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A MODEL FOR MONETARY POLICY UNDER INFLATION TARGETING: THE CASE OF ISRAEL

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abstract

In 1992 the Bank of Israel started to implement an inflation targeting regime. In this paper we formulate and estimate a small model to explain the determination of inflation, currency devaluation and the nominal interest rate under an interest rate rule designed to achieve the inflation target. We use quarterly data from the third quarter of 1992 to the third quarter of 2000.

Monetary policy is represented by an interest rate rule according to which the nominal interest rate is adjusted according to the gap between inflation expectations and the inflation target, and the gap between the present nominal interest rate and its rate in the long run. In this formulation we use data on inflation expectations derived from the bond market.

Inflation in the model is determined by currency devaluation *plus* the increase in import prices (abroad), inflation expectations and the gap between the short-term and the long-term real interest rates. The last item represents the influence of monetary policy on the output gap.

Currency devaluation is determined by the gap between domestic inflation and inflation abroad, and by the change in the differential between the domestic interest rate and that abroad.

The model can be used for forecasting and for policy analysis, i.e., to evaluate the effect of shocks—for example unexpected devaluation—on the course of the endogenous variables. In such implementation we need to assume how expectations are made. We use two alternatives: rational expectations and adaptive expectations.

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1. INTRODUCTION

In 1992 the Bank of Israel started to implement an inflation targeting regime. From then till 2000 the annual inflation target was reduced gradually from 14 percent to 3 percent. In the same period actual inflation declined from 9 percent to 0 percent a year.

During that period the theory and the implementation of the relationship between the interest rate policy of the central bank and the inflation rate developed rapidly.[2] The aim of this paper is to apply the theory to Israel's economy. For that purpose we formulate and estimate a small model which describes the determination of the inflation rate and the nominal interest rate, derived from the interest rate rule which is designed to achieve the inflation target. We test how well it fits the Israeli data in the period from 1992 and demonstrate its use for forecasting and simulations.

The second section reviews the theoretical framework and describes how we suggest implementing it to the Israeli data by formulating equations for inflation, exchange rate devaluation, inflation expectations (adaptive) and the nominal interest rate. The third section presents the estimates of the parameters of the model. Section 4 demonstrates how the model can be used for forecasting and simulations, and section 5 summarizes the results.

2. THE THEORETICAL FRAMEWORK (THE MODEL)

The theoretical framework common to most central banks (at least those which use an inflation targeting regime) is based on three basic relations (equations). The first is the output gap equation, according to which the output gap is negatively related to the short-term real interest rate. The second equation is a Phillips curve according to which inflation is positively related to the output gap. According to those two equations, a rise in the short-term real interest rate reduces the output gap, and thus reduces inflation. The third equation describes how the central bank determines the nominal interest rate so as to achieve the inflation target.

[2] For a survey of the development see Mccallum (1999), Walsh (1998) and Clarida, Gali, Gertler (henceforth CGG) (1999).

The output gap equation can be written as follows:

(1) $$y = -a *(i - Edp - r)+ e_y,$$

where

y = the output gap;

i = the nominal interest rate;

Edp = inflation expectations;

r = the long-term real interest rate (the “natural” real interest rate);

and

e_y = an error term.

According to equation (1), the output gap is negatively influenced by the gap between the short-term (expected) real interest rate and the long-term real interest rate. The error e_y represents other factors such as unexpected shocks in fiscal policy, the real exchange rate or output abroad. Another factor that should appear in that equation is the expected output gap, but we ignore it for the sake of simplicity.

The inflation equation that we use is:

(2) $$dp = b_1*(de + dpim) + b_2*Edp + (1 - b_1 - b_2)*dp(-1) + b_3* y + e_p ,$$

where

dp = inflation;

de = exchange rate devaluation;

dpim = the rate of change of import prices;

and

e_p = an error term.

This equation is an extension of the Phillips curve to the case of a small open economy. The extension is done by including the influence of the rate of devaluation and the change in import price.[3]

[3] See for example Ball (1999), Walsh (1998) .

Potential output and thus the output gap are unobservables. During the years several methods have been developed to estimate them. Each method has its pros and cons, and some doubt always remains regarding the reliability of the estimates.[4] Israel's economy underwent a significant structural change as a result of the huge influx in immigrants during the 1990's, which made it even harder to estimate the output gap. Because of this, and also in order to concentrate on the relationship between monetary policy and the inflation rate we chose to use a semi structural form.

Substituting (1) in (2), we get:

$$(2') \qquad dp = b_1*(de + dpim) + b_2*Edp + (1- b_1 - b_2)*dp(-1) - b_4*(i - Edp - r) + (e_p + b_3*e_y) ,$$

where $b_4 = -a * b_3$.

According to equation (2'), a rise in the nominal interest rate causes inflation to be reduced, *ceteris paribus*. The advantage of using this form is that it enables us to bypass the difficulties of estimating the output gap and to concentrate on the relationship between monetary policy and inflation. The disadvantage is that the output gap, and thus inflation, can change for reasons other than the interest rate, and this might increase the variance of the error term.

It can be shown that in such a model, if the interest rate were chosen arbitrarily, inflation would diverge.[5] So, in order to achieve the inflation target, the nominal rate of interest has to be adjusted constantly according to the gap between the course of inflation and the target. Following CGG (1999), we shall assume a forward-looking rule of the form:[6]

$$(3) \qquad iT = r + dpT + c_1 * (Edp - dpT) ,$$

where

iT = the desired nominal interest rate, and

[4] For a survey of some of the methods see Kieran and Werner (2001) .
[5] See Haldane (1999).
[6] We ignore the output gap, which usually also appears in the rule.

dpT = the inflation target for the following period for which expectations are modeled.

The desired nominal rate of interest is the rate that would be chosen if there were no constraint of interest-rate smoothing. This rate equals the long-term nominal rate of interest *plus* a factor that depends on the gap between expected inflation and the inflation target (the inflation gap). This equation can also be written as:

$$(3') \qquad iT – Edp = r + (c_1 - 1) * (Edp – dpT) .$$

It can be shown that if c_1 is less than 1, the inflation rate might diverge.[7] For inflation to converge to the target, a rise in expected inflation should be followed by larger rise in the nominal interest rate such that the real short-term interest rate would rise.

In setting the nominal interest rate there is a common phenomena of smoothing,[8] i.e., a gradual adjustment to the desired rate. This usually takes the form:

$$(4) \qquad i = q * iT + (1-q) * i(-1) ,$$

where *q* is the rate of the adjustment in each period.

Substituting (3) in (4) we get:

$$(5) \qquad i = q *(r + dpT+ c_1 * (Edp - dpT)) + (1-q) * i(-1) .$$

The model consists of equations (2') and (5). Let us restate them as equations (6) and (7).

$$(6) \qquad dp = b_1*(de+dpim) + b_2*Edp + (1-b_1 - b_2)*dp(-1) - b_4* (i – Edp - r) ;$$

$$(7) \qquad i = q *(r + dpT + c_1 * (Edp - dpT)) + (1-q) * i(-1) .$$

To close the model we need to specify how inflation expectations are formed and how exchange rate devaluation is determined. Actually, for estimation it is not necessary to specify the way expectations are made since in Israel, unlike in most other

[7] See for example CGG (1999), CGG (2000), Taylor (1999).

countries, there exist relatively reliable data on inflation expectations, derived from the difference between the rate to maturity on unindexed and indexed bonds. But without specifying how expectations are formed, the model is of only limited use. In the following we shall use two alternatives: adaptive expectations and model-consistent expectations. Under the assumption of adaptive expectations we formulate and estimate the following equation:

(8) $$Edp = d_1 * dp + (1 - d_1)*Edp(-1) .$$

From the data it seems that during the relevant periods the rate of devaluation of the NIS against the dollar was positively correlated to the gap between inflation in Israel and abroad. It was also negatively correlated with the change in the interest-rate differential between Israel and abroad. So for the rate of devaluation we specify and estimate the following equation:

(9) $$de = dp - dpex + e_1 * [i - i(-1) - (id - id(-1))] + e_e ,$$

where

dpex= the rate of change of the export price (in dollar terms);

id = the dollar interest rate abroad; and

e_{e-} = an error term.

3. ESTIMATION OF THE MODEL

The model consist of equations (6), (7), (8) and (9). The data are quarterly data from the third quarter of 1992 to the third quarter of 2000.[9] We used the two-stage least squares method (2SLS).[10] For that purpose we add the following instrumental variables: dpex(-1), dpim(-1), drwt, and drwt(-1),

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[8] For a summary of possible explanations, see CGG (1999), Walsh (1998).

[9] Equation (9) was estimated with data from the third quarter of 1992 to the fourth quarter of 1999.

[10] We used 2SLS and not 3SLS in order to prevent bias in all the equation due to possible misspecification of one or more of the equations.

where:

dumi = dummy variable for quarter i (i= 1, 2, 3, 4);

dp = the rate of change of C.P.I;

de = the rate of change of the NIS/$ exchange rate;

dpim = the rate of change of the import price (abroad, in dollar terms);

Edp = expected inflation for the following four quarters;

dpex = the rate of change of the price of export (in dollar terms).

i = the nominal interest rate set by the Bank of Israel

r = the real yield to maturity on indexed 10-year bonds;

dpT = the inflation target for the following four quarters;

drwta = the rate of change of the import unit value (industrial countries)

id = the libid interest rate on dollars.

A. The inflation equation

$$(6') \quad dp = \underset{(-1.9)}{-1.032}*dum1 + \underset{(3.9)}{1.940}*dum2 - \underset{(-2.2)}{1.097}*dum3 + (1.032 - 1.940 + 1.097)*dum4$$

$$+ \underset{(4.8)}{0.191}*(de + dpim) + \underset{(5.3)}{0.583}*Edp + (1-0.191-0.583)*dpsa(-1) - \underset{(-3.2)}{0.761}*(i - Edp - r)$$

Rsq = 0.799 DW=1.30 s=2.89 T=33 (92.3 - 2000.3) ,

where

dpsa =dp-(- 1.032*dum1 + 1.940*dum2- 1.097*dum3 + (1.032-1.940+1.097)*dum4)

B. The monetary policy reaction function

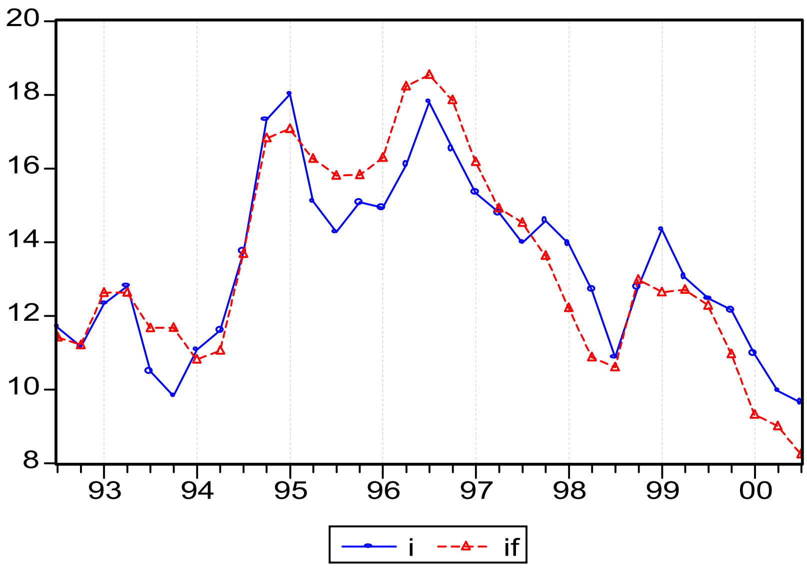
$$(7') \quad i = \underset{(3.0)}{0.452}*(r + dpT + \underset{(3.6)}{1.738}*(Edp-dpT)) + (1- 0.452)*i(-1) ,$$

Rsq = 0.855 DW = 1.84 s = 0.897 T = 33 (92.3 - 2000.3) .

Note that the coefficient of the inflation gap turns out to be more than 1, as is needed for convergence of inflation to the target. Also note that the coefficient of adaptation is about 0.45, much larger than in other countries.[11]

Figure 1 shows the actual nominal interest rate and the rate derived from the equation (dynamic simulation with respect to the nominal interest rate). As can be seen, there is quite a high correlation between the actual and simulated series. In the second half of 1993 and during 1995 and 1996 the actual rate was below what it should have been according to the rule, and from the last quarter of 1999 to the third quarter of 2000 it was above what it should have been according to the estimated rule.

Figure 1 Actual (i) and simulated (if) nominal interest rate, from equation 2



C. Inflation expectations (adaptive expectations)

(8') $$\underset{(2.8)}{Edp = 0.217}*dpsa + (1- 0.217)*Edp(-1) ,$$

Rsq = 0.908 DW = 1.73 s = 0.949 T = 33 (92.3 - 2000.3) .

[11] CGG (1998) report on coefficients between 0.1 and 0.2.

D. Exchange rate devaluation

$$\text{(9')} \qquad de = -\, dpex + dpsa - \underset{(-2.5)}{2.540} * [i - i(-1) - (id - id(-1))] + \underset{(7.0)}{46.539} * dum984\ ,$$

Rsq = 0.761 DW = 1.35 s = 6.281 T = 26 (93.3 – 99.4) ,

where

dum984 is a dummy variable for the last quarter of 1998.

As can be seen, the change in the interest-rate differential has a large short-term effect on the rate of devaluation. So a reduction in the nominal domestic interest rate causes inflation to rise through two channels: by reducing the output gap, and by increasing devaluation in the short run.

4. FORECASTING AND SIMULATION

a. Forecasting

We present below a forecast for several years of the path of inflation and the rate of interest derived from the model. For that purpose we need to assume how inflation expectations are formed. Since we have estimates of expected inflation, we could in principle try to infer from the data whether the adaptive or the rational model of expectations fits the data better. But such an exercise is not an easy task because we have quarterly data on expected inflation for the following four quarters. This overlap poses difficult econometric problems when one wishes to test for rationality of expectations. One solution could be to change to annual data, by dropping observations relating to three quarters of each year. But this would leave us with only 10 observations (instead of 40). We therefore chose to forecast under two alternative scenarios, i.e., adaptive and rational expectations. By rational expectations we mean model-consistent expectations.

We start the forecast in the forth quarter of 2000. We assume that the central bank will continue to operate the same rule which was estimated by us and that the inflation target is 3 percent (in annual terms) for 2001, 2.5 percent for 2002 and 2 percent from 2003 onwards. We assume also that the import and export price is constant in dollar terms and that the real rate of interest on 10 year-bonds will remain 5.5 percent.

In Figure 2 we present the inflation target (4 quarters ahead) and the forecast path of inflation under adaptive expectations (dpsaf0) and under rational expectations (dpsaf1). As can easily be seen, in both cases inflation converges to the target, but under rational expectations the convergence is monotonic and faster. Under adaptive expectations, inflation is initially below the target, then above it, then below it again, converging only in 2005.

Figure 2 Inflation forecast under adaptive (dpsaf0) and rational (dpsaf) expectations

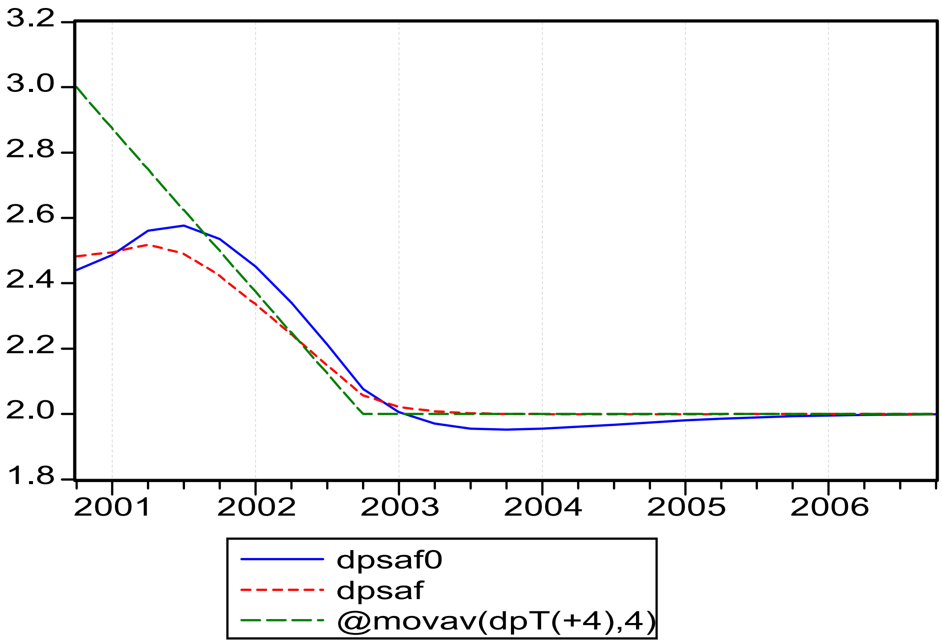
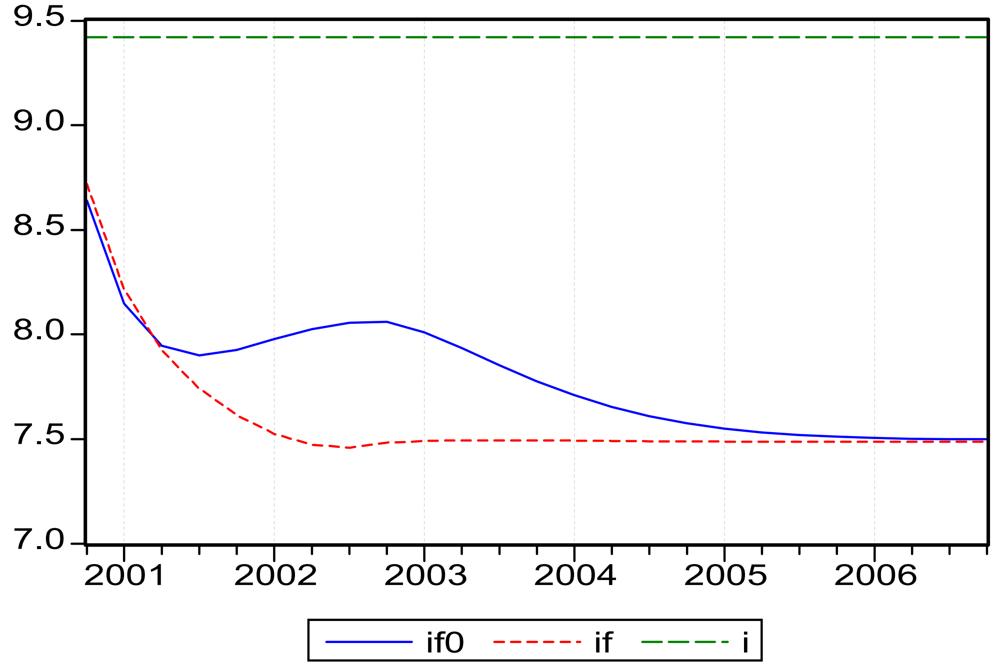


Figure 3 shows the path of the nominal interest rate under the two alternatives. Under rational expectations the path is monotonic, and convergence occurs at the beginning of 2002. Under adaptive expectations the nominal interest declines faster initially, then starts to rise in the middle of 2001, and from 2003 onwards it declines again, converging at the end of 2005.

Figure 3 Forecasts of the nominal interest rate under adaptive (if0) and rational (if) expectations

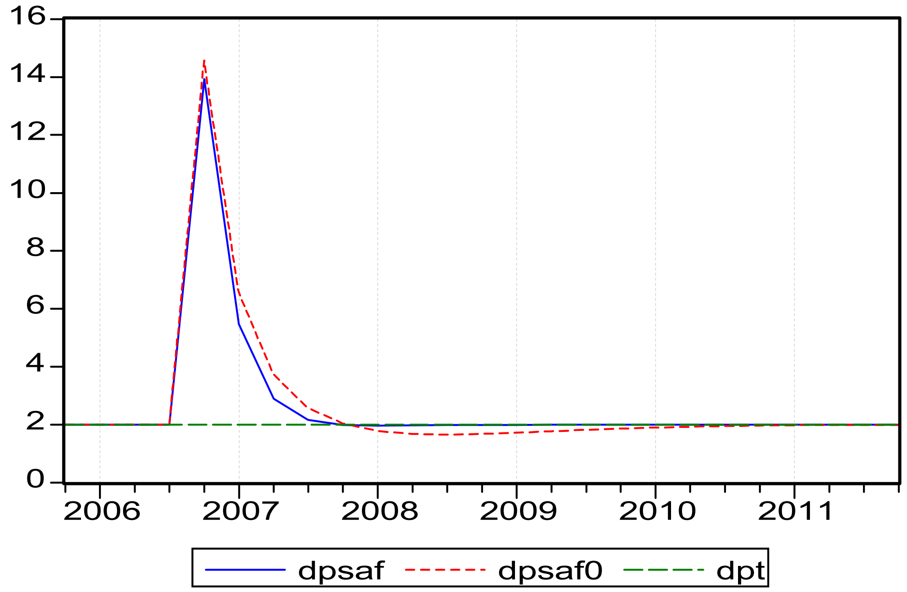


b. The impact of unexpected devaluation on the path of inflation and the nominal interest rate

We now simulate how the path of inflation and the nominal interest rate are influenced by unexpected devaluation. Assume that inflation is on target for some time. Assume that the target is 2 percent. Given that the real interest rate is 5.5 percent, the nominal interest rate converges to 7.5 percent. Now assume that in a certain quarter an unexpected devaluation of 10 percent occurs (i.e., 46 percent in yearly terms). As we shall see, the way expectations are formed has a crucial effect on the results.

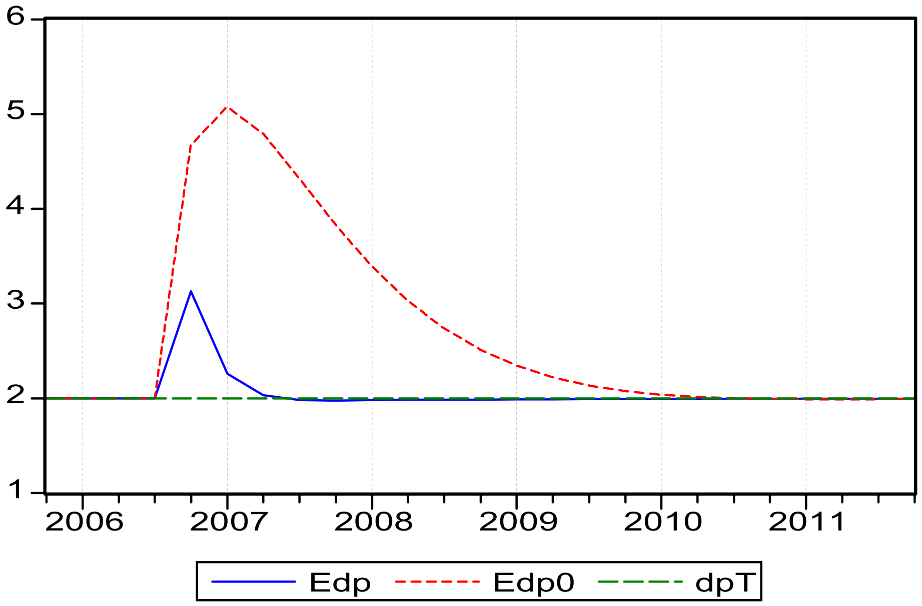
In Figure 4 we present the inflation target (2 percent) and the path of inflation under adaptive (dpsaf0) and rational (dpsaf) expectations. As can be seen, as a result of the unexpected devaluation inflation increases sharply under both alternatives and then gradually declines, until it reverts to the target. Under rational expectations the rise in inflation is slightly lower and the convergence with the target is a bit faster, but the overall picture is similar.

Figure 4 The effect of unexpected devaluation on the path of inflation under adaptive (dpsaf0) and rational (dpsaf) expectations



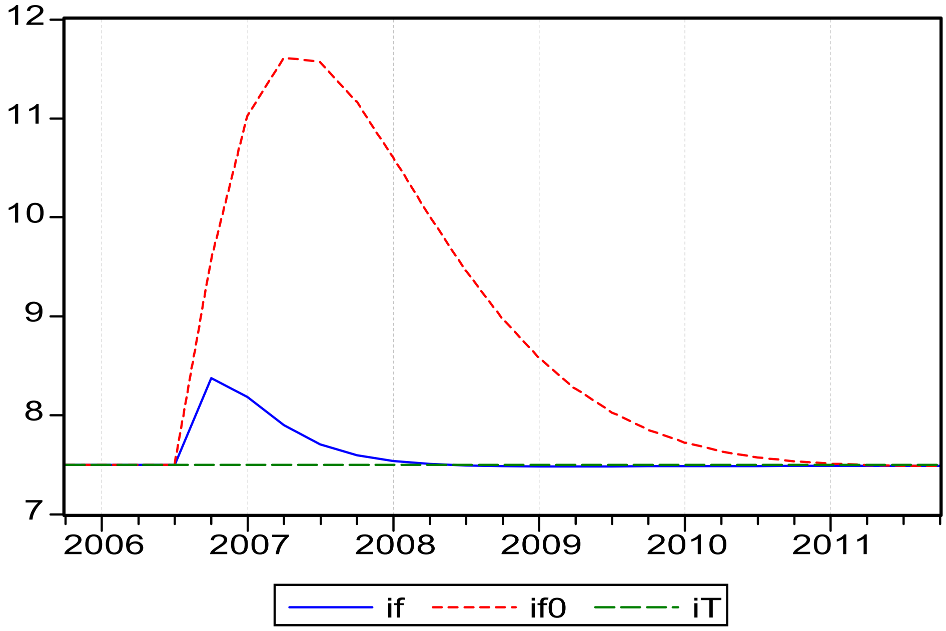
In Figure 5 we present the path of expected inflation under the two alternatives. Here there is a significant difference between the two cases. Adaptive expectations increase much more than rational expectations and converge much more slowly.

Figure 5 The effect of unexpected devaluation on the path of expected inflation under adaptive (Edp0) and rational (Edp) expectations



In Figure 6 we present the path of the nominal rate of interest under the two alternatives. Here as well there is a significant difference between the two cases. Under the adaptive case, as a result of the large increase in the inflation expectations, the nominal interest rate increases sharply and the convergence is slow. Under rationality, on the other hand, the increase in the interest rate is much smaller and convergence much faster.

Figure 6 The effect of unexpected devaluation on the path of the nominal rate of interest under adaptive (if0) and rational (if) expectations



From the above we can conclude that the reaction of inflation to unexpected devaluation is similar under both alternatives. But the reaction of inflation expectations, and as a result that of the nominal interest rate, is much more moderate under adaptive expectations.

5. SUMMARY AND CONCLUSIONS

We conclude that the nominal interest rate set by the central bank has a significant effect on inflation. But inflation is also heavily affected by exchange rate devaluation, increases in import prices, and unexpected shocks. So, in order to achieve the inflation target, the nominal interest rate should be constantly adjusted.

The monetary policy of the central bank, during the sample period, can be specified by a stabilizing interest rate rule designed to achieve the inflation target. According to that rule the nominal interest rate is adjusted according to two factors: the gap between the public's inflation expectations and the inflation target, and the differential between the current nominal rate of interest and its long-term rate.

The rate of devaluation is positively correlated with the gap between domestic inflation and inflation abroad and in the short run is negatively affected also by the change in the differential between the domestic interest rate and the rate abroad. So, reducing the domestic interest rate increases inflation through two channels: by increasing the output gap and by increasing devaluation.

This model can be used to derive the path of the nominal interest rate that is needed to achieve the inflation target. It can also be used to evaluate the effect of shocks—for example unexpected devaluation—on the future path of inflation, inflation expectations, the rate of devaluation and the nominal interest rate. However, in such implementations we must be aware that this model, like any other model, is only a rough simplistic approximation of a complex reality.

Appendix

The data

obs	dp	de	dpim	dpex	Edp	dpT	r	i	id	drwta
1992:1	5.91	-2.56	-6.85	1.43	12.30	13.38	3.20	13.78	4.01	7.37
1992:2	12.17	15.81	3.15	-3.47	12.02	12.25	2.79	11.68	3.79	-1.33
1992:3	6.68	2.29	11.71	8.98	9.78	11.12	2.29	11.69	3.22	6.82
1992:4	10.05	31.12	-12.79	-6.33	9.30	10.00	2.16	11.16	3.21	0.63
1993:1	14.63	29.56	-10.63	-6.59	10.99	9.50	2.29	12.33	3.00	-5.20
1993:2	12.36	-6.01	3.78	-4.32	9.23	9.00	3.24	12.81	2.99	8.50
1993:3	5.55	14.94	-9.13	-2.86	7.70	8.50	3.37	10.49	2.99	11.61
1993:4	13.38	13.09	-0.36	0.35	8.46	8.00	2.88	9.82	3.11	7.96
1994:1	9.02	5.99	-6.15	-5.65	7.49	8.38	2.91	11.08	3.25	7.32
1994:2	17.65	5.59	11.28	0.86	8.38	8.75	3.26	11.61	4.05	17.50
1994:3	14.75	1.33	13.26	6.46	11.77	9.12	3.22	13.73	4.60	13.88
1994:4	15.52	-1.11	11.48	5.56	13.98	9.50	3.43	17.32	5.42	14.39
1995:1	5.04	-2.75	14.67	12.15	11.69	9.38	4.02	18.01	5.93	7.52
1995:2	6.95	-2.35	21.81	3.68	10.21	9.25	4.36	15.11	5.95	7.10
1995:3	7.99	3.51	-4.25	0.00	10.16	9.12	4.33	14.28	5.76	3.67
1995:4	12.44	6.84	0.80	0.80	10.42	9.00	4.40	15.09	5.73	3.28
1996:1	11.84	7.61	-6.57	-1.79	11.00	8.88	4.31	14.93	5.30	7.39
1996:2	17.20	14.96	-1.60	-5.49	13.10	8.75	4.32	16.09	5.32	2.95
1996:3	7.09	-7.26	-3.60	-2.42	11.74	8.62	4.90	17.79	5.32	12.03
1996:4	7.77	11.13	-2.42	3.31	10.82	8.50	4.49	16.54	5.34	5.61
1997:1	9.42	9.92	-8.16	-4.33	9.33	8.50	4.16	15.33	5.34	5.51
1997:2	10.28	10.94	-8.20	-5.16	8.97	8.50	4.06	14.81	5.57	24.64
1997:3	8.78	13.96	-4.15	-7.76	9.52	8.50	3.78	13.98	5.53	12.46
1997:4	4.00	0.29	1.29	2.96	8.57	8.50	3.91	14.58	5.65	4.56
1998:1	-0.35	6.51	-13.40	-3.43	6.44	7.38	4.71	13.96	5.52	8.53
1998:2	6.59	10.70	-5.87	-6.10	5.10	6.25	4.96	12.71	5.53	8.77
1998:3	4.35	6.60	-8.98	-4.53	5.33	5.12	4.80	10.87	5.52	10.70
1998:4	21.81	59.30	6.09	3.34	8.03	4.00	4.93	12.78	5.27	5.42
1999:1	-2.28	-12.64	-10.58	-2.32	5.74	3.88	5.12	14.35	4.83	-2.31
1999:2	1.29	2.97	-5.08	-6.13	6.10	3.75	4.97	13.04	4.88	8.35
1999:3	4.54	3.35	12.64	1.98	5.35	3.62	5.14	12.47	5.21	17.15
1999:4	4.10	10.54	6.36	5.05	3.87	3.50	5.20	12.16	5.69	5.39
2000:1	-3.70	-15.43	3.52	-6.08	2.64	3.38	5.20	10.96	5.82	16.91
2000:2	3.19	4.35	-4.39	-9.72	3.40	3.25	5.11	9.96	6.36	4.26
2000:3	0.75	-3.74	3.01	0.24	2.35	3.12	5.59	9.64	6.53	17.50

where

dp = the rate of change of C.P.I;

de = the rate of change of the NIS/$ exchange rate;

dpim = the rate of change of the import price (abroad, in do;lar terms);

Edp = expected inflation for the following four quarters;

dpex = the rate of change of the price of export (in dollar terms);

i = the nominal rate of interest set by the Bank of Israel;

r = the real yield to maturity on 10-year indexed bonds;

dpT = the inflation target for the following four quarters;

drwta = the rate of change of the import unit value (industrial countries);

id = the libid interest rate on dollars

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