Monetary policy in response to imported price shocks: the Israeli case

Zvi Eckstein[1] and Guy Segal[2]

1 Introduction

Like any other small open economy, the Israeli economy is exposed to global price shocks, which have recently presented greater challenges to the conduct of monetary policy. The high volatility of international food and energy prices during the last two years highlights the question of whether monetary policy should respond to external price shocks using the same rule it uses to respond to domestic price shocks. Israel adopted the headline (CPI) inflation target range of 1-3% in 2003. Within a flexible inflation targeting framework, the monetary policy responds to both lagged and expected price changes in order to preserve price stability while minimising output (gap) volatility and maintaining interest rate stability. Due to the fact that an external price shock leads to a trade-off between inflation and output gap, a monetary policy that focuses on headline inflation may cause a deeper recession than a policy that responds to a measure of inflation that excludes external price shocks that are highly flexible - known as core inflation.

Since about the fourth quarter of 2007, headline inflation in Israel has been distinguished from core inflation, defined as the CPI excluding the energy, food, and fruit and vegetables components.[3] At that time, and in the first half of 2008, the Bank of Israel faced a dilemma regarding the appropriate interest rate policy response to the increase in inflation that was mainly due to changes in energy and food prices.

In this paper we analyse the impact on inflation and the output gap of different interest-rate-policy responses to external price shocks, using a variant of an estimated New Keynesian (NK) model for Israel (Argov and Elkayam (2007)). The model consists of four structural equations: a New Keynesian Phillips curve for domestic inflation, derived from firms' optimal price setting following Rotemberg (1982); an output gap equation, derived from optimal consumer allocation; a nominal exchange rate (ILS/US$) equation, based on an uncovered interest parity (UIP) condition with partial indexation; and an expanded forward-looking Taylor rule, by which the central bank (CB) sets the interest rate.

We compare the predicted outcome of the model relating to a transitory shock to imported consumer prices, when the Taylor rule responds to headline (HI) CPI inflation with a Taylor rule that responds to our definition of core inflation, following the literature. Specifically, we follow Aoki (2001), who defined core inflation as resulting from sticky-price sector components of the price index. Assuming that external prices that exhibit high price volatility should be viewed as flexible, and assuming immediate pass-through, we define two core inflation indices for the Israeli model; I) headline inflation excluding housing, fuel, fruit and

[1] Deputy Governor, Bank of Israel, ez@ Bank of Israel.gov.il

[2] Research Department, Bank of Israel, guy.segal@ Bank of Israel.org

[3] This is informal core inflation.

vegetables and imported consumer price components. II) The same as I, but including the housing price component.[4]

Comparing the response of the economy using the three rules, we find that using the headline (CPI) inflation rule gives higher volatility of inflation than do the core inflation rules, while the volatilities of the output gap and interest rates are lower. Using an ad hoc quadratic welfare-loss function of inflation, consumption gap and interest rate, we find that a Taylor rule that responds to core inflation including the housing price component yields higher welfare for the representative household.

The paper is organised as follows. Section 2 describes the model and defines core inflation, section 3 summarises the literature on the welfare-loss function, section 4 describes inflation and commodity prices in Israel in 2007 and 2008, section 5 discusses the results of the model, and section 6 concludes.

2 A New Keynesian (NK) model for Israel

In this section we describe the model used at the Bank of Israel (Argov and Elkayam (2007)) for monetary policy analysis, and we define headline inflation and core inflation. This framework will be used later to analyse the main question of this paper.

2.1.1 The model

We use a variant of the small quarterly estimated NK model for Israel used by the Bank of Israel (Argov and Elkayam (2007); Argov et al (2007)). The model consists of four structural equations (see Appendix A for details):

a) An open economy New Keynesian Phillips Curve (NKPC) derived from firms' optimal price setting a la Rotemberg (1982) for domestic inflation, π_t^h:

(1) $\pi_t^h = a_\pi E_t \pi_{t+1}^h + (1-a_\pi)\pi_{t-1}^h + a_y \cdot 0.5 \cdot (y_t + y_{t-1}) + a_{p^*} p_t^{zc*} + a_q q_t + \upsilon_t^{\pi h}$,[5]

where y_t is the output gap, p_t^{zc*} is the world price of inputs relative to consumer goods expressed in log deviation from trend,[6] q_t is the real exchange rate, defined as the price of imported consumer goods, p_t^*, in local currency (ILS) relative to the domestic price, that is $q_t \equiv p_t^* + e_t - p_t^h$, where e_t is the nominal ILS/US$ exchange rate. Domestic inflation, π_t^h, is defined herein as headline inflation (CPI) excluding prices of housing, fuel, fruit and vegetables, and imported consumer goods. Finally, $\upsilon_t^{\pi h}$ is a cost-push shock.

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4 Housing prices were highly flexible and were linked to the ILS/US$ exchange rate and, therefore, were traditionally excluded from the definition of core inflation in Israel. However, within the model we use, housing prices are sticky.

5 The derived Phillips curve should include only the current output gap (see Appendix A). However, a better fit was achieved by including a simple average of the current and lagged output gap.

6 All variables apart from interest rates are expressed in log deviations from trend, which is calculated by HP filter in the estimation.

b) A dynamic IS curve, the output gap equation, y_t, which is derived from optimal consumer allocation (the inter-temporal Euler equation):

$$\begin{aligned} & y_t = a_h E_t y_{t+1} + (1-a_h) y_{t-1} - a_i (i_t - E_t \pi_{t+1}) + a_q (q_t - a_h E_t q_{t+1} - (1-a_h) q_{t-1}) \\ (2)\quad & + a_g ((g_t^h - a_h E_t g_{t+1}^h - (1-a_h) g_{t-1}^h) + a_{inv} ((inv_t^h - a_h E_t inv_{t+1}^h - (1-a_h) inv_{t-1}^h) \\ & + ((y_t^* - a_h E_t y_{t+1}^* - (1-a_h) y_{t-1}^*) + \upsilon_t^y , \end{aligned}$$

where government consumption, g_t, investment, inv_t, world trade, y_t^*, and υ_t^y, which is an error term, are all given exogenous variables, i_t is the domestic risk-free interest rate, and π_t is defined as the weighted sum of domestic inflation, π_t^h, and imported consumer goods inflation in local currency, π_t^*.

Argov and Elkayam (2007) estimated the domestic NKPC under two assumptions: a gradual pass-through and an immediate pass-through from the exchange rate and imported consumer goods prices to local prices. In this paper we assume an immediate pass-through of imported consumer inflation, and, as a result, imported consumer price inflation in local currency, π_t^*, is fully flexible. Thus, π_t^* is given by $\pi_t^* = p_t^* - p_{t-1}^* + de_t + \varepsilon_t^*$, where de_t is the nominal depreciation of the ILS against the dollar, and ε_t^* is an error term. Finally, $a_h = 1/(1+h)$, where $h \in (0,1)$ represents the strength of external habit formation, and σ^{-1} is the inter-temporal elasticity of substitution in the intra-temporal utility function of the representative household *j*, which is assumed to be

$$u(C(j)_t) = \frac{(C(j)_t - hC_{t-1})^{1-\sigma}}{1-\sigma} .$$

c) A nominal ILS/US$ exchange rate equation, e_t, which is derived from an expanded uncovered interest rate parity (UIP) condition for no-arbitrage between domestic and foreign bonds and is given by

$$(3)\quad e_t = \omega E_t e_{t+1} + (1-\omega) e_{t-1} + (i_t^* - i_t) - (1-\omega)(i_{t-1}^* - i_{t-1}) + \phi_t - (1-\omega)\phi_{t-1} + \varepsilon_t^e ,$$

where i_t^* is the foreign risk-free rate, ϕ_t is a risk premium paid on foreign assets, and ε_t^e is a nominal exchange rate random shock.

d) The central bank (CB) sets interest rates following a forward-looking Taylor rule, with interest rate smoothing, given by

$$(4)\quad i_t = (1-k_i)[r_t + \overline{\pi} + k_\pi (E_t \pi_{t+3}^R - \overline{\pi}) + k_y y_t] + k_i i_{t-1} ,$$

where r_t is the forward yield to maturity on indexed-linked Treasury bonds, a proxy to the natural rate, and $\overline{\pi}$ is the inflation target.

We use a Taylor rule which responds to three-period forward inflation, ie $E_t \pi_{t+3}^R = 0.25(\pi_t^R + \pi_{t+1}^R + \pi_{t+2}^R + E_t \pi_{t+3}^R)$, which is regarded as the standard monetary policy that aims to anchor inflation expectations.

The model is closed with three equations for the housing, fuel, and fruit and vegetables price components of the CPI. The CPI housing component equation is a function of the nominal rate of ILS/US$ depreciation, de_t, reflecting the indexation of housing prices to the dollar (Eckstein and Soffer (2006)), and the long run impact of the inflation target, $\overline{\pi}$:

(5) $\pi_t^{housing} = \rho(de_t + \overline{\pi}) + (1-\rho)(de_{t-1} + \overline{\pi})$.

The CPI fuel price equation is given by:

(6) $\pi_t^{fuel} = f\overline{\pi}_t + (1-f)(de_t + \pi_t^{brent})$,

where $\pi_t^{brent} = \overline{\pi}_t + \varepsilon_t^{brent}$ is the price change of a barrel of crude oil, and ε_t^{brent} is a random shock.

The fruit and vegetables price equation is:

(7) $\pi_t^{f\&v} = \pi_t^h + \varepsilon_t^{f\&v}$.

Finally, the CPI inflation is calculated from the identity:

(8) $\pi_t^{CPI} = w^H \pi_t^{housing} + w^{fuel}\pi_t^{fuel} + w^{f\&v}\pi_t^{f\&v} + w\pi_t$.

This completes the description of the dynamic Bank of Israel model for the analysis of monetary policy. We now turn to the definitions of core inflation.

2.1.2 Core inflation indices

Within a flexible inflation targeting framework, monetary policy responds to both lagged and expected price changes to preserve price stability while minimising output (gap) volatility and maintaining interest rate stability. Due to the fact that an external price shock leads to a trade-off between inflation and the output gap, a monetary policy that focuses on headline inflation may react too aggressively compared with a policy that responds to core inflation. Hence, most central banks monitor core inflation as part of the interest rate decision-making process, as core inflation reduces transitory noise and could prevent the central bank from responding too strongly to transitory shocks (Mishkin (2007)).

Aoki (2001) shows that in a closed-economy two-sector DSGE model with a flexible-price sector and a sticky-price sector, the sticky-price inflation equation is a function of the relative price of the flexible-price sector. In that framework, following Rotemberg and Woodford (1997), Aoki derives a second-order approximation of the expected utility of the representative household (a loss function), and shows that it is a function of only the sticky-price inflation. As a result, he finds that stabilising sticky-price inflation is the optimal monetary policy. Hence, optimisation in Aoki's model is reached by a rule that responds only to core inflation.

Bodenstein, Erceg and Guerrieri (2008) show that in a DSGE model with a flexible price energy production factor, optimal monetary policy responds to core inflation. This core inflation is defined as the CPI excluding food and energy prices.

Following the above and the assumption in our model of immediate pass-through from the exchange rate and world prices to the import price in the local market, we define two core indices within the framework of the model:

I. Domestic inflation, π_t^h, which is the CPI index excluding prices of housing, fuel, fruit and vegetables and imported consumer goods. We denote this core inflation index as CI. This price index accounts for about 43% of the CPI.

II. The weighted sum of CI and the housing price component. We denote this second core inflation as CIH.[7] This price index accounts for about 64% of the CPI.

We compare the impulse response function of inflation, output gap and interest rate to a transitory 1% shock to prices of imported goods using three different inflation indices' Taylor rules:

I. The year-on year expected CPI (headline inflation rule, HIR).

II. The year-on year expected CI (core inflation rule, CIR).

III. The year-on year expected CIH (CIHR).

The above is a simple positive method for analysing the monetary policy response to external imported price shocks. To perform a normative analysis, and following the literature, we use an ad hoc loss function. In the next section we summarise the loss function literature and analyse the implications of the different Taylor rules on the policy loss function.

3 The loss function

We assume that the loss function has three terms: the gap between actual core inflation and the inflation target, the consumption gap and the change in the policy interest rate. This is a loss function that represents the welfare of the representative household.

Next, we calculate the loss function defined above using the three alternative Taylor rule responses to a transitory shock in imported consumer goods. By comparing the ratio of the loss function calculated using one Taylor rule to that calculated using an alternative Taylor rule, we can conclude which of the two yields higher welfare.

Rotemberg and Woodford (1997) showed that in a closed economy model with price-setting framework a la Calvo,[8] the second-order approximation of the expected utility of the representative household, the loss function, is a function of inflation and output gap variance. The output gap variance stems from the household utility from consumption, which in a closed economy model without investments and government is equal to output. The inflation variance stems from the price dispersion, which in a staggered price-setting framework distorts the optimal allocation across consumer goods. Following Rotemberg and Woodford's analysis, the loss function has been widely used to compare monetary policy reaction functions in term of representative household welfare.

Levine et al (2008) showed that in a closed economy model for the Euro area with price-setting framework a la Calvo, an external[9] habit formation, investments and government, the external habit formation implies a loss function which is a function of the quasi-change in consumption gap. As consumption, which enters the utility function, does not equal output, the loss function is a function of the consumption gap instead of the output gap. They also showed, similar to Woodford (2003), that in the case of indexation of prices to the lagged

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[7] H stands for the CPI housing component.

[8] Although the Phillips curve in the model we use is derived within Rotemberg and not Calvo price-setting, because its basic structure is similar to a Calvo-style NKPC (although not in deep parameters, of course) we can proceed and follow Woodford.

[9] External habit formation means that the household utility depends on the difference between the household current consumption and the lagged aggregate consumption. Woodford (2003) assumes internal habit formation, ie that the household utility depends on the difference between its current and lagged consumption, when deriving a loss function.

price index, the loss function is also a function of a quasi-change in the inflation, and is given by

(9) $L_t = (\pi_t - \gamma\pi_{t-1})^2 + \lambda_c (c_t - hc_{t-1})^2$,

where γ measures the degree of price indexation and h denotes the level of external habit formation in consumption.

In order to derive the loss function, the utility function of the representative household should include disutility from labour in addition to consumption, and labour should be included in the output production function. Due to the fact that the model we use lacks these two characteristics, the loss function cannot be derived analytically. We therefore use an ad hoc quadratic loss function following the guidelines of Woodford (2003) and Levine et al (2008).

Following Levine et al (2008), the relative weight of consumption gap in the loss function, λ_c, when inflation weight is normalized, is given by:

$$\lambda_c = \frac{(1-h)^{-1}\sigma\gamma_c\phi_F(1-\beta\xi_p)(1-\xi_p)}{(1-1/\eta)(1-\alpha)\varsigma\xi_p},$$

where σ is the inverse of the inter-temporal elasticity of substitution in the household utility function, γ_c is the share of consumption gap in the output gap, ϕ_F is the gross share of fixed costs in output, β is the discount factor, ξ_p is Calvo parameter, η is the CES among differentiated labor types, ς is the elasticity of substitution among the competitive final goods and α is the capital share in the Cobb-Douglas intermediate-goods-sector production function. Accordingly, in the core model of Levine et al (2008) $\lambda_c = 0.081$, assuming $\alpha = 0.3$ and $\gamma_c = 0.6$.[10] Assuming that the Calvo parameter corresponds to our model is 0.75, $\varsigma = 7$, and setting $\eta = \infty$ and $\phi_F = 1$ as our model lacks differentiated labor types and fixed costs respectively, and calibrating $\alpha = 0.32$ we get that $\lambda_c = 0.081$ in our model too.

However, for sensitivity analysis we choose to set $\lambda_c = \{[0,...,0.1], \quad by \quad 0.005\}$.

The observed tendency of central banks to adjust interest rates gradually implies that the loss function should also include an interest smoothing term. By including an interest rate smoothing term we use the ad hoc intra-temporal loss function

(10) $L_t = (\pi_t - \gamma\pi_{t-1})^2 + \lambda_c (c_t - hc_{t-1})^2 + \lambda_i (i_t - i_{t-1})^2$.

The result of estimation and calibration of a three-term loss function with an interest rate smoothing term is a wide range for the relative weight of the interest rate change, λ_i. In a small-scale NK model for the American economy, Dennis (2004) finds that λ_i=12.82 from 1966:Q1 to 2002:Q2, λ_i=2.5 for the Volker-Greenspan period, and λ_i=2.78 for the Greenspan period. Argov (2005) calibrates λ_i=4 for a small NK model for Israel, and Segal (2007) finds by calibration that λ_i should be higher than one, for a variant of the model we

[10] Following Smets and Wouters (2003), which Levine et al (2008) use their model.

use in this paper. Hence, for sensitivity analysis we choose to set $\lambda_i = \{[0,...,16], \quad by \quad 0.25\}$.

The difference between the various policy rules in terms of the approximated welfare of the representative household can now be summarised by the expected loss function, $Loss(t,\infty) = E_t \sum_{j=0}^{\infty} \beta^j L_{t+j}$.

4 Israeli data 2007–08

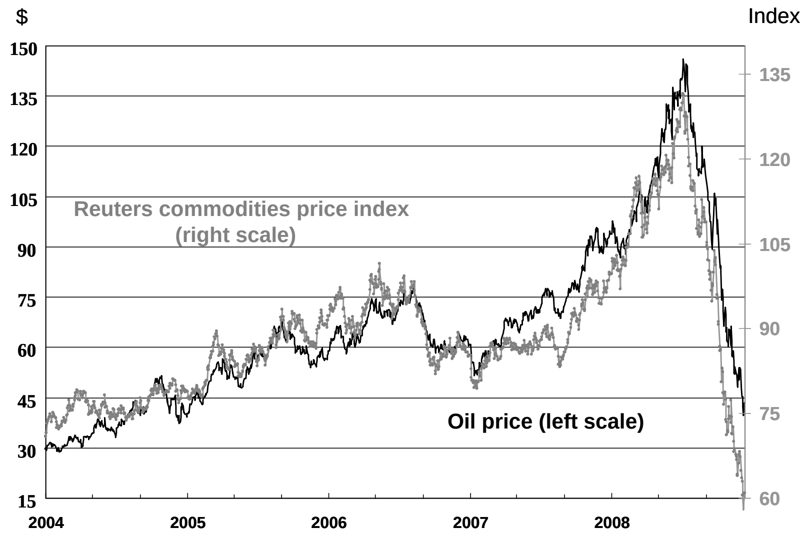
In this section we describe the main implications of the recent changes in commodity and oil prices on inflation and monetary policy in Israel.

The high volatility in international commodity and oil prices during the last two years was reflected both in the CPI and in core inflation indices in Israel. From January 2007 to July 2008 the Reuters commodity price index rose by 52.2% and oil prices by 131.1% (Figure 1); in the second half of 2008 the Reuters commodity price index fell by 53.1% and the price of oil by 69.1% as the global financial crisis intensified and economic activity contracted.

Figure 1

The commodity price index and oil prices, 2003 to December 2008

Daily data



Source: Bloomberg.

The high volatility in international prices trickled into the CPI in Israel, which rose by 3.4% in 2007 and by 4.5% during the 12 months to November 2008 (Table 1). This inflation environment is considerably higher than the upper limit of the Israeli inflation target (1–3%).

However, this high price volatility was not fully reflected in core inflation indices,[11] which were separated from the CPI in August 2007. Hence, a monetary policy dilemma emerged regarding the appropriate inflation index to which to respond (Figure 2).

Table 1

The CPI and selected core inflation indices in Israel, 2007 to November 2008

Percentage change in annual term

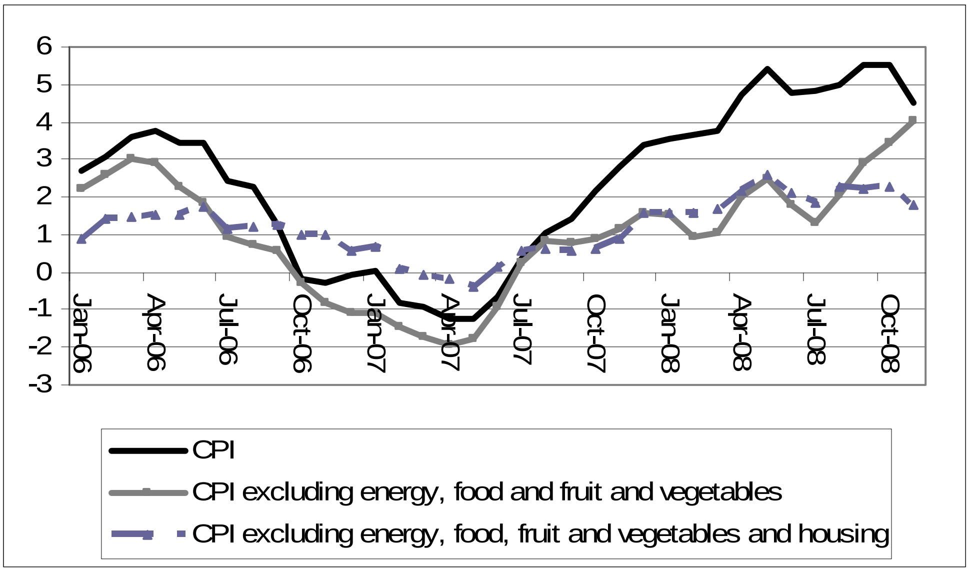
	2007	Dec. 2007-Nov. 2008	Jan.-June 2008	July-Nov. 2008
CPI	**3.4**	**4.5**	**4.7**	**0.9**
Energy	14.4	-2.8	11.5	-27.9
Food (excluding fruit and vegetables)	6.3	10.4	17.2	0.6
Fruit and vegetables	7.0	6.9	3.8	2.5
Housing	1.9	10.3	-2.6	23.4
CPI excluding energy, food and fruit and vegetables	**1.6**	**4.0**	**1.8**	**4.5**
CPI excluding energy, food, fruit and vegetables and housing	**1.5**	**1.8**	**3.6**	**-1.8**

Source: Based on Central Bureau of Statistics.

Figure 2

CPI and core inflation indices development in Israel, 2006 to November 2008

Percent change in previous 12 months



Source: Based on Central Bureau of Statistics.

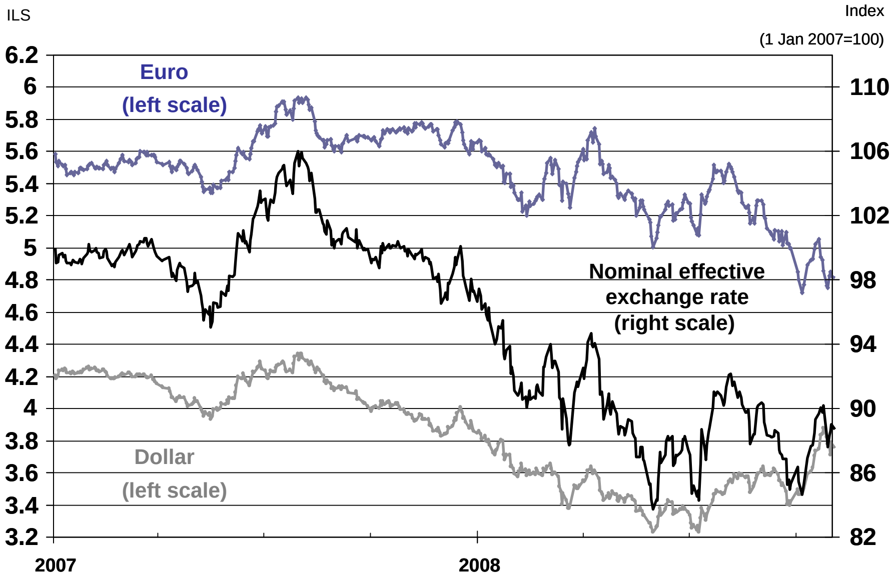
[11] These observable indices, unlike the indices in the model, do not relate to the unobserved imported consumer goods inflation,. Also, these indices exclude food and energy prices while the indices in the model exclude fuel prices instead..

The change in world food and oil prices has been reflected only partly in local prices due to the appreciation of the ILS throughout most of the period. The nominal effective exchange rate[12] showed appreciation of 12.9% from January 2007 to July 2008 (Figure 3), continuing the trend that started in 2006; in that period the ILS appreciated by 8.5% against the euro, and by 20.1% against the dollar. In March 2008 the Bank of Israel announced a plan to increase foreign exchange reserves by $10 billion over the next two years by purchasing approximately $25 million per day in the market, starting on 24 March. As a result of strengthening of the ILS, the indexation of the housing component[13] to the USD that resulted from the high inflation era of 1978-85 (Eckstein and Soffer (2006)) has weakened. Another reason for the fact that the change in domestic energy prices does not fully reflect the global change is the high tax component in the fuel price.[14]

Whereas the steep rise in local prices until the third quarter of 2008 mainly resulted from increases in food and energy prices, in the second half of 2008 the housing index, which rose by 9.2% (regular terms), led the rise in the CPI. This rise in the housing index was primarily the result of the renewal of rental contracts.[15]

Figure 3

The ILS/US$, ILS/Euro and the nominal effective exchange rates, 2007 to December 2008



Source: Bank of Israel.

In the second half of 2008 the trend of the strengthening ILS against the dollar reversed, and the ILS depreciated by 21.8%. This occurred against the background of the worldwide strengthening of the dollar and the Bank of Israel announcement on 10 July to increase the rate of its purchases of foreign currency in the framework of its plan to increase the forex reserves (see above), from $25 million to $100 million per day.

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12 The weighted average exchange rate of the shekel against the currencies of Israel's trading partners.

13 The housing component accounts for about 21% of the CPI.

14 Tax accounts for 62% of the price of fuel (ILS5 per litre in December 2008).

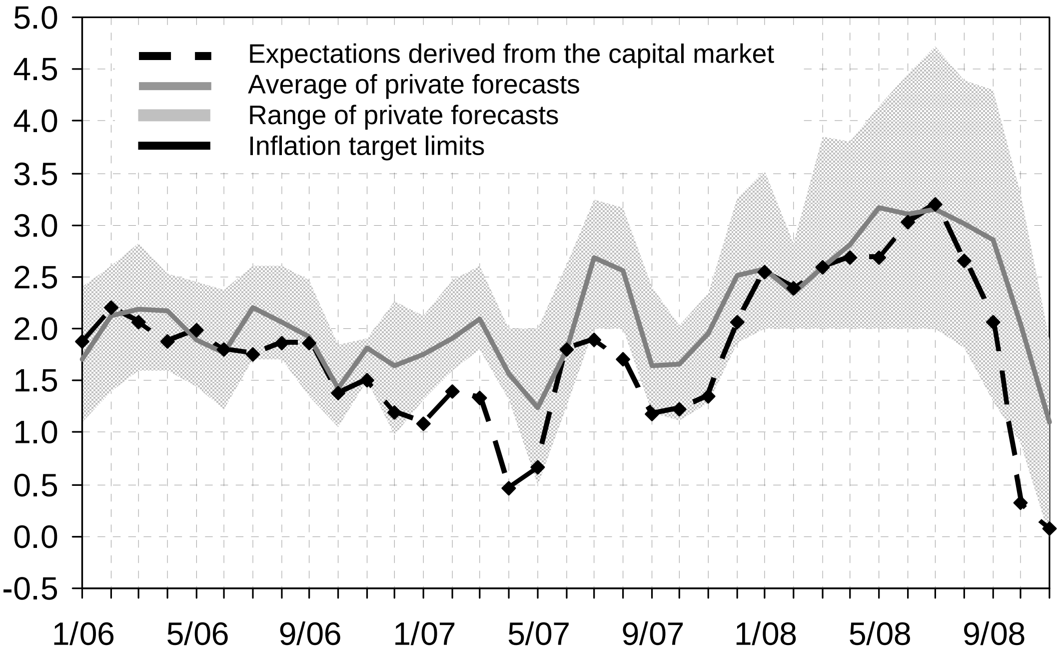
15 Renewed rental contracts constitute about 75% of the housing index.

Israel's economic growth continued in the third quarter of 2008, albeit at a slower pace than in the last four years, when growth had averaged 5.3% a year. This slowdown was expected in light of the previous high growth rates and the global slowdown in economic activity.

Following these developments, policy decisions became more complex, with inflation risks countered by considerations of financial stability on the one hand and the support of real economic activity on the other. Expectations of inflation for the next 12 months, those derived from the capital market and those of private forecasters, were highly volatile during the last two years (Figure 4).

Figure 4

Expectations of inflation for the next 12 months, derived from the capital market and according to private forecasters, December 2005 to November 2008



Source: Private forecasters' reports and Bank of Israel.

In the first half of 2007 expectations were around the lower limit of the inflation target, due to the appreciation trend of the ILS. As a result, Bank of Israel gradually lowered the interest rate from 5.5% in October 2006 until it reached a level of 3.5% in June 2007. The appreciation trend, which reversed temporarily in the second quarter of 2007, together with the steep rise in food and energy prices and rapid domestic growth, brought inflation expectations to around the middle of the inflation target and led to increases in the Bank of Israel's interest rate for August and September 2007 and January 2008.

In March and April 2008 the interest rate was lowered again in light of expectations of an economic slowdown, but following the further rises in world and local prices, expectations in the second and third quarters climbed to the upper limit of the inflation target, and the interest rate was raised again in order to maintain credibility. In the end of the third quarter of 2008, in light of the deterioration in the global financial market and the economic slowdown, inflation expectations fell sharply to below the lower limit of the target. Hence, similarly to other central banks throughout the world, in the fourth quarter of 2008 the interest rate was cut sharply, twice in unscheduled decisions, and again for January 2009, to reach an unprecedented low level of 1.75%.

The question of whether monetary policy reacted too aggressively during 2008 arises because core inflation increased by less than 2% until August 2008, while headline inflation was significantly above the upper limit of the inflation target from December 2007. We analyse this question empirically in the next section.

5 Core inflation or headline inflation?

A 1% shock to the world price of imported goods raises inflation, and raises the real exchange rate as foreign prices denominated in local currency are higher than local prices. As a result, the different measures of inflation increase in the following order, HI>CI>CIH, and hence the policy rule implies that the interest rate should be raised. Figure 5 summarises the impulse response of the endogenous variables determined by the model as a result of import price shock.[16]

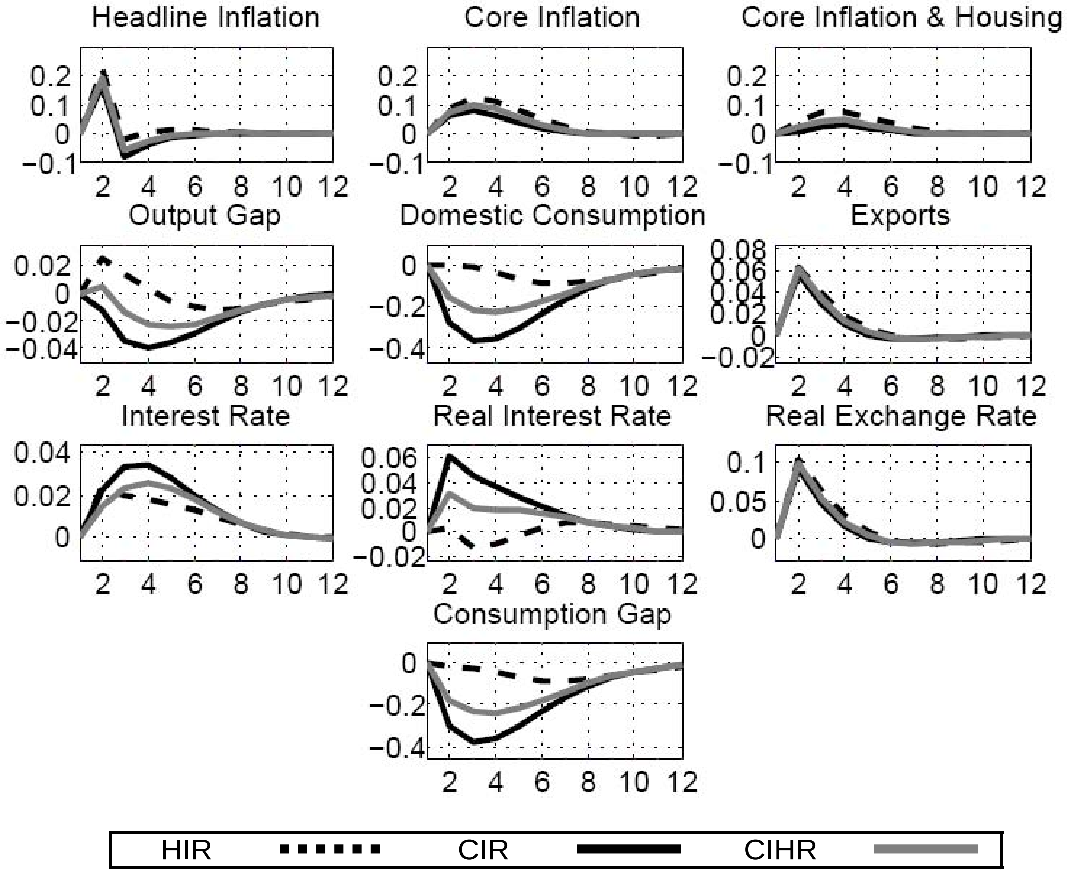
As the nominal interest rate increases, and due to nominal frictions in prices, the real interest rate also increases. Figure 5 indicates that the real interest rate path under policy rule that responds to core inflation, either CI or CIH, is higher than under headline inflation rule. Hence, the output gap and consumption gap are lower under core inflation rules (See Appendix B). As a result of the rise in the interest rates, both nominal and real exchange rate decrease and converge back to steady state.

By assumption, investments and government spending are exogenous, hence the change in the output gap can be decomposed into two components: domestic consumption and exports. Affected by the real depreciation, domestic consumption declines (dominant effect), whereas exports rise.

[16] All variables are expressed in log deviations from trend.

Figure 5

Impulse response function relating to a 1% shock to world price of imported goods, alternative policy rules



As a result of the shock, CI is higher than CIH due to the indexation of the housing component to the current and lagged nominal ILS/US$ exchange rates. Due to the fact that the interest rate rises in response to the shock, according to the UIP condition, the expected nominal exchange rate reflects appreciation. Thus, CIH is lower than CI and the implication is a more moderate interest rate response for the CIH. The reason for the higher rise in the interest rate under CIR than under HIR is the negative headline inflation gap (CPI-$\bar{\pi}$) from the third quarter, whereas the CI gap is positive until the seventh quarter. The higher decline in the expected output gap under CIR also contributes to the further increase in the interest rate.

Table 2 summarises the variances of the key variables among the alternative policy rules. The headline (CPI) inflation rule gives higher volatility of inflation than do the core inflation rules, while the volatilities of the output gap, consumption gap and interest rates are lower.

Table 2

Output gap, inflation and interest rate variances among alternative policy rules

	Output gap	Headline inflation	CI	CIH	Interest rate	Consumption gap
HIR	0.00009	0.00316	0.00215	0.00084	0.00007	0.00096
CIR	0.00021	0.00239	0.00078	0.00009	0.00017	0.02055
CIHR	0.00009	0.00276	0.00124	0.00028	0.00010	0.00853

The volatility of the consumption gap under CIR is 21 times higher than HIR and 9 times higher than CIHR. Furthermore, the volatility of the consumption gap under the CIR is higher than all other volatilities by more than the ratio of the corresponding relative weights in the loss function. The result is that the CIR is "out of the game," as shown below. The fact that interest rate volatility is lower under the CIH Taylor rule than under the CI Taylor rule is explained by the lower inflation—as the interest rate rises, the resulting nominal appreciation leads to a decline in the housing component of the CPI.

In what follows we describe the welfare implications of the different Taylor rules using the above loss function. As described in section 3, we use the following loss function:

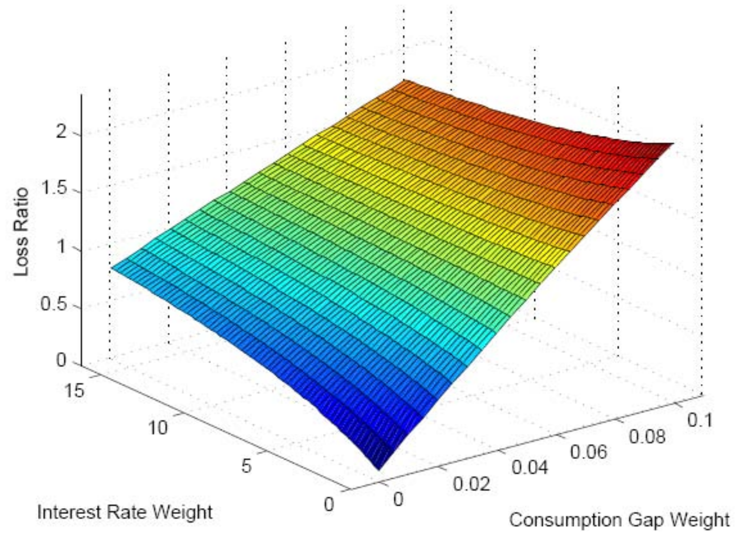
$$L_t = (\pi_t^{CIH} - \gamma\pi_{t-1}^{CIH})^2 + \lambda_c(c_t - hc_{t-1})^2 + \lambda_i(i_t - i_{t-1})^2,$$

where π^{CIH} enters the loss function because the CPI housing prices are sticky, by assumption, as housing prices develop as a function of both current and lagged nominal rates of ILS/US$ depreciation.

Using Argov and Elkayam (2007) estimates, we set the degree of price indexation, $\gamma = 0.42$, and the level of external habit formation, $h = 0.542$. We found, as it is expected and described in Table 2, that the ratio of the loss function under the domestic inflation Taylor rule (CIR), to the loss function under the CPI Taylor rule (HIR) is above unity when the relative weight of the quasi-change in consumption is $\lambda_c > 0.014$. This implies that HIR is preferable to CIR for plausible loss function parameters (Figure 6).

Figure 6

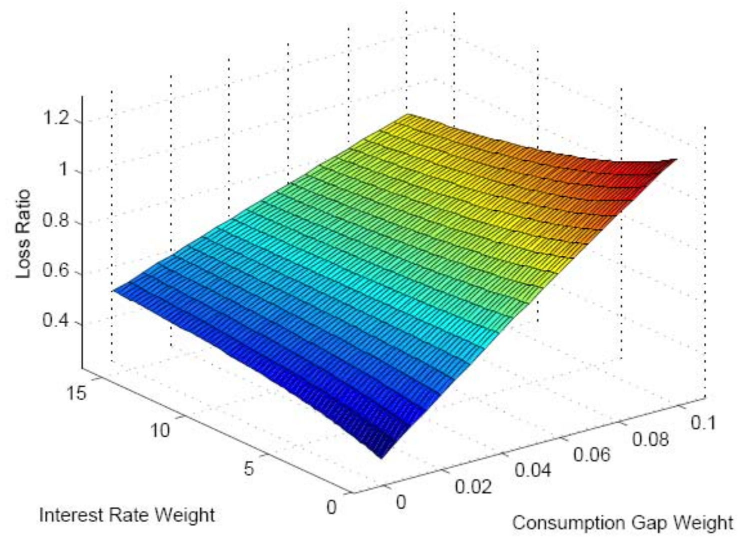
Welfare loss ratio of CI Taylor rule to headline inflation Taylor rule



Next, we calculated the ratio of the loss function under CIHR to that under HIR (Figure 7).

Figure 7

Welfare loss ratio - CIH Taylor rule over headline inflation Taylor rule

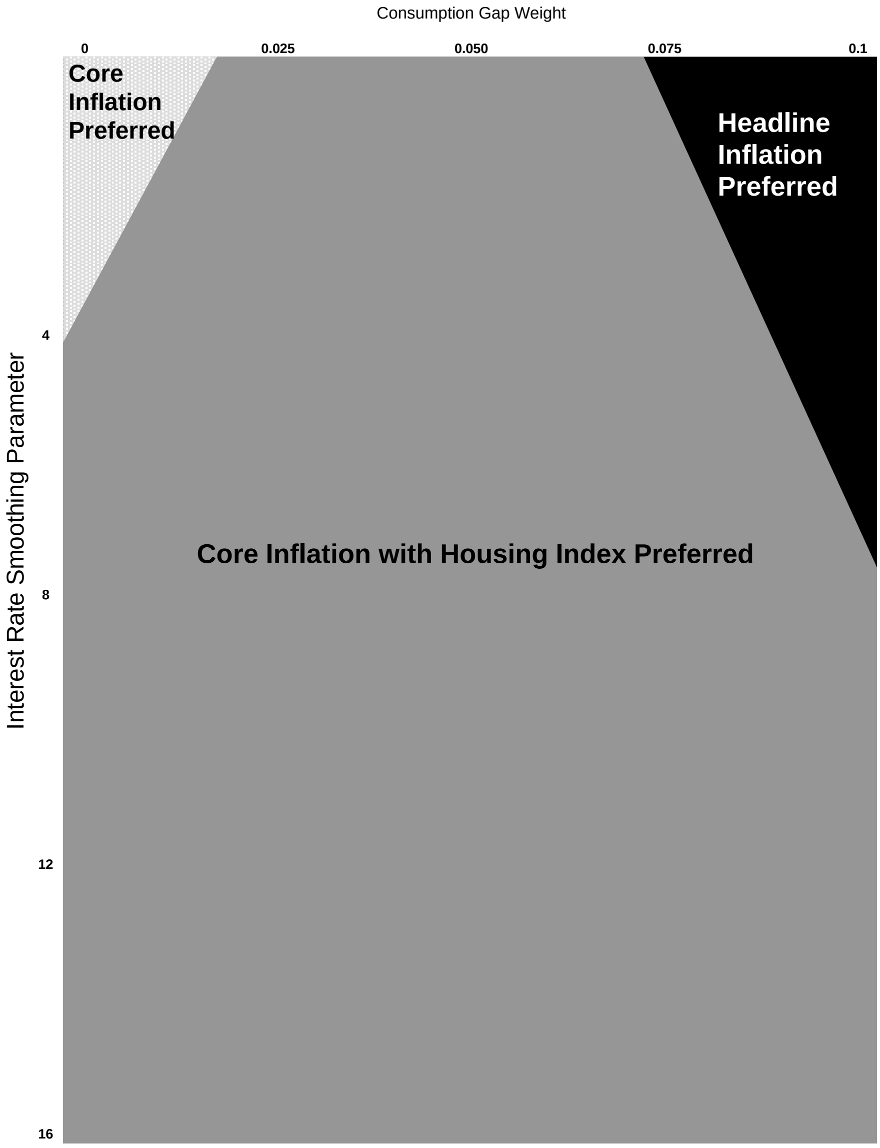


On the other hand, Figure 7 implies that for most of the plausible range of the loss function parameter values, monetary policy should respond to core inflation including housing, CIH, rather than to headline inflation. The advantage of CIHR (Figure 7) derives from the lower core inflation than that measured by HIR and the lower ratio between the volatilities of the consumption gap under the two policy rules, compared to the CIR and HIR consumption-gap ratio. This result is enhanced with the decrease in the weights of the consumption gap, but it is not monotonic with respect to the weights of the interest rate; for low weights of the consumption gap, the loss function ratio increases with the increase in the weights of the interest rate, while for high weights of the consumption gap it decreases.

Figure 8 summarises the results of Figure 6 and Figure 7.

Figure 8

Inflation indices with respect to loss function parameters



6 Conclusions

Should monetary policy respond to headline inflation or core inflation? Most central banks' primary mandate is to achieve overall CPI price stability. However, as an external price shock leads to a trade-off between inflation and the output gap, most central banks monitor core inflation as part of the policy decision-making process, as it reduces transitory noise and could prevent the central bank from responding too strongly to transitory shocks. For example, the January 2009 minutes of the Federal Open Markets Committee (FOMC) contain projections of PCE (Personal Consumption Expenditures) inflation as well as Core PCE, which is the price index for PCE excluding food and energy. Similarly, The Bank of Israel minutes of discussions on the interest rate for February 2008-January 2009 contain overall CPI change in the last 12 months as well as CPI excluding food, energy and fruit and vegetables.

We answer this question using a small open economy New Keynesian model and a simple loss function adapted to the Israeli economy. We find that a Taylor rule that responds to core inflation that includes the CPI housing component is preferred. Analysing an impulse response function relating to a shock to imported consumer prices, we find that the output gap loss is lower when policy responds to headline inflation rather than to core inflation. However, as welfare is affected not only by output gap volatility but also by inflation volatility and interest rate changes, using an ad hoc quadratic loss function we find that the monetary policy should respond to core inflation in order to maximise the welfare of the household, despite the higher loss in terms of the output gap and consumption gap.

However, the conclusion that monetary policy should respond to core inflation cannot be viewed as a general result, as the welfare loss function depends on the particular structure of the model, and by definition, contains price components that are not flexible. Moreover, the analysis above ignores credibility considerations. When headline inflation diverges from core inflation for a long period, a central bank that responds to core inflation may find it hard to communicate with the public and explain the advantages of its policy.

Appendix A:
The stages of development of the model
(Argov and Elkayam (2007))

I. Households

The representative household *j* consumes a Dixit-Stiglitz bundle of domestic and imported goods, C_t^h and C_t^f respectively. The households' utility is characterised by external habit formation - it depends on households' current consumption relative to lagged aggregate consumption:

(1) $u(C(j)_t) = \frac{(C(j)_t - hC_{t-1})^{1-\sigma}}{1-\sigma}$,

where $h \in (0,1)$ represents the strength of habit formation and σ^{-1} is the inter-temporal elasticity of substitution. Household *j* chooses consumption, domestic bond holdings, $B(j)_t$, and foreign bond holdings, $B(j)_t^f$, which maximises its expected utility subject to the budget constraint:

(2) $C(j)_t + \frac{B(j)_t}{(1+i_t)P_t^c} + \frac{\varepsilon_t B(j)_t^f}{(1+i_t^*)\Phi_t P_t^c} = \frac{B(j)_{t-1}}{P_{t-1}^c} + \frac{\varepsilon_t B(j)_{t-1}^f}{P_t^c} + X(j)_t$,

where Φ_t is a risk premium paid on foreign assets, ε_t is the nominal exchange rate, $X(j)$ is the household share of aggregate real profits in the domestic economy, i_t and i_t^* are domestic and foreign risk-free rates, respectively, and β is the subjective quarterly discount rate.

Log-linearisation of the first-order conditions of the household problem yields the inter-temporal consumption condition (Euler equation):[17]

(3) $c_t = \frac{1}{1+h} E_t c_{t+1} + \frac{h}{1+h} c_{t-1} - \frac{1-h}{(1+h)\sigma}(i_t - E_t \pi_{t+1}^c)$,

the UIP condition:

(4) $e_t = E_t e_{t+1} + i_t^* - i_t + \phi_t$,

and the demand for domestically produced goods bundles:

(5) $c_t^h = c_t - \eta(p_t^h - p_t^c)$,

where η is the intra-temporal elasticity of substitution. The aggregate price level, excluding housing, fuel, and fruit and vegetables prices, which is a CES function of domestic goods, p_t^h, and imported goods, p_t^f , is given by

(6) $p_t^c = (1-w_c^f)p_t^h + w_c^f p_t^f$,

[17] Lower-case letters denote log deviations from steady-state of the variables.

where w_c^f is the long-run share of imports in consumption. Assuming the same intra-temporal elasticity of substitution η abroad, the demand for the local economy's exports is

(7) $x_t^h = y_t^* - \eta(p_t^h - e_t - p_t^*)$,

where y_t^* is world trade and p_t^* is the price of consumer goods in the foreign economy. Assuming the law of one price, and that prices in the export sector are flexible, $p_t^h - e_t$ is the export price in foreign currency. Finally, the real exchange rate is defined as

(8) $q_t = p_t^* + e_t - p_t^h$.

Log-linearisation of the national account identity yields:

(9) $y_t = \gamma_c c_t^h + \gamma_g g_t^h + \gamma_x x_t^h + (1 - \gamma_c - \gamma_g - \gamma_x) inv_t^h$,

where y_t is the output gap, g_t^h and inv_t^h are government consumption and investment, in value added terms, and γ_i is the long-run share in output of component *i*.

Using (3)–(9) the output gap equation is given by:

$$\begin{aligned} & y_t = a_h E_t y_{t+1} + (1-a_h) y_{t-1} - a_i (i_t - E_t \pi_{t+1}) + a_q (q_t - a_h E_t q_{t+1} - (1-a_h) q_{t-1}) \\ (10)\quad & + a_g ((g_t^h - a_h E_t g_{t+1}^h - (1-a_h) g_{t-1}^h) + a_{inv} ((inv_t^h - a_h E_t inv_{t+1}^h - (1-a_h) inv_{t-1}^h) \\ & + ((y_t^* - a_h E_t y_{t+1}^* - (1-a_h) y_{t-1}^*) + \upsilon_t^y , \end{aligned}$$

where

$$a_i = -\frac{(1-h)\gamma_c}{(1+h)\sigma}; \quad a_q = \frac{\eta(\gamma_c w_c^f + \gamma_x)}{1 - w_c^f}; \quad a_g = \gamma_g; \quad a_{inv} = (1 - \gamma_c - \gamma_g - \gamma_x); \quad a_x = \gamma_x ,$$

and $\pi_t^c = p_t^c - p_{t-1}^c$.

According to equation (10), the output gap is determined by the real interest rate, the real exchange rate, government spending, investments and world trade.

II. Domestic producers inflation equation

Following Rotemberg's (1982) price-setting, firms choose a price sequence to minimise the cost of price changes due to a menu cost shock and the cost of deviating from the flexible price:

$$(11)\quad \min_{\{p(i)_{t+\tau}^h\}_{\tau=0}^{\infty}} \quad E_t \sum_{\tau=0}^{\infty} \delta^\tau [(p(i)_{t+\tau}^h - \tilde{p}(i)_{t+\tau}^h)^2 + c(p(i)_{t+\tau}^h - p(i)_{t+\tau-1}^h)^2],$$

where $\tilde{p}(i)_t^h$ is the optimal flexible price that would have been chosen by the firms in the absence of adjustment costs, and δ is a discount factor.

The first order condition for the firm's optimisation problem is

$$(12)\quad p(i)_t^h - p(i)_{t-1}^h = \delta(E_t p(i)_{t+1}^h - p(i)_t^h) + \frac{1}{c}(\tilde{p}(i)_t^h - p(i)_t^h) ,$$

where $\tilde{p}(i)_t^h$ is solved from the profit maximisation under flexible prices:

(13) $\max \quad \tilde{P}(i)_t^h C(i)_t^h + \tilde{P}(i)_t^x \varepsilon_t X(i)_t^h + P_t^g G_t^h + P_t^{inv} INV_t^h - P_t^z Z(i)$,

$\tilde{P}(i)_t^h, \tilde{P}(i)_t^x, Z(i)$

subject to the aggregate output identity, and the production function

(14) $Y(i)_t = Z(i)_t^{1-\theta} = [(Z(i)_t^h)^{1-w_f^z} (Z(i)_t^f)^{w_f^z}]^{1-\theta}$,

where $Z(i)_t^h$ and $Z(i)_t^f$ are intermediate domestic and imported inputs respectively, P_t^z is the aggregate price of intermediate inputs and w_f^z is the share of imports in intermediate goods. The price and quantity of government spending and investments are, by assumption, exogenous.

The local demand function (5), demand for export (7), the production function (14) and F.O.C. of the flexible price optimisation problem yield the optimal flexible price

(15) $\tilde{p}_t^h = p^t z + \dfrac{\theta}{1+\theta} y_t$.

The RHS of the optimal flexible price is the log deviation of nominal marginal cost, where the cost minimising input price aggregator is given by

(16) $p_t^z = (1 - w_f^z) p_t^{zh} + w_f^z p_t^{zf}$.,

where p_t^{zh} and p_t^{zf} are the prices of domestic and imported inputs to production. The local price of inputs is, by assumption, equal to domestic consumer prices, $p_t^{zh} = p_t^h$.

From this assumption and the first-order condition for the firm's optimisation problem, the optimal flexible price and the input price aggregator, the inflation of domestically produced consumer goods is given by

(17) $\pi_t^h = \delta E_t \pi_{t+1}^h + \dfrac{1}{c}\dfrac{\theta}{1-\theta} y_t + \dfrac{w_f^z}{c}(p_t^{zf} - p_t^h)$.

Assuming that only a fraction λ of the firms set their price accordingly, while a fraction $(1-\lambda)$ adjust their price to last period's domestic inflation (and set $\delta = 1$), domestically produced consumer goods inflation is given by:

(18) $\pi_t^h = \lambda E_t \pi_{t+1}^h + (1-\lambda)\pi_{t-1}^h + \lambda \dfrac{1}{c}\dfrac{\theta}{1-\theta} y_t + \lambda \dfrac{w_f^z}{c}(p_t^{zf} - p_t^h)$.

The assumption of an immediate pass-through from the exchange rate and world prices to the import price in the domestic market yields $p_t^f = e_t + p_t^*$. The unobservable difference p_t^{zf} - p_t^h can be written as the sum of two components:[18] the temporary deviation (from trend) in the world relative price of inputs, $p_t^{zc*} = p_t^{z*} - p_t^*$, and a weighted real exchange rate, $\dfrac{1}{1-w_f^c} q_t$.

[18] See Argov and Elkayam (2007), Appendix A.

Plugging this decomposition, the Phillips curve for domestically produced consumer goods, which can be estimated, is

$$(19)\ \pi_t^h = \lambda E_t \pi_{t+1}^h + (1-\lambda)\pi_{t-1}^h + \lambda \frac{1}{c}\frac{\theta}{1-\theta} y_t + \lambda \frac{w_f^z}{c}[p_t^{zc*} + \frac{1}{1-w_f^c} q_t].$$

III. The nominal exchange rate equation

According to the UIP condition (4), the spot nominal exchange rate is affected by future rate expectations, $e_{t+1}^{\exp}$, and the interest rate differential:

$$(20)\ e_t = e_{t+1}^{\exp} + i_t^* - i_t + \phi_t.$$

By assuming that households' expectations with respect to the exchange rate are partly rational and partly adaptive,

$$(21)\ e_{t+1}^{\exp} = (1-\omega)e_t^{\exp} + \omega E_t e_{e+1},$$

the equation for the exchange rate is given by

$$(22)\ e_t = \omega E_t e_{t+1} + (1-\omega)e_{t-1} + (i_t^* - i_t) - (1-\omega)(i_{t-1}^* - i_{t-1}) + \phi_t - (1-\omega)\phi_{t-1}.$$

IV. The monetary policy rule

The central bank sets its interest rate according to an expanded forward-looking Taylor rule:

$$(23)\ i_t = (1-k_i)[r_t + \bar{\pi}_t + k_\pi(E_t \pi_{t+\vartheta}^R - \bar{\pi}) + k_y y_t] + k_i i_{t-1},$$

where $\pi_{t+\vartheta}^R$ is the year-on-year inflation rate at $t+\vartheta$, $\bar{\pi}$ is the inflation target, r_t is the forward yield to maturity on indexed-linked Treasury bonds, a proxy to the natural rate, and the inflation forecast horizon is ϑ quarters.

V. CPI component equations

The model is closed with three ad hoc equations for housing, fuel, and fruit and vegetable prices in the CPI. The CPI housing component equation is a function of the nominal rate of depreciation of the ILS against the dollar, de_t, and the inflation target, $\bar{\pi}_t$:

$$(24)\ \pi_t^{housing} = \rho(de_t + \bar{\pi}) + (1-\rho)(de_{t-1} + \bar{\pi}).$$

The CPI fuel component equation is given by

$$(25)\ \pi_t^{fuel} = f\bar{\pi} + (1-f)(de_t + \pi_t^{brent}),$$

where $\pi_t^{brent} = \bar{\pi} + \varepsilon_t^{brent}$ is the price change of a barrel of crude oil, and ε_t^{brent} is a random shock.

The equation for the fruit and vegetables component is

$$(26)\ \pi_t^{f\&v} = \pi_t^h + \varepsilon_t^{f\&v}.$$

CPI inflation is calculated from the identity

$$(27)\ \pi_t^{CPI} = w^H \pi_t^{housing} + w^{fuel}\pi_t^{fuel} + w^{f\&v}\pi_t^{f\&v} + w\pi_t.$$

Finally, imported consumer goods inflation in local currency, assuming an immediate pass-through, is given by

(28) $\pi_t^* = p_t^* - p_{t-1}^* + de_t + \varepsilon_t^*$.

Appendix B:
Deriving the consumption gap from the Euler equation

Starting from the Euler equation

(3) $c_t = \frac{1}{1+h} E_t c_{t+1} + \frac{h}{1+h} c_{t-1} - \frac{1-h}{(1+h)\sigma} (i_t - E_t \pi^c_{t+1})$,

we obtain:

(1+h) $c_t = E_t c_{t+1} + h c_{t-1} - \frac{1-h}{\sigma} (i_t - E_t \pi^c_{t+1})$

$$\Downarrow$$

$$(c_t - h c_{t-1}) = (E_t c_{t+1} - h c_t) - \frac{1-h}{\sigma} (i_t - E_t \pi^c_{t+1}) ,$$

which by iterating forward, and assuming the law of iterated expectations, yields

$$(c_t - h c_{t-1}) = -\frac{1-h}{\sigma} \sum_{j=0}^{\infty} (E_t i_{t+j} - E_t \pi^c_{t+j+1}) .$$

Hence, the consumption gap is given by:

$$c_t = h c_{t-1} - \frac{1-h}{\sigma} \sum_{j=0}^{\infty} (E_t i_{t+j} - E_t \pi^c_{t+j+1}) .$$

Appendix C:
Estimated and calibrated parameters
(Argov and Elkayam (2007))

β	h	σ	η	w^f
0.99	0.542	0.336	0.379	0.39
γ_c	γ_x	γ_g	λ	k_i
0.48	0.156	0.225	0.58	0.8
k_y	k_π	ρ	f_1	k
0.5	2.0	0.75	0.75	0.0254

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