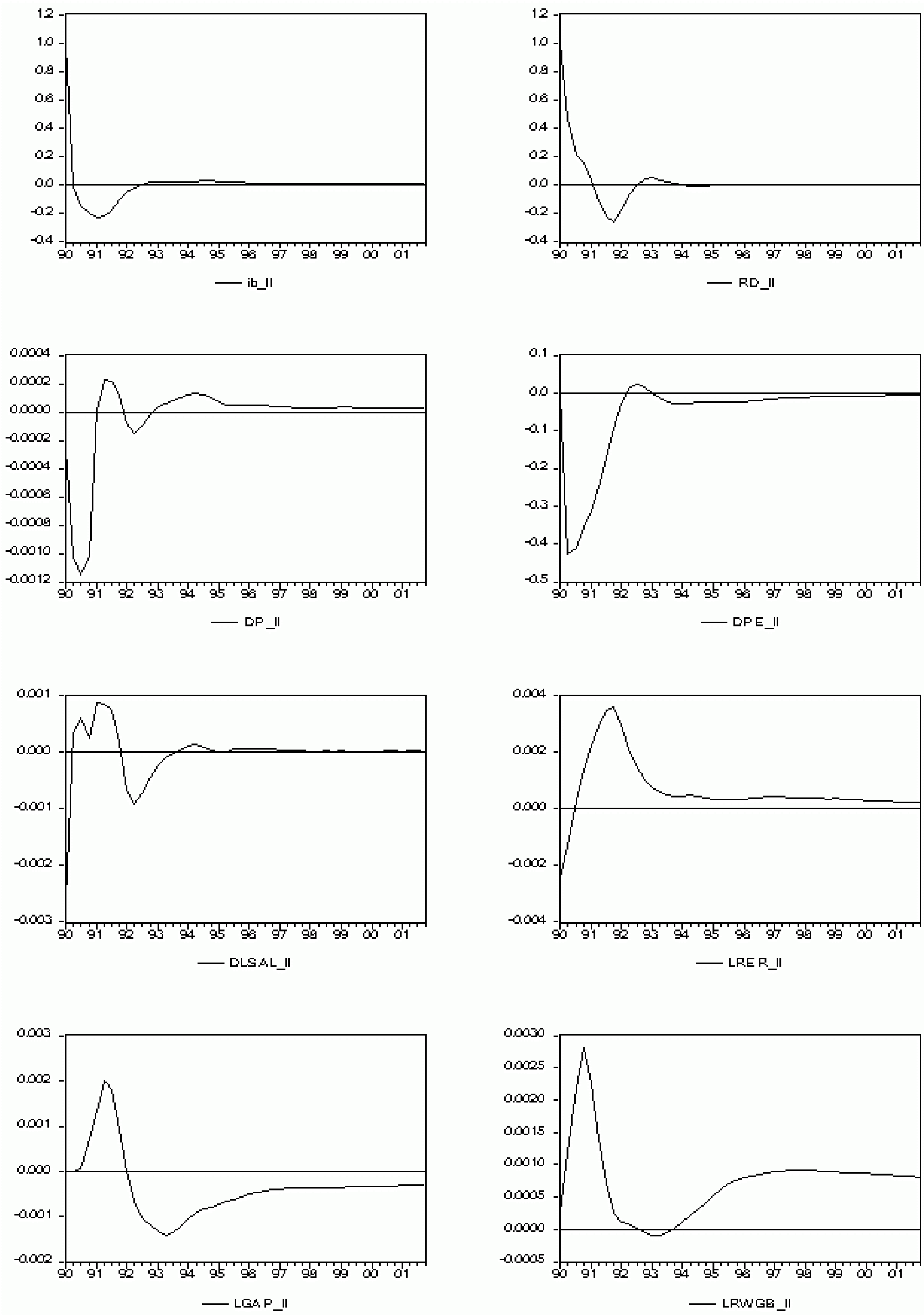

Diagram 3- Dynamic Multipliers

B1: a 1 p.p. shock to inflation rate in 91Q1

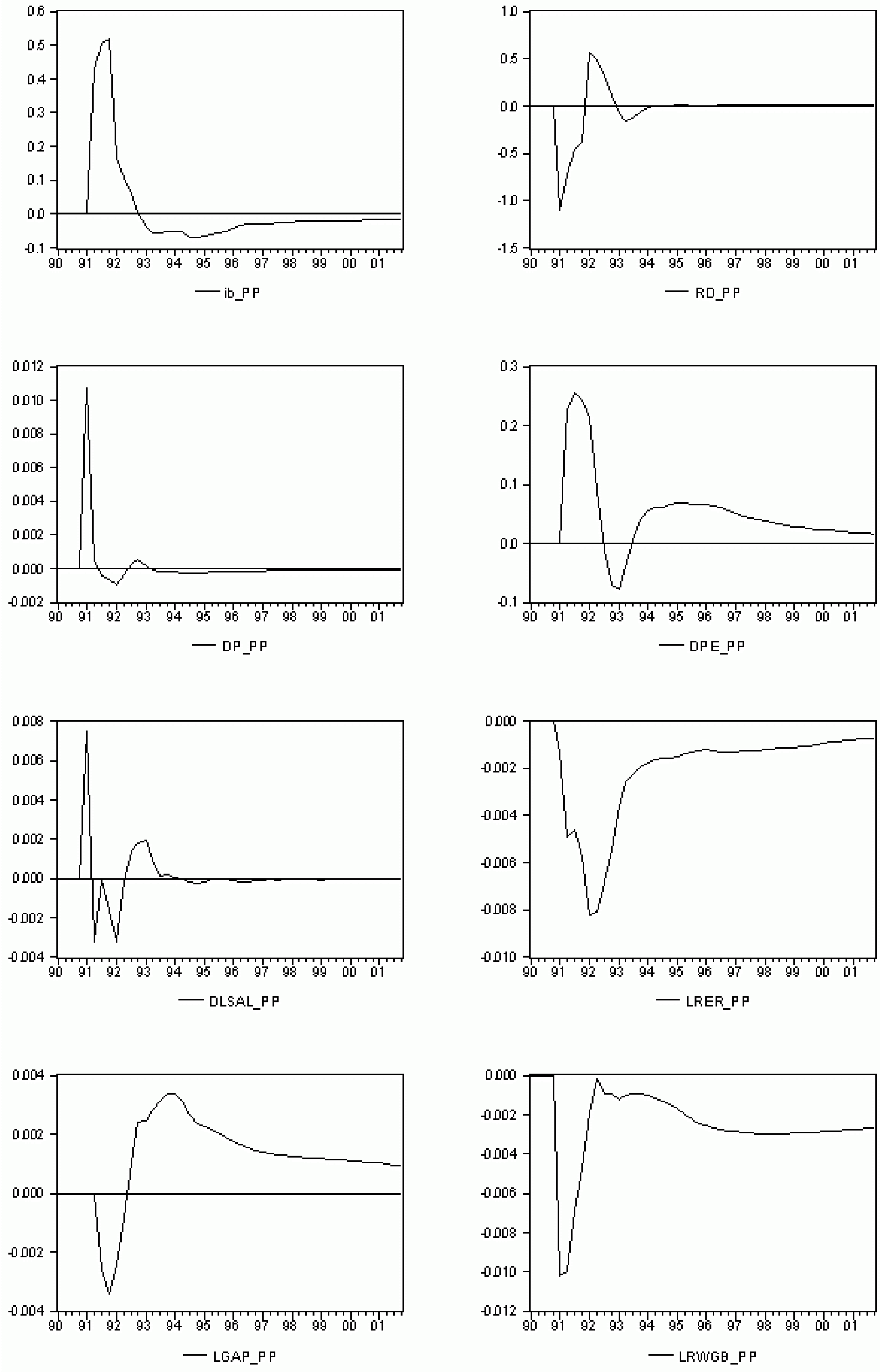

Diagram 3- Dynamic Multipliers

B2: a 1 p.p. shock to inflation rate in 97Q1

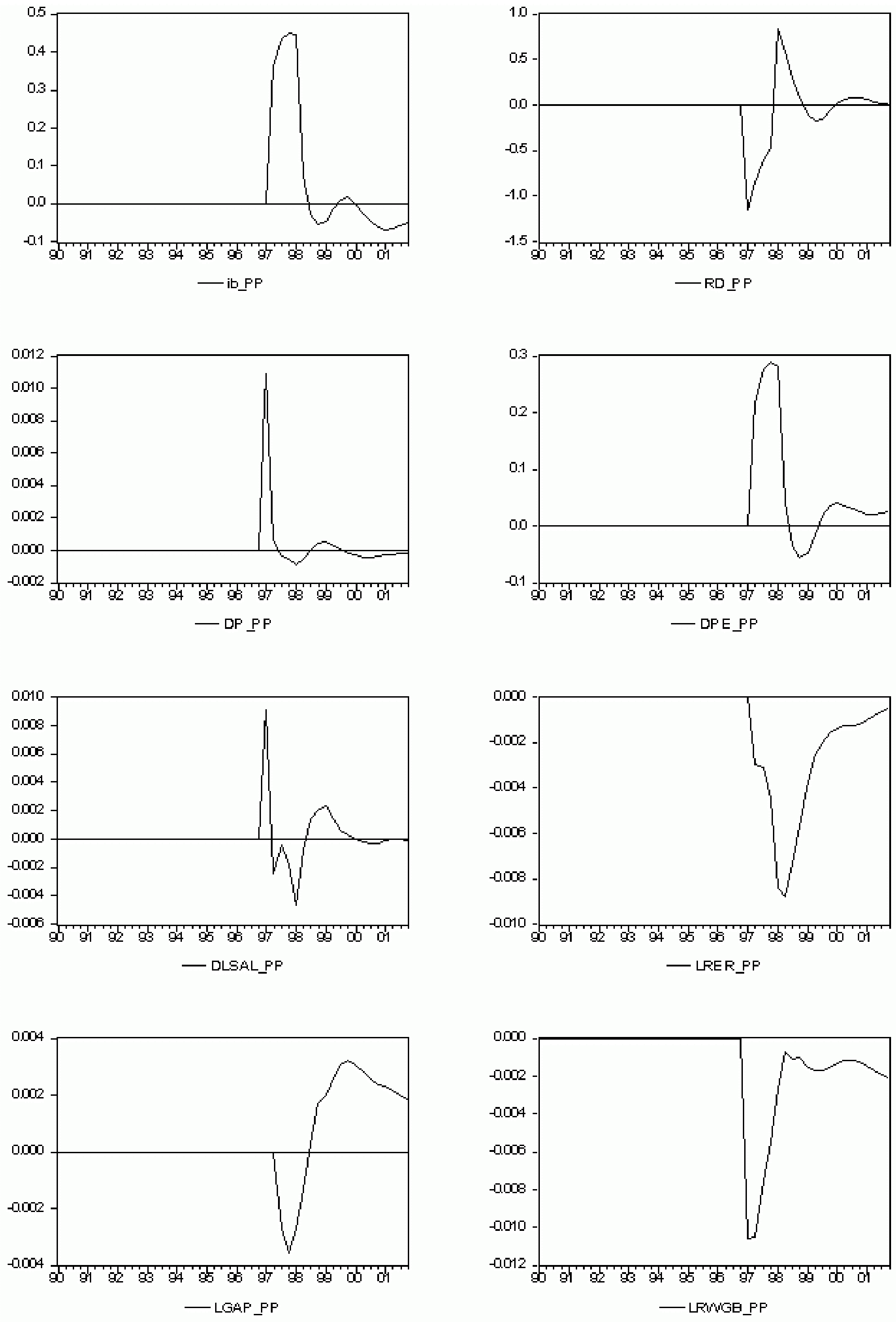

Diagram 3- Dynamic Multipliers

C: a 0.1 p.p. shock to nominal wages in 90Q1

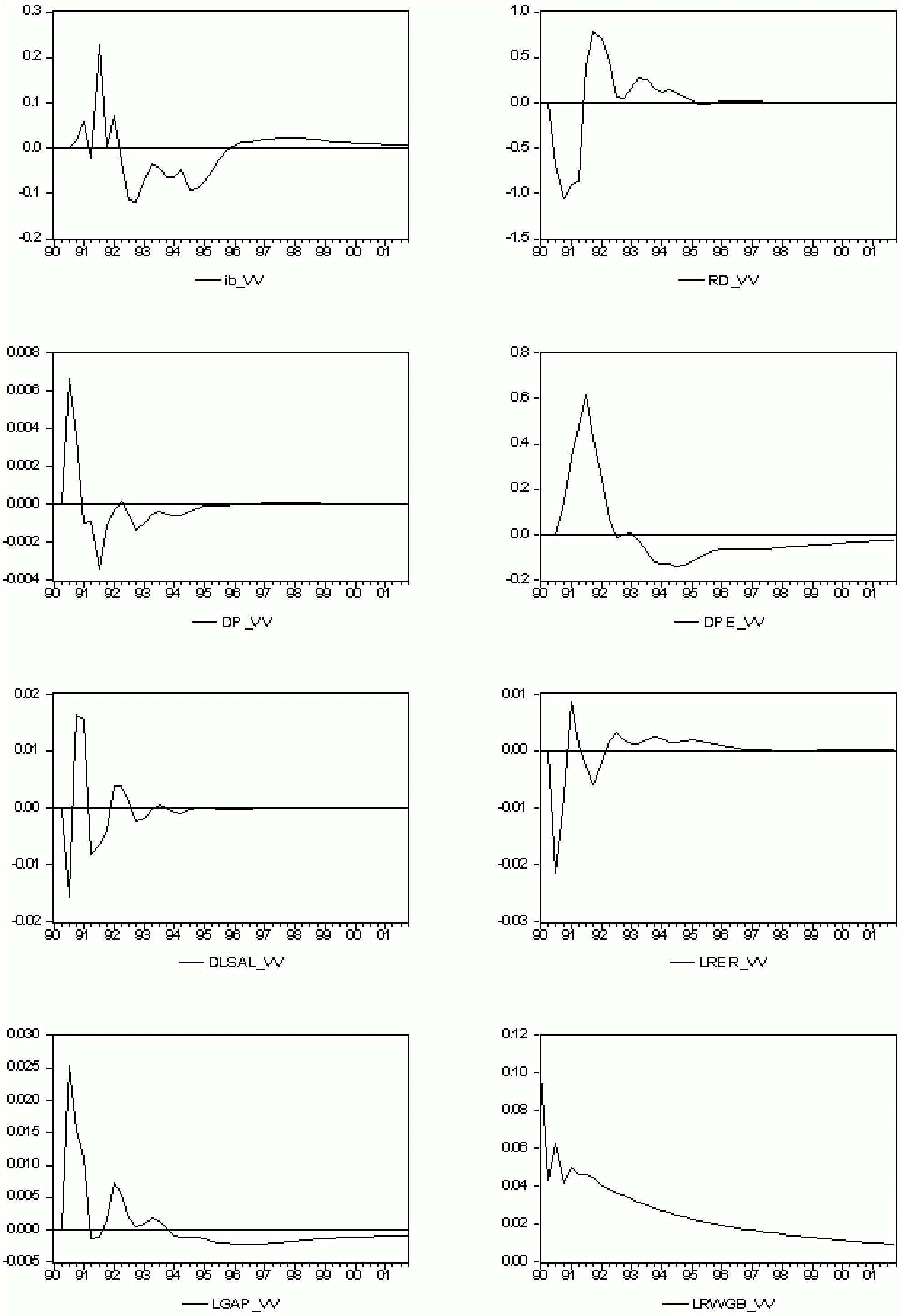

Diagram 3 – Dynamic Multipliers

D: a 1 p.p. shock to government deficit ratio to GDP in 89Q3

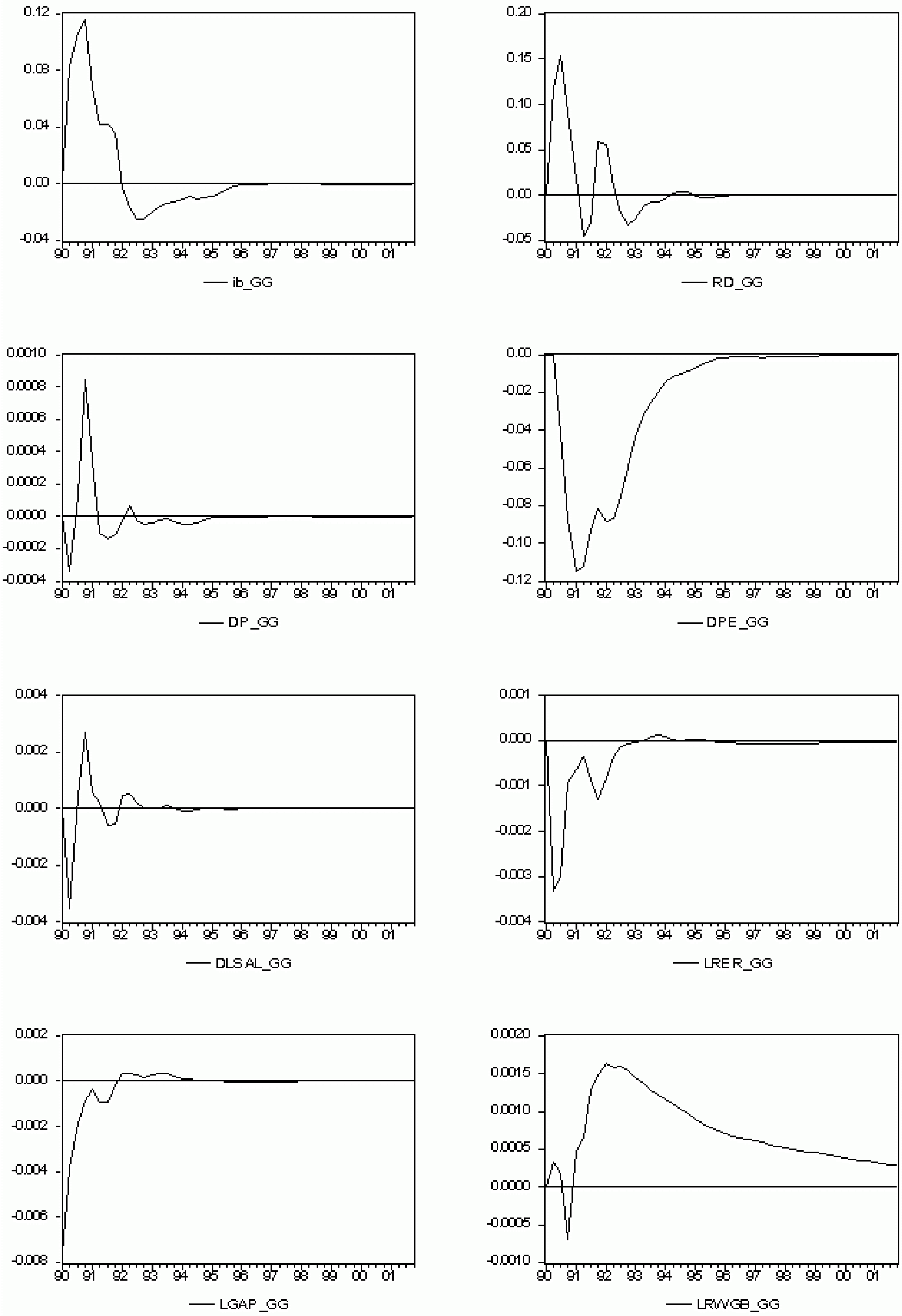

Diagram 3- Dynamic Multipliers

E: a 1 p.p. shock to world trade in 90Q1