

Research Department



Bank of Israel

**The Choice of a Foreign Price Measure in a Bayesian
Estimated New-Keynesian Model for Israel***

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Discussion Paper No. 2009.04
June 2009

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I would like to thank Douglas Laxton, Ondra Kamenik and Alon Binyamini for helpful comments. The author also benefited from comments made by the participants of the Macroeconomic Modeling Workshop 2009 (Banco de la Republica de Colombia) and the Bank of Israel's Research Department Seminar.

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Abstract

We estimate a small DSGE model by full information Bayesian techniques on Israeli data from 1995 to 2006. The model was first developed and estimated by classical GMM in Argov and Elkayam (2007). We extend the model by: (1) Separating the fuel component from the CPI; (2) Estimating trends and natural rates simultaneously with the parameters; (3) Adopting an optimization-based approach to modeling imported inflation. Testing the model's fit we find that it replicates the main cross-correlations observed in the data. In terms of forecast performance we find that simple VARs outperform our model, which outperforms a naïve RW. Analyzing the source of variation in the data, and specifically inflation, we find that exchange-rate shocks play a major role (accounting for 67% of the variation in CPI inflation).

Our baseline model attributes most of the high inflation in 2007 to supply shocks, whereas it has been widely accepted that inflation rose in Israel due to high commodity prices in the global markets. One conjecture is that the original use of the unit value of imported consumer goods (which do not include unprocessed food and energy) as the main foreign price measure was not appropriate. We test this conjecture by re-estimating the model with various other foreign price measures that typically do reflect the global rise in commodity prices and compare the log-marginal likelihoods. We find that no other price measure outperforms the original choice in the sample period. Only the foreign trade-weighted CPI equals the performance of the original choice, while improving the 2007 interpretation of inflation, and therefore should be considered for the main foreign price measure.

בחירת מצרף מחירי חו"ל במסגרת אמידה בייסיאנית של מודל ניאו-קיינסיאני למשק הישראלי

איל ארגוב

תקציר

בעבודה זו נאמד מודל DSGE קטן בשיטה הבייסיאנית לנתוני המשק הישראלי מ-1995 עד 2006. המודל פותח לראשונה ונאמד בשיטה הקלאסית GMM אצל Argov and Elkayam (2007). כאן אני מרחיב אותו במספר כיוונים: (1) הפרדת רכיבי הדלקים ממדד המחירים לצרכן; (2) אמידה סימולטנית של המגמות והמשתנים ה"טבעיים" עם הפרמטרים של המודל; (3) ביסוס המידול של האינפלציה מיבוא על אופטימיזציה של יחידות מיקרו-כלכליות.

בבדיקת ההתאמה האמפירית של המודל נמצא כי הוא משחזר את עיקר המיתאמים הצולבים בין המשתנים הנצפים בנתונים. בבחינת טיב תחזיותיו נמצא כי הוא פחות טוב ממודלים סטטיסטיים מסוג VAR, אך עדיף על מודל נאיבי של הילוך מקרי (Random Walk). מניתוח של מקור התנודתיות במשתנים הכלכליים, ובפרט באינפלציה, עולה כי לזעזועים בשער החליפין השפעה מכרעת. (הם מסבירים 67% מהשונות באינפלציה במדד המחירים לצרכן.)

התפיסה המקובלת היום היא שעליות האינפלציה ב-2007 נגרמה בישראל, כמו בשאר בעולם, בגלל האמרת מחירי הסחורות בשווקים הגלובאליים. לעומת זאת מייחס המודל האמור את רוב האינפלציה הגבוהה של שנה זו לזעזועי היצע. יש המשערים שתוצאה זו של המודל נובעת מן הבחירה במדד מחירי יבוא מוצרי הצריכה (שאינו כולל מזון גולמי ואנרגיה) כמחיר חו"ל המרכזי – בחירה שאינה מתאימה. אני בוחן השערה זו על ידי אמידה-מחדש של המודל עם שלל אומדנים אחרים למחירי חו"ל, המשקפים, באופן כללי, את עליית מחירי הסחורות בעולם, ומשווה את הנראויות השוליות (Log-marginal likelihood) המתקבלות מהאמידות השונות. נמצא כי לתקופת המדגם אף אומדן מחירים אינו עולה על הבחירה המקורית. רק המדד האפקטיבי של המחירים לצרכן בעולם (משוקלל במשקל הסחר עם ישראל) משתווה באמידה לבחירה המקורית, וכי הוא אף משפר את האינטרפטציה של האינפלציה הגבוהה ב-2007. על כן מוצע לשקול את השימוש במדד זה כמשתנה המרכזי לייצוג מחירי חו"ל במודל.

A. Introduction

New-Keynesian dynamic-stochastic-general-equilibrium (DSGE) models are the work-horses of central banks in analyzing monetary policy. Most of them have been estimated using the Bayesian approach. Outstanding examples of medium size DSGE models in use are the Riksbank's RAMSES model,¹ the ECB's NWAM,² the Norges Bank's NEMO³ and the Bank of Canada's TOTEM.⁴ The Bank of Israel developed its own *small* DSGE model for use in the monetary discussions at the Bank. Contrary to the current common procedure, the model was estimated by limited information classical econometrics which yielded reasonable results. In order to better fit the data, some deviations from pure, optimization-based theory were allowed. In this paper we re-estimate the model using full-information Bayesian estimation. Using the full information estimation has some advantages: it better ensures that the model will work properly as one unit, whereas equation-by-equation estimation may ensure that each equation is properly specified, but working together may generate unreasonable properties; the full information allows us to estimate model-consistent gaps via the use of the Kalman filter; it also bases the estimation on model-consistent rational expectations. The Bayesian estimation has the advantages that it allows the econometrician to restrict parameters to their feasible space and estimate a model when only a subset of the parameters is well-identified from the data. This enables the estimation of models with rather short sample periods and flat likelihood functions. These advantages will prove to be important in the context of this paper's estimation.

The model was developed in Argov and Elkayam (2007). Argov et al. (2007a) present its operational version and discuss how it is used for regular forecasting at the Bank of Israel. The model is almost the smallest one which can be used to describe the main ingredients of the transmission mechanism in a small open economy. Its main behavioral equations are an IS curve for the output gap (as a function of a lead, a lag, the real interest rate and the real exchange rate), a Phillips curve for locally produced good's inflation (as a function of a lead, a lag, the output gap and the real price of imported production inputs), a UIP condition relating the exchange rate to its expected level and interest differentials, and monetary-policy-reaction function in terms of an interest rate rule (as a function of the natural rate, expected or realized

¹ See Adolfson et al. (2005).

² See Christoffel et al. (2008).

³ See Brubakk et al. (2006).

⁴ See Murchison and Rennison (2006).

inflation, the output gap and the lagged rate). The model also has ad hoc equations for the imported good's inflation (which are part of the CPI) as a function of foreign prices and the exchange rate, and an equation for the housing component in the CPI. The latter is treated separately due to its close (and almost complete) connection with the exchange rate (see section B-2). In this model the interest rate transmission mechanism works through two channels: the real rate channel, in which higher interest rates reduce demand for private consumption, and the UIP channel where higher interest rates deliver an appreciation of the currency and hence lower the prices of foreign goods.

In the present paper we extend the model in a few ways: (1) we separate the fuel component from the overall CPI because of its close relation with global oil prices. (2) Taking advantage of the full information estimation we specify a data-generating process for some trends and natural variable, allowing us to estimate the model-consistent output gap, real exchange rate gap and natural real interest rate simultaneously. The original model made use of the HP filter to clean out trends from all real variables. (3) We follow Monacelli (2005), and adopt an optimization-based approach to modeling imported inflation. That too is made possible only in a full information estimation procedure.

The model is estimated for the sample of 1995:Q2-2006:Q4. Following the estimation we run a few applications to study its properties. To test its fit to the data we run a cross-correlation test, checking whether various observed cross-correlations (across time and variables) might have been produced by the model. We check the model's forecasting ability by comparing its forecast errors (RMSE) to VARs and naive random walk or steady state models.

To study the model's interpretation of the past, we report a variance decomposition and an historical shock decomposition by decomposing the observed year-on-year inflation into five groups of shocks (supply, demand, monetary, exchange rate and foreign prices). The decomposition shows that unexpected exchange rate shocks (deviations from the model's UIP) played a key role in the variation of inflation, including missing the target in 2000, 2002, 2003 and 2006. However the last years of the disinflation process, 1997-2001, tell a different story. Inflation was lower than the target, but not due to exchange rate shocks. Three forces were at work: (1) moderating foreign prices as globalization opened low-cost markets for imports; (2) supply shocks that presumably reflect reduction of mark-ups due to

increasing competition; and (3) monetary policy shocks reflecting tight policy in those years.

A troubling fact that emerges from the historical shock decomposition is that our baseline model attributes most of the high inflation in 2007 to domestic supply shocks, where it has been widely accepted that inflation rose in Israel, as well as world wide, due to high global commodity prices (mainly unprocessed food and energy prices). Why does the model misinterpret that year? One conjecture is an ill choice of the foreign price measure. Following Argov and Elkayam (2007), we used the unit value of imported consumer goods as the main foreign price measure. However its development in the last years did not reflect the increase in global commodity prices, for it does not contain unprocessed food and fuel. Therefore the model interpreted the rise in inflation as domestic inflation shocks (categorized as supply shocks). In the last part of this paper we try to check whether the choice of this foreign price measure was wrong a priori. We re-estimate the model with various other foreign price measures that typically do reflect the global rise in commodity prices. We compare the log-marginal likelihood to see which price measure is most appropriate for the role of foreign price measure within our estimation sample.

The paper is organized as follows: in section B we present the model, including the micro foundations from which some equation are derived. Section C discusses the estimation and some post-estimation applications checking the model's properties (variance decomposition, historical decomposition, cross-correlations test and forecast error comparison). In section D we compare estimations with alternative foreign price measures, and sections E offers a conclusion.

B. The Theoretical and Estimated Model

The model is an extended version of the Argov and Elkayam (2007) model.⁵ It is an open economy New-Keynesian simplified small DSGE model. It nests on micro foundations, to be detailed below, but allows some deviations from pure theory in order to both simplify and better fit the data. The model consists of four main domestic agents – households, intermediate goods firms, importers and a central bank. The foreign economy is taken as exogenous.

⁵ The original model was based on Svensson (2000), Adolfson (2001) and Linde et al. (2004).

We extended the model of Argov and Elkayam in the following manners: (1) In contrast to their GMM limited information estimation, we employ a full information (Bayesian) estimation. Therefore we estimate the unobservable trends of the economy simultaneously with the parameters via the Kallman filter. We follow an ad hoc approach of modeling those trends as described in section B-5. (2) In addition to the housing component, we model the fuel component of the CPI outside the theoretical model. We use the CPI excluding housing, fuel, fruit and vegetables as our basic theoretic price level determined by Phillips curves and model the rest of the index in ad hoc ways described in section B-2. (3) We closely follow Monacelli (2005), and take an optimization-based approach to modeling the imported inflation, rather than specifying its dynamics in an ad hoc manner. That too is made possible only in a full information estimation procedure.

In what follows we will present the main structure for each agent and the log-linearised equations that constitute the final estimated model.

B-1. Households, foreign demand and output

The domestic economy is populated by a continuum of infinitely-lived households indexed by j , who consume Dixit-Stiglitz bundles of domestic and imported goods, denoted $C(j)_t^h$ and $C(j)_t^f$ respectively. Each bundle is a continuum of differentiated locally produced or imported good indexed by i :

$$(1.1) \quad C(j)_t^h = \left[\int_0^1 C(j,i)_t^h \frac{\eta_h - 1}{\eta_h} di \right]^{\frac{\eta_h}{\eta_h - 1}} ; \quad C(j)_t^f = \left[\int_0^1 C(j,i)_t^f \frac{\eta_f - 1}{\eta_f} di \right]^{\frac{\eta_f}{\eta_f - 1}},$$

where $\eta_h, \eta_f > 1$ are the elasticities of substitution between goods in the same group.

The composite consumption index is defined by:

$$(1.2) \quad C(j)_t = \left[(1 - w_f^c)^{\frac{1}{\eta}} (C(j)_t^h)^{\frac{\eta - 1}{\eta}} + (w_f^c)^{\frac{1}{\eta}} (C(j)_t^f)^{\frac{\eta - 1}{\eta}} \right]^{\frac{\eta}{\eta - 1}},$$

where w_f^c is the long-run share of imports in consumption, and η is the elasticity of substitution between imported and domestic goods. The corresponding minimum cost price aggregator (consumer price index) is:

$$(1.3) \quad P_t^c = \left[(1 - w_f^c)(P_t^h)^{1 - \eta} + (w_f^c)(P_t^f)^{1 - \eta} \right]^{\frac{1}{1 - \eta}},$$

where P_t^h and P_t^f are the price aggregators of domestically produced and imported goods, all in local currency units. Household j chooses a sequence of consumption, domestic bond holdings and foreign bond holdings to maximize utility from consumption:

$$(1.4) \quad \max_{C(j)_t, B(j)_t, B(j)_t^f} E_t \sum_{k=0}^{\infty} \beta^k u(C(j)_{t+k}); \quad u(C(j)_t) \frac{(C(j)_t - hC_{t-1})^{-\sigma}}{1-\sigma}.$$

Apparent from (1.4), we allow for external habit formation captured by the parameter $h \in (0,1)$: household j 's contemporaneous utility depends on its own consumption, $C(j)_t$, relative to lagged aggregate consumption C_{t-1} ; σ^{-1} is the inter-temporal elasticity of substitution and E_t is the expectation operator.

The household is subject to the budget constraint:

$$(1.5) \quad C(j)_t + \frac{B(j)_t}{(1+i_t)P_t^c} + \frac{\mathcal{E}_t B(j)_t^f}{(1+i_t^*)\Phi_t P_t^c} = \frac{B(j)_{t-1}}{P_t^c} + \frac{\mathcal{E}_t B(j)_{t-1}^f}{P_t^c} + X(j)_t,$$

where $B(j)_t$ is household j 's holdings of one-period nominal bonds denominated in the domestic currency; $B(j)_t^f$ is its foreign counterpart denominated in the foreign currency (dollar); Φ_t is an exogenous risk premium paid on foreign assets; \mathcal{E}_t is the nominal exchange rate (the price of foreign currency in terms of the domestic currency); $X(j)_t$ is household j 's share of aggregate real profits in the domestic economy and i_t and i_t^* are domestic and foreign nominal risk-free interest rates, i.e., the domestic bonds yield the gross return of NIS $(1+i_t)$ and the foreign bonds yield the gross return of \$ $(1+i_t^*)$. β is the quarterly discount rate.

We assume the foreign economy is big, so that it is only marginally affected by the local economy. The world economy's imports is a bundle of exports from all states apart from our local economy (X_t^{-h}), and the local economy's exports (X_t^h):

$$(1.6) \quad Y_t^* = \left[(1-w_h^m)^{\frac{1}{\eta}} (X_t^{-h})^{\frac{\eta-1}{\eta}} + (w_h^m)^{\frac{1}{\eta}} (X_t^h)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}.$$

⁶ See Smets and Wouters (2003) and Christiano et al. (2005).

For simplicity we have assumed that the elasticity of substitution is the same as in (1.2), η , and that the law of one price holds in the export sector so that the price of exports coincides with the local price of domestic goods adjusted for the nominal exchange rate, i.e., $P_t^X = P_t^h / \mathcal{E}_t$.

Following Adolfson (2001) and Monacelli (2005), we assume that the pass-through from the exchange rate and the relevant world prices (P_t^*) to the import price at the local market is incomplete. Let us define Ψ_t^c as a temporary deviation from the law of one price (L.O.P. gap), that is:

$$(1.7) \quad \Psi_t^c = \frac{P_t^f}{P_t^* \mathcal{E}_t}.$$

Finally, the economy-wide aggregate resource constraint is:

$$(1.8) \quad Y_t = C_t^h + G_t^h + X_t^h + INV_t^h,$$

where Y_t is the output, G_t^h and INV_t^h are public consumption and investment (both in value added terms).

Next we solve the first-order conditions of the households for the level of consumption and inter-temporal allocation of consumption. Log-linearizing the first-order conditions around a time varying trend⁷ and combining equations yields the final output gap equation. This equation is similar to that derived in Argov and Elkayam (2007). Small letters mark logs, upper 'p' index marks the time varying trend and letters with a circumflex ($\hat{\cdot}$) mark log-deviations from trend. For example $\hat{y}_t = y_t - y_t^p$ is the deviation of output from the trend which we interchangeably call the output gap:

$$(1.9) \quad \hat{y}_t = \frac{1}{1+h} E_t \hat{y}_{t+1} + \frac{h}{1+h} \hat{y}_{t-1} - \frac{(1-h)\gamma_c}{(1+h)\sigma} (i_t - E_t \pi_{t+1}^c - r_t^p) + \frac{\eta(\gamma_c w_f^c + \gamma_x)}{(1-w_f^c)} \left(\hat{q}_t - \frac{h}{1+h} \hat{q}_{t-1} - \frac{1}{1+h} E_t \hat{q}_{t+1} \right) \\ + \frac{\eta w_f^c (\gamma_c + \gamma_x)}{(1-w_f^c)} \left(\hat{\psi}_t^c - \frac{h}{1+h} \hat{\psi}_{t-1}^c - \frac{1}{1+h} E_t \hat{\psi}_{t+1}^c \right) + \gamma_g \left(\hat{g}_t^h - \frac{h}{1+h} \hat{g}_{t-1}^h - \frac{1}{1+h} E_t \hat{g}_{t+1}^h \right) \\ + (1-\gamma_c - \gamma_g - \gamma_x) \left(i \hat{nv}_t^h - \frac{h}{1+h} i \hat{nv}_{t-1}^h - \frac{1}{1+h} E_t i \hat{nv}_{t+1}^h \right) + \gamma_x \left(\hat{y}_t^* - \frac{h}{1+h} \hat{y}_{t-1}^* - \frac{1}{1+h} E_t \hat{y}_{t+1}^* \right).$$

⁷ In the behavior model we do not define a stochastic trend. Therefore we actually log linearize the first-order conditions around steady state. Later we will assume this steady state is time varying, including a real trend. The trend specification is given in section B-5.

The forward looking terms arise from consumption smoothing characterizing standard Euler equations, and the backward looking terms come from the habit-formation. The real interest rate ($i_t - E_t \pi_{t+1}^c$) lowers the demand for consumption. In this case we make the trend of the real interest rate, r_t^p , explicit. The real exchange rate (q_t) is defined by:

$$(1.10) \quad q_t = p_t^* + e_t - p_t^c ,$$

where e_t is the (log of the) nominal exchange rate and p_t^* is the world price in foreign currency.

A higher real exchange rate (i.e., depreciation) increases exports and reduces imports, contributing to a higher output level. A positive L.O.P gap ($\hat{\psi}_t^c$) means that the price of imports faced by local households is higher than the world price, leading to lower imports and higher output. Government consumption and investment have direct effects on output. For simplicity only, we will assume they are exogenous variables. A higher level of world imports (\hat{y}_t^*) raises the demand for the local economy's exports, therefore raising output.

In the estimation we will neglect the structural parameters of equation (1.9) and rather estimate reduced forms of the parameters. In other words we, release some cross-coefficient restrictions existing in the theoretical derivation. In addition, we will not impose the homogeneity of the equation (notice that in equation [1.9] the sum of the forward and backward looking components is unity). In order to generate some lag between interest rate changes and output gap fluctuations due to pre-commitments and incomplete information, we will assume the prevailed expectations of the interest rate, $E_{t-1}(i_t - \pi_{t+1}^c - r_t^p)$, appear in the equation rather than the realized rate. Finally, we will add a serially correlated demand shock as a residual to the equation above. The estimated equation is therefore:

$$(1.11) \quad \hat{y}_t = b_{11} E_t \hat{y}_{t+1} + b_{12} (1 - b_{11}) \hat{y}_{t-1} - b_2 E_{t-1} (i_t - \pi_{t+1}^c - r_t^p) + b_3 (\hat{q}_t - b_{11} E_t \hat{q}_{t+1} - b_{12} (1 - b_{11}) \hat{q}_{t-1}) \\ + (b_3 - b_4) (\hat{\psi}_t^c - b_{11} E_t \hat{\psi}_{t+1}^c - b_{12} (1 - b_{11}) \hat{\psi}_{t-1}^c) + b_5 (\hat{y}_t^* - b_{11} E_t \hat{y}_{t+1}^* - b_{12} (1 - b_{11}) \hat{y}_{t-1}^*) \\ + b_6 (i \hat{v}_t^h - b_{11} E_t i \hat{v}_{t+1}^h - b_{12} (1 - b_{11}) i \hat{v}_{t-1}^h) + b_7 (\hat{g}_t^h - b_{11} E_t \hat{g}_{t+1}^h - b_{12} (1 - b_{11}) \hat{g}_{t-1}^h) + z_t^y ,$$

where

$$(1.12) \quad z_t^y = \delta_{w^y} z_{t-1}^y + \varepsilon_t^y .$$

In equation (1.11), b_{12} is the degree of deviation from homogeneity ($b_{12} = 1$ reduces to the homogeneity of the Euler condition).

B-2. Inflation block

We characterize overall CPI inflation as a weighted average of four components: housing services ($\pi_t^{Housing}$), Fuel (π_t^{Fuel}), fruit and vegetables (π_t^{Veg}) and the CPI excluding those components (π_t^C); w^i is the average weight of component i in the CPI basket.

$$(2.1) \quad \pi_t^{Cpi} = w^{Housing} \pi_t^{Housing} + w^{Fuel} \pi_t^{Fuel} + w^{Veg} \pi_t^{Veg} + w^C \pi_t^C .$$

The last term, π_t^C , which we will refer to as "core" inflation, is the theoretical part of the CPI which will appear in the behavioral equations. The rest are subtracted due to special mechanisms governing their dynamics which are not explained by pure theory.⁸

The housing component accounts for approximately 23% of the CPI. It has very special characteristics in Israel: due to the hyper-inflation era of mid-1980s most rental contracts are nominated in dollars. Therefore, the housing price inflation was almost ultimately determined by the fluctuations in the NIS/dollar exchange rate.⁹ We use approximately the same specification as Argov and Elkayam (2007):

$$(2.2) \quad \pi_t^{Housing} = \eta^{Housing} (\Delta e_t + \pi_t^{T*}) + (1 - \eta^{Housing}) \cdot (\Delta e_{t-1} + \pi_{t-1}^{T*}) + z_t^{Housing} .$$

We allow the current and first lag of the nominal depreciation rate (Δe_t) to affect the housing price inflation. The foreign inflation target (π_t^{T*}) was included to ensure that all CPI components grow in steady state at the same rate (local inflation target). $z_t^{Housing}$ is a serially correlated shock to the price of housing:

$$(2.3) \quad z_t^{Housing} = \delta_{Housing} z_{t-1}^{Housing} + \varepsilon_t^{Housing} ,$$

where $\varepsilon_t^{Housing}$ is an i.i.d, zero-mean shock.

⁸ It should be clear that we use the term "core" arbitrarily. We do not attribute any special "core" characteristics to the CPI excluding housing, fuel, fruits and vegetables. We are only implying that these three components behave differently.

⁹ During 2007 this link began to weaken. For details see Bank of Israel (2007).

The fuel component accounts for approximately 2.5% of the CPI. It is basically determined by the global price of oil according to a supervised scheme. The fixed tax on fuel serves as a buffer, making local fuel prices less volatile than global oil prices. This tax is adjusted, once a quarter, to the change in overall CPI. We specify the following equation for the fuel components:

$$(2.4) \quad \pi_t^{Fuel} = \chi_1 [\chi_2 (\Delta p_t^{*,oil} + \Delta e_t) + (1 - \chi_2) (\Delta p_{t-1}^{*,oil} + \Delta e_{t-1})] + (1 - \chi_1) \pi_t^C + \varepsilon_t^{Fuel} .$$

The parameter χ_1 controls for the sensitivity of the fuel component of the CPI to the global dollar price of oil, $\Delta p_t^{*,oil}$, adjusted for depreciation (Δe_t). The complementary part is adjusted according to the "core" inflation rate (π_t^C). ε_t^{Fuel} is a shock to the relative price of fuel in the domestic economy. χ_2 controls for the degree of sensitivity to current developments in global oil prices relative to previous quarter.

The fruit and vegetables component constitutes approximately 5% of the CPI. It is a very noisy component due to changes in supply conditions, with irregular seasonality. Therefore, in line with Argov and Elkayam (2007), we treat it as white noise around the inflation target (π_t^T):

$$(2.5) \quad \pi_t^{Veg} = \pi_t^T + \varepsilon_t^{Veg} ,$$

where ε_t^{Veg} is a shock to the prices of fruit and vegetables.

In what follows we shall treat the remainder of the CPI, π_t^C , as the theoretically consistent part of inflation. Log-linearizing equation (1.3) and first-differencing we derive the identity relating core inflation to imported goods inflation (π_t^f) and locally produced goods inflation (π_t^h):

$$(2.6) \quad \pi_t^C = (1 - w_f^c) \pi_t^h + w_f^c \pi_t^f .$$

The first will be derived from the optimization of local intermediate goods firms and the latter from the optimization of the importing firms.

B-2-1. Local intermediate-good firms

The economy is populated by infinite symmetric local firms facing a Rotemberg (1982) price adjustment cost. They minimize the following quadratic costs of changing their price at a different rate from the inflation target and costs of deviating

from their optimal flexible price level, $P_t^{h,flex}$, which they would have chosen in the absence of adjustment costs:

$$(2.7) \quad \min_{\{P_{t+\tau}^h\}_{\tau=0}^{\infty}} \sum_{\tau=0}^{\infty} \beta^{\tau} \left\{ \left[\log(P_{t+\tau}^h) - \log(P_{t+\tau}^{h,flex}) \right]^2 + c \left[\log(P_{t+\tau}^h) - \log(P_{t+\tau-1}^h) - \pi_{t+\tau}^T \right]^2 \right\},$$

where c is the relative weight of the price adjustment cost. Had prices been flexible, the representative firm would have maximized periodic profits subject to her production function and the aggregate constraint of meeting all demand:

$$(2.8) \quad \max_{\hat{p}_t^{h,flex}, \hat{p}_t^{x,flex}, Z_t} P_t^{h,flex} C_t^h + P_t^{x,flex} S_t X_t^h + P_t^g G_t^h + P_t^{inv} INV_t^h - P_t^z Z_t$$

$$s.t. \quad Y_t = A_t Z_t^{1-\theta} = A_t \left[(Z_t^h)^{1-w_j^z} (Z_t^f)^{w_j^z} \right]^{1-\theta}$$

$$Y_t = C_t^h + X_t^h + G_t^h + INV_t^h .$$

In (2.8), income is derived from sales to local consumers and foreign households. In addition the price and quantity of government goods and investments are exogenously given to the firms. The firms use two kinds of inputs – local (Z_t^h) and imported (Z_t^f) paid P_t^{zh} and P_t^{zf} respectively; Z_t and P_t^z are the aggregate quantity and price of inputs and A_t measures the level of technology that is related to the potential level of output.

Solving these sets of problems yields a purely forward looking, Adolfson (2007) type, local-inflation Phillips curve in which the driving forces are the output gap and the real price of imported production inputs ($p_t^{zf} - p_t^h$). In order to allow some inertia in inflation we will assume not all producers follow this optimal scheme, but rather index their price to past year-on-year overall CPI inflation. A price shock ($\varepsilon_t^{\pi^h}$), reflecting temporary changes in mark-ups was introduced to the equation. Our final local inflation equation is:

$$(2.9) \quad \pi_t^h - \pi_t^T = \lambda_1 \beta E_t (\pi_{t+1}^h - \pi_{t+1}^T) + (1 - \lambda_1) \cdot (\pi 4_{t-1}^{CPI} - \pi 4_{t-1}^T)$$

$$+ \lambda_1 \lambda_2 \hat{y}_t + \lambda_1 \lambda_3 \left[\hat{p}_t^{zcm} + \frac{1}{(1-w_j^c)} (\hat{q}_t + \hat{\psi}_t^c) \right] + \varepsilon_t^{\pi^h} ,$$

where

$$(2.10) \quad \pi 4_{t-1}^T = (\pi_{t-1}^T + \pi_{t-2}^T + \pi_{t-3}^T + \pi_{t-4}^T) \cdot 0.25 ,$$

$$(2.11) \quad \pi 4_{t-1}^{CPI} = (\pi_{t-1}^{CPI} + \pi_{t-2}^{CPI} + \pi_{t-3}^{CPI} + \pi_{t-4}^{CPI}) \cdot 0.25 .$$

λ_1 is the weight of optimizing producers, λ_2 governs the elasticity of inflation with respect to the output gap (\hat{y}_t); it is inversely related to the price adjustment costs c and the returns to scale $(1-\theta)$. The last term is a decomposition of the real price of imported inputs into one exogenous and two endogenous components: $\hat{p}_t^{z^*}$ is the stationary gap between the world price of imported inputs and imported consumer goods ($p_t^{*z} - p_t^*$), introduced in order to allow a differential between these two exogenous prices; \hat{q}_t is the real exchange rate; and $\hat{\psi}_t^c$ is the Law of One Price gap defined by log-linearization of equation (1.7). It has been assumed that the LOP gap in the inputs sector is identical to that in the consumer goods sector. The parameter λ_3 governs the elasticity of locally-produced-goods inflation with respect to the real price of imported inputs. It is positively related to the weight of imported inputs in the production function (w_f^z) and inversely related to the price adjustment costs (c). Further details on the derivation of this equation can be found in Argov and Elkayam (2007). We deviated from their original specification by: including the inflation target in the equation, not assuming that the discount factor is one, assuming that the LOP gaps are identical across sectors and, similar to Binyamini (2007), assuming the indexation is to year-on-year overall CPI inflation rather than first lag of local inflation. This choice was supported by estimation results not reported in this paper.

B-2-2. Importing firms

Following Monacelli (2005), we introduce price rigidity in the imported goods sector which generates the L.O.P gap. Monacelli (2005) assumed importers face the Calvo (1983) problem in which they have a constant probability of receiving a signal to re-optimize their local currency price. Under this model, the following Phillips curve arises for the local currency price of imported goods:

$$(2.12) \quad \pi_t^f - \pi_t^T = \beta E_t(\pi_{t+1}^f - \pi_{t+1}^T) - \lambda_f \hat{\psi}_t^c + \varepsilon_t^{\pi^f} ,$$

where $\varepsilon_t^{\pi^f}$ is a shock to the imported goods inflation rate, possibly reflecting mark-up shocks in the imported goods sector or temporary changes in the pass-through. The L.O.P. gap, $\hat{\psi}_t^c$, is actually the inverse of the importers' real marginal cost. Log-

linearising (1.7) and taking first differences we derive the law of motion for the L.O.P. gap:

$$(2.13) \quad \hat{\psi}_t^c = \hat{\psi}_{t-1}^c + \pi_t^f - \pi_t^* - \Delta e_t - \varepsilon_t^{LOP} ,$$

where ε_t^{LOP} is a shock allowing a permanent shift in the price of imports relative to their foreign price. This shock allows the model to account for permanent deviation from the law of one price.

B-3. The nominal exchange rate

Households first-order conditions with respect to local and foreign bonds form the well-known uncovered interest rate parity (UIP) condition, adjusted for the exogenous risk premium (ϕ). As in Argov and Elkayam (2007) we will assume that exchange-rate expectations (e_{t+1}^{exp}) are partly rational ($E_t e_{t+1}$) and partly sticky up to the inflation target differential ($e_t^{\text{exp}} + \pi_t^T - \pi_t^{T*}$); ω is the weight of rationality:

$$(3.1) \quad e_{t+1}^{\text{exp}} = (1-\omega)(e_t^{\text{exp}} + \pi_t^T - \pi_t^{T*}) + \omega E_t e_{t+1} .$$

Using (3.1) we derive a UIP condition which includes a lag of the exchange rate, the interest rate differential and the risk premium. We add a depreciation shock ($\varepsilon_t^{\Delta e}$) reflecting movements in the exchange rate not arising from interest rate movements.

$$(3.2) \quad e_t = \omega E_t e_{t+1} + (1-\omega)e_{t-1} + (i_t^* - i_t) - (1-\omega)(i_{t-1}^* - i_{t-1}) + \phi_t - (1-\omega)\phi_{t-1} + \varepsilon_t^{\Delta e} .$$

It was found that allowing ω to be bigger than $\frac{1}{2}$ may introduce model indeterminacy. Therefore, as an ad hoc solution, we induce this restriction by replacing ω by $\frac{1}{2 + \tilde{\omega}}$, and restricting $\tilde{\omega} > 0$.

B-4. Monetary policy

We assume that the central bank follows a hybrid forward-backward looking inflation-based rule of the form:

$$(4.1) \quad i_t = (1-\kappa_i) \cdot [r_t^p + \pi_t^T + \kappa_\pi E_t (\pi_{t+1}^{CPI} - \pi_t^T) + \kappa_y \hat{y}_{t-1}] + \kappa_i \cdot i_{t-1} + \varepsilon_t^i ,$$

where the official inflation target, π_i^T , evolves according to

$$(4.2) \quad \pi_i^T = \delta_\pi \pi_{i-1}^T + (1 - \delta_\pi) \bar{\pi}^T + \varepsilon_i^{\pi^T} .$$

In estimation we will set δ_π very close to unity in order to render stationarity on inflation on the one hand, and to capture the last stages of Israel's disinflation process on the other.

$E_t \pi_{t+1}^{CPI}$, defined in (2.11), is the partly forward looking, partly simultaneous and partly backward looking yearly inflation rate. Argov and Elkayam (2007) found this formulation empirically better, as well as being superior in terms of policy loss function, to rules that look further in the future or the past. Notice that while the behavioral model related almost exclusively to the CPI excluding housing, fruit and vegetables – the interest rate rule relates to the overall CPI. The motivation is clear: the inflation target is defined on overall inflation, and therefore monetary policy is likely to react to overall inflation.

B-5. Trends – output, real interest rate and real exchange rate

Though the heart of model is derived from micro structure, we take an ad hoc approach to modeling the real trends in the economy. The purpose is to estimate the model's parameters and the unobservable trends jointly, using the Kallman filter. Unlike Argov and Elkayam (2007), we will reduce the uses of the univariate Hodrick-Prescott filter as much as possible.

The log of per capita GDP (y_t) can be decomposed to potential (y_t^p) and gap (\hat{y}_t) according to

$$(5.1) \quad y_t = y_t^p + \hat{y}_t .$$

We will assume that potential output growth is composed of a one-time shock ($\varepsilon_t^{y^p}$) and a persistent growth rate (gr_t):

$$(5.2) \quad \Delta y_t^p = gr_t + \varepsilon_t^{y^p} ,$$

where the growth rate is a stationary AR process with a long run of \overline{gr} and i.i.d. shock (ε_t^{gr}):

$$(5.3) \quad gr_t = (1 - \delta_{gr}) \overline{gr} + \delta_{gr} gr_{t-1} + \varepsilon_t^{gr} .$$

Similarly we decompose the log of world trade (y_t^*) into potential ($y_t^{*,p}$) and gap (\hat{y}_t^*) according to

$$(5.4) \quad y_t^* = y_t^{*,p} + \hat{y}_t^* .$$

We will assume that potential world trade growth is an auto-regressive process with long-run value of $\overline{gr^*}$:

$$(5.5) \quad \Delta y_t^{*,p} = \delta_{y^{*,p}} \Delta y_{t-1}^{*,p} + (1 - \delta_{y^{*,p}}) \overline{gr^*} + \varepsilon_t^{y^{*,p}} .$$

In addition we decompose the log of the real exchange rate (q_t) into potential (q_t^p) and gap (\hat{q}_t) according to

$$(5.6) \quad q_t = q_t^p + \hat{q}_t .$$

We will assume that the potential real exchange rate does not incur a trend, but it may change according to productivity growth differentials expressed in local or foreign potential growth rates. The potential real exchange rate may also change due to permanent changes in the law of one price (ε_t^{LOP} , see equation 2.13). The weight of each determinant is related to the relative weight of locally produced goods and imported goods in consumption:

$$(5.7) \quad \Delta q_t^p = (1 - w_f^c) \left[(\Delta y_t^p - \overline{gr}) - (\Delta y_t^{*,p} - \overline{gr^*}) \right] - w_f^c \varepsilon_t^{LOP} .$$

We decompose the relative price of production inputs (p_t^{zc*}) to trend ($p_t^{zc*,p}$) and gap (\hat{p}_t^{zc*}) according to

$$(5.8) \quad p_t^{zc*} = p_t^{zc*,p} + \hat{p}_t^{zc*} .$$

Although not a natural assumption, we will assume the trend corrects itself so that it gradually closes the gap, but that it may vary due to a shock ($\varepsilon_t^{zc*,p}$):

$$(5.9) \quad p_t^{zc*,p} = \delta_z \hat{p}_{t-1}^{zc*} + \varepsilon_t^{zc*,p} .$$

Due to the upward trend in the relative price of inputs observed in the data (largely due to the rise of oil prices) we found it important to estimate the trend jointly with the model, rather than use some univariate filter. This will enable us to learn to what extent the upward trend in the relative price of inputs reflected a permanent shift and to what extent it reflected a gap-generating pressure on prices of consumer goods. We assumed the trend would correct itself toward the actual relative price. This was essential in order to render stationarity on the gap (bearing in mind that this is a world relative price and therefore unlike the real exchange rate, it does not converge due to domestic monetary policy). Alternately we could assume that the dynamics of the consumer goods price or inputs price are directly affected by the gap. We refrained from pursuing this option in order to estimate dynamic equations for the price indices, which potentially could serve as the consumer goods and input prices in the model, independent of its parameters or structure. This point should become clearer after we discuss the choice of world prices in section B-8.

The natural real interest rate is assumed to be partly related to the expected potential growth rate, as implied by standard DSGE models,¹⁰ and partly autoregressive with a shock (ε_t^r):

$$(5.10) \quad r_t^p = \delta_r r_{t-1}^p + (1 - \delta_r) \left(\frac{1 - \beta}{\beta} + E_t g_{t+1} \right) + \varepsilon_t^r .$$

B-6. Identification block

In this block we specify simple macroeconomic relations that will help the Kalman filter identify the output gap, the natural real interest rate and inflation expectations. The output gap and the natural real interest rate are important macroeconomic variables in the conduct of monetary policy. The output gap directly affects local inflation as in equation (2.9), and usually appears in to the central bank's loss function.¹¹ The natural real interest rate is a reference point in monetary policy decision making, as illustrated in equation (4.1).

In order to improve the identification of the output gap, we will use data on the unemployment rate as well as the real unit labor cost.¹² The connection with the first

¹⁰ For example Erceg et al. (2000) or Gali (2000).

¹¹ See Rotemberg and Woodford (1998) for a theoretical derivation and Segal (2007) for an application to Israel.

¹² The weight of the wage bill in nominal output.

is derived by Okun's law¹³ and the connection with the latter appears in basic New-Keynesian models such as Gali (2003).

We decompose the unemployment rate (u_t) into the natural rate (u_t^p) and gap (\hat{u}_t) according to

$$(6.1) \quad u_t = u_t^p - \hat{u}_t .$$

Notice that a positive gap means that the actual unemployment rate is *below* the natural rate so as to coincide, in sign, with the output gap. We will assume the natural rate evolves in an auto-regressive process with a long-run value of \bar{u} and an i.i.d. shock $\varepsilon_t^{u^p}$:

$$(6.2) \quad u_t^p = \delta_u u_{t-1}^p + (1 - \delta_u) \bar{u} + \varepsilon_t^{u^p} .$$

The unemployment gap is also auto-regressive, but driven by the output gap and a shock ($\varepsilon_t^{\hat{u}}$):

$$(6.3) \quad \hat{u}_t = \alpha_1 \hat{u}_{t-1} + (1 - \alpha_1) \alpha_2 \hat{y}_t + \varepsilon_t^{\hat{u}} .$$

The estimated parameter α_2 controls for the degree of connection between the output gap and the unemployment rate.

The unit labor cost (ulc_t) is assumed to be a stationary auto-regressive process, driven by the second lag of the output gap and a shock (ε_t^{ulc}), with long-run value of \overline{ulc} . The choice of the second lag of the output gap is based on empirical considerations:

$$(6.4) \quad ulc_t = \zeta_1 ulc_{t-1} + (1 - \zeta_1) \overline{ulc} + \zeta_2 \hat{y}_{t-2} + \varepsilon_t^{ulc} .$$

The estimated parameter ζ_2 controls for the degree of connection between the output gap and the unit labor cost.

In order to improve the identification of the natural real interest rate (r_t^p), we will take advantage of the yields to maturity on government CPI-indexed bonds. These could serve as good proxies for medium- to long-run risk-free real interest

¹³ See Prachowny (1993).

rates. Specifically we will assume that 5-year yields to maturity (r_t^{5year}) are partly linked to the natural real interest rate according to

$$(6.5) \quad r_t^{5year} = \delta_{r5} \cdot r_{t-1}^{5year} + (1 - \delta_{r5})r_t^p + \varepsilon_t^{r5}$$

The existence of CPI-linked bonds (as well as regular nominal bonds) allows us to derive market-based inflation expectations (break-even inflation). At times, the one-year ahead inflation expectations were a key indicator in the conduct of monetary policy. For example, Argov and Elkayam (2007), Elkayam (2001) and Barnea and Djivre (2004) estimated good econometric monetary policy reaction functions using year ahead market-based inflation expectations. In the context of this study, we will use these expectations to help filter out the model consistent year ahead inflation expectations. We add to the model the following relation:

$$(6.6) \quad \pi_t^e = (1 - \nu) \cdot E_t \pi_{t+4} + \nu \cdot \pi_{t-1}^e + \varepsilon_t^{\pi^e}$$

In (6.6) we assume that the one-year ahead market-based inflation expectations (π_t^e) is characterized by partial adjustment to the model-consistent year-ahead inflation expectations ($E_t \pi_{t+4}$).

B-7. Exogenous variables

In addition to the inflation target and the trends discussed in section B-5, the model includes 8 exogenous variables: Three domestic variables – foreign exchange risk premium (ϕ_t), government consumption gap (\hat{g}_t^h) and gross investment ($i\hat{n}v_t^h$), which was assumed to be exogenous; Five related to the world economy – world trade gap (\hat{y}_t^*), dollar interest rate (i_t^*), oil price inflation ($\Delta p_t^{*,oil}$), world consumer goods price inflation (Δp_t^*) and world inputs price inflation ($\Delta p_t^{*,z}$).

In general, auto-regressive equations were estimated for each variable. Some were estimated within the whole model and some were univariately estimated by OLS in order to reduce the parameter space in the time-consuming Bayesian estimation procedure.

To estimate the exogenous process of the exchange-rate risk premium we use the measure developed by Hecht and Pompushko (2006) and assume an AR(1) process:

$$(7.1) \quad \phi_t = \delta_\phi \phi_{t-1} + (1 - \delta_\phi) \bar{\phi} + \varepsilon_t^\phi .$$

For the government consumption gap and investment gap we assume an AR(2) and AR(1) process, respectively. We calculate the gaps by applying the HP filter on the log of real government purchases and the log of gross investment. We used the estimated process from Argov et al. (2007a):

$$(7.2) \quad \hat{g}_t^h = \underset{(0.12)}{0.23} \cdot \hat{g}_{t-1}^h + \underset{(0.11)}{0.23} \cdot \hat{g}_{t-2}^h + \varepsilon_t^g$$

$$R^2 = 0.18 \quad \text{S.E.} = 2.87 \quad \text{D.W.} = 2.32 \quad \text{Sample : 94q2 - 05q4} ,$$

$$(7.3) \quad i\hat{n}v_t^h = \underset{(0.14)}{0.25} \cdot i\hat{n}v_{t-1}^h + \varepsilon_t^{inv}$$

$$R^2 = 0.06 \quad \text{S.E.} = 9.08 \quad \text{D.W.} = 1.98 \quad \text{Sample : 94q2 - 05q4} ,$$

where ε_t^g is a shock to government consumption and ε_t^{inv} is a shock to gross investment.

The world trade gap is assumed to follow an AR(2) process with a shock ($\varepsilon_t^{y^*}$):

$$(7.4) \quad \hat{y}_t^* = \delta_{y^*,1} \hat{y}_{t-1}^* + \delta_{y^*,2} (\hat{y}_{t-1}^* - \hat{y}_{t-2}^*) + \varepsilon_t^{y^*} .$$

The annualized dollar interest rate is assumed to follow an AR(2) process. We use the estimation from Argov et al. (2007a):

$$(7.5) \quad 4 \cdot i_t^* = \underset{(0.85)}{(1 - 0.95)} \cdot 4.3 + \underset{(0.03)}{0.95} \cdot 4 \cdot i_{t-1}^* + \underset{(0.10)}{0.74} \cdot 4 \cdot (i_{t-1}^* - i_{t-2}^*) + \varepsilon_t^i$$

$$R^2 = 0.97 \quad \text{S.E.} = 0.32 \quad \text{D.W.} = 2.17 \quad \text{Sample : 94q1 - 05q4} .$$

We will use two measures of price indices to express the world input price inflation (Δp_t^{*z}) – price of imported oil ($\Delta p_t^{*,oil}$) and the price of non-oil raw materials ($\Delta p_t^{z*,nonoil}$). We will assume it is a linear combination:

$$(7.6) \quad \Delta p_t^{*z} = w^{p*z} \Delta p_t^{z*,nonoil} + (1 - w^{p*z}) \Delta p_t^{*,oil} .$$

In the formal series of total raw materials prices published by the Central Bureau of Statistics, w^{p*z} is approximately 0.87, reflecting the weight of non-fuels in raw material imports. However, we would like to allow for a different degree of effect

on consumer prices, and therefore estimate $w^{p^{*z}}$. For the two observable price components we adjust simple equations.

The annualized import price of non-oil raw materials was estimated to follow an AR(1) process and to be affected by lagged oil prices. We estimated the following equation, assuming that the long-run annualized change is two percent:

$$(7.8) \quad 4 \cdot \Delta p_t^{z^*,nonoil} = (1 - 0.53 - 0.05) \cdot 2.0 + \underset{(0.114)}{0.528} \cdot 4 \cdot \Delta p_{t-1}^{z^*,nonoil} + \underset{(0.021)}{0.051} \cdot 4 \cdot \Delta p_{t-1}^{*,oil} + \varepsilon_t^{z^*,nonoil}$$

$R^2 = 0.35 \quad S.E. = 5.73 \quad D.W. = 1.91 \quad \text{Sample: 95q1-06q4.}$

We were unable to adjust any simple equation with predictive power to the world price of oil. This is not surprising since this is not just a price of a commodity but also a traded asset (like currency). Therefore we assumed it was white noise around an annualized two-percent change:

$$(7.7) \quad 4 \cdot \Delta p_t^{*,oil} = 2.0 + \varepsilon_t^{*,oil}$$

In the next section we discuss the role of world prices of consumer goods (Δp_t^*) and their specification.

B-8. World prices

We are left with one final variable to specify – world prices of consumption goods – p_t^* . This (together with the nominal exchange rate) is the price governing the unobservable imported CPI inflation (see equations [2.12] and [2.13]). Although we attribute p_t^* to consumption, it has a wider role in our model: It affects the relative demand for locally produced consumer goods – if these prices go up, demand will be shifted from imports to local production. Therefore this price measure captures imported substitutes for locally produced goods; for instance, that could be the case with some textile commodities but is certainly not the case with oil or vehicles which Israel does not manufacture.¹⁴ This role is the first reason that the real exchange rate (in terms of p_t^*) appears in the output gap equation (1.9) and (1.11). The second reason is that p_t^* is the exporters' competitors' price: if it rises, so does the relative demand for Israeli exports. Therefore this price should also reflect the equivalent foreign prices of goods exported by Israel.

¹⁴ If the price of oil rises, we will hardly see any movement to locally produced substitutes.

Naturally, there is no single price index that perfectly matches all those conditions. Israel, like every other nation, imports, produces and exports different products. In what follows we would like to test for various variables that could serve as the world consumer goods price inflation ($\pi_t^* = p_t^* - p_{t-1}^*$). Argov and Elkayam (2007) used the percent change in the unit value of imported consumer goods (Δp_t^{*C-IM}). This may seem like a natural choice, however it is not necessarily so. This price measure includes goods that the Central Bureau of Statistics defines as consumer goods. They constitute only 10% of the final consumption basket. For example they do not include fuels used for private vehicles (these are included in the import oil price – Δp_t^{*oil}). This price does not include services either. As stated, p_t^* also has a role in explaining output – it is assumed that it affects exports and overall imports, which is not necessarily the case. Therefore it is not obvious that this is the optimal measure of Δp_t^* .

Other candidates will be the percent change in: the trade-weighted foreign CPI inflation ($\Delta p_t^{*TW-CPI}$), US inflation (Δp_t^{*US}), the unit value of world trade ($\Delta p_t^{*y^*}$) and the national accounts imports deflator in dollar terms (Δp_t^{*M}). For each series we will estimate a simple characterizing equation using lags and the oil price inflation (Δp_t^{*oil}). These equations were estimated by OLS outside the model's main system:

$$(8.2) \quad 4 \cdot \Delta p_t^{*TW-CPI} = (1 - 0.44 - 0.04 + 0.05) \cdot 2.0 + \underset{(0.135)}{0.440} \cdot 4 \cdot \Delta p_{t-1}^{*TW-CPI} + \underset{(0.021)}{0.043} \cdot 4 \cdot \Delta p_{t-1}^{*oil} \\ - \underset{(0.022)}{0.051} \cdot 4 \cdot \Delta p_{t-2}^{*oil} + \varepsilon_t^{*TW-CPI}$$

$R^2 = 0.28 \quad S.E. = 5.57 \quad D.W. = 2.12 \quad \text{Sample: } 96q1-06q4 \quad ;$

$$(8.3) \quad 4 \cdot \Delta p_t^{*US} = (1 - 0.37 - 0.12 + 0.28) \cdot 2.0 + \underset{(0.112)}{0.374} \cdot 4 \cdot \Delta p_{t-1}^{*US} + \underset{(0.119)}{0.115} \cdot 4 \cdot \Delta p_{t-2}^{*US} \\ + \underset{(0.112)}{0.277} \cdot 4 \cdot \Delta p_{t-3}^{*US} + \varepsilon_t^{*US}$$

$R^2 = 0.17 \quad S.E. = 1.38 \quad D.W. = 1.81 \quad \text{Sample: } 85q1-06q4 \quad ;$

$$(8.4) \quad 4 \cdot \Delta p_t^{*y^*} = (1 - 0.31 - 0.055) \cdot 2.0 + \underset{(0.141)}{0.314} \cdot 4 \cdot \Delta p_{t-1}^{*y^*} + \underset{(0.031)}{0.055} \cdot 4 \cdot \Delta p_{t-1}^{*oil} + \varepsilon_t^{*py^*}$$

$R^2 = 0.22 \quad S.E. = 7.77 \quad D.W. = 1.83 \quad \text{Sample: } 95q1-06q4 \quad ;$

$$(8.5) \quad 4 \cdot \Delta p_t^{*M} = (1 - 0.409 - 0.047) \cdot 2.0 + \underset{(0.160)}{0.409} \cdot 4 \cdot 0.5 \cdot (\Delta p_{t-1}^{*M} + \Delta p_{t-2}^{*M}) + \underset{(0.022)}{0.047} \cdot 4 \cdot \Delta p_{t-1}^{*oil} + \varepsilon_t^{*M}$$

$R^2 = 0.21 \quad S.E. = 5.84 \quad D.W. = 1.85 \quad \text{Sample: } 95q1-06q4 \quad .$

As in Argov et al. (2007a), we were not able to adjust an acceptable equation for the unit value of imported consumer goods (Δp_t^{*C-IM}). We assumed it is white noise around a long-run value of two percent:

$$(8.6) \quad 4 \cdot \Delta p_t^{*C-IM} = 2.0 + \varepsilon_t^{*C-IM}.$$

Finally to close the model we need to define to which measure the world price of consumer goods is related. In the baseline specification we will follow Argov and Elkayam (2007) and attribute it to the unit value of imported consumer goods:

$$(8.7) \quad \pi_t^* = \Delta p_t^{*C-IM}.$$

C. Estimation

C-1. Data and sample

We apply Bayesian estimation techniques to evaluate the posterior distribution of the parameters. For that we use the DYNARE software.¹⁵

We use the following set of quarterly observable variables:¹⁶

- Annualized quarterly inflation rates – overall CPI (π_t^{Cpi}), CPI housing component ($\pi_t^{Housing}$), CPI fuel component (π_t^{Fuel}) and CPI excluding Housing, fuel, fruit and vegetables (π_t^C). The fruit and vegetables component is derived residually from equation (2.1).
- The formal inflation target (π_t^T).
- The annualized quarterly depreciation rate of the NIS/dollar exchange rate (Δe_t).
- The Bank of Israel's effective key nominal interest rate (i_t).
- The per capita business sector GDP quarterly growth rate (Δy_t); gross investment ($i\hat{m}v_t^h$) and government purchases (\hat{g}_t^h), both per capita in deviation from HP-filter.
- The seasonally adjusted unemployment rate (u_t), the unit labor cost (ulc_t) and the yield to maturity on 5-year CPI indexed government bonds (r_t^{5year}). These serve to help identify the output gap and the

¹⁵ For reference see Dynare web site: www.ceprenmap.cnrs.fr/dynare.

¹⁶ For extensive data description, see appendix 1.

natural real interest rate. The one-year ahead market-based inflation expectations (π_t^e) serve to identify the model-consistent expectations.

- For the foreign exchange risk premium (ϕ_t), we use the computation developed and presented in Hecht and Pompushko (2006).
- The one-month LIBID dollar interest rate (i_t^*). For world trade we use the annualized quarterly growth of the industrialized countries' imports, divided by their unit value (Δy_t^*).
- We use the following set of foreign annualized inflation measures (all in dollar terms): the unit value of imported consumer goods (Δp_t^{*C-IM}), the unit value of imported inputs (excluding fuels) and investment goods ($\Delta p_t^{*z,nonoil}$), the price of imported fuel (Δp_t^{*oil}), the trade-weighted foreign CPI inflation ($\Delta p_t^{*TW-CPI}$), US inflation (Δp_t^{*US}), the unit value of the industrialized countries' imports – world trade – (Δp_t^{*y}) and the national accounts import deflator in dollar terms (Δp_t^{*M}).

In total we use 24 observable variables. Variables were seasonally adjusted as necessary. As stated, all the nominal change variables (inflation, depreciation) are annualized quarterly changes. The equations are adjusted accordingly.

Our data is from 1994:Q2 to 2006:Q4. However, to evaluate the posterior likelihood we drop the first four observations, which serve only to initialize the Kallman filter. Inflation targeting was adopted in 1992; however, in the first two years the target was only implicit: the slope of the exchange-rate crawling-band was set to equal the desired inflation differential between Israel and the United States (see Elkayam, 2003 for details). Data for the foreign exchange risk premium is only available from 1994:Q2. For these reasons we chose to begin our sample in 1994:Q2. Some caveats are in place: (1) until 1997 the exchange rate band was effective and the Bank of Israel intervened in the market also inside the band. Only afterwards was the zone widened and the Bank avoided intervention. This is surely a structural break in monetary policy. (2) In 1999 the measurement of the CPI housing component

changed from actual prices of second-hand housing to the imputed rent approach. This might have changed the sensitivity of this component to changes in the NIS/dollar exchange rate. We will mention that in 2007-08 the proportion of dollar rental contracts has dropped steeply from 90% to 20%. Obviously this brought a disengagement of the CPI housing component from the exchange rate. We do not come up against this problem, for our sample ends in 2006. Regardless of these two caveats, we need a sufficient number of observations, so we proceed to estimate the model from 1994:Q2 and keep those potential problems in mind.

In what follows we will discuss the pre-estimation calibrated parameters, the choice of priors and the posterior results of the baseline specification.

C-2. Calibration

We calibrated parameters that are hard to identify in the data, parameters controlling weights that are identifiable by sample means and exogenous processes that were estimated by observable variables outside the system (see section B-7 and B-8).

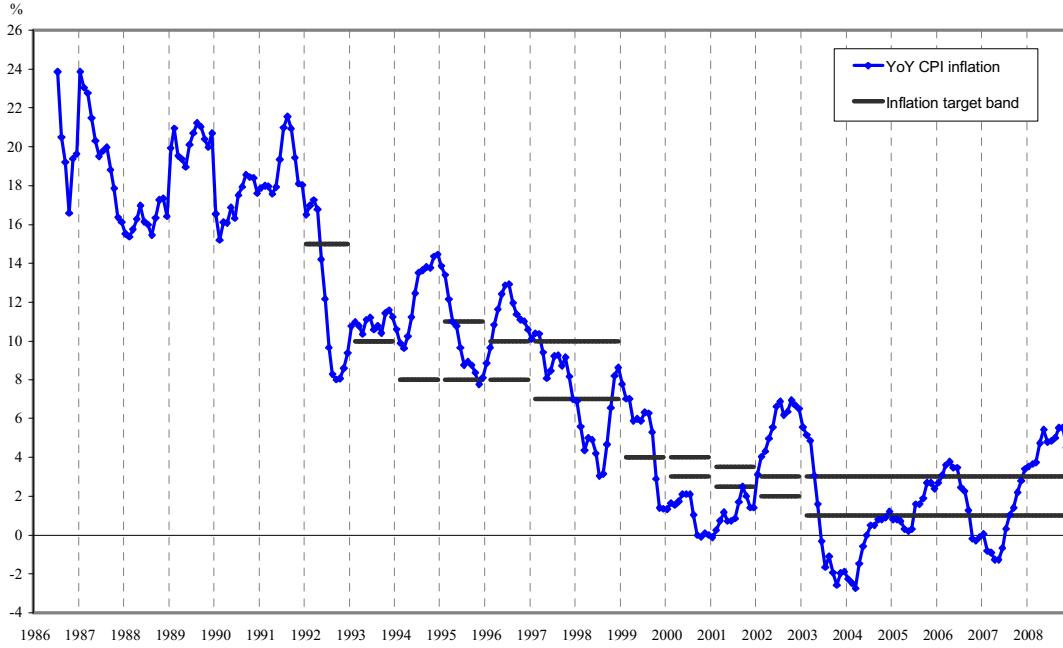
The weights of housing, fuel and fruit and vegetables in the CPI index ($w^{Housing}$, w^{Fuel} and w^{Veg}) were calibrated to their sample mean: 23%, 2.5% and 4.7% respectively. Accordingly, the "core" inflation measure, π^c , captures approximately 70% of the CPI.

Israel began a disinflation process in 1986, after experiencing a 400% hyperinflation. As of 1992, the disinflation process was conducted within an inflation targeting framework (see figure C.1).¹⁷ During the process, it was not known what the final low-digit level of inflation rate would be, and how many years it would take to reach it. In some cases the inflation target for the next year was set at the very end of the previous year, possibly taking an opportunistic approach to actual drops in inflation. Only in 2000 a multi-year path for reducing the target from 4% to 2% by 2003 was announced publicly. Therefore we wanted to model the inflation target as a random walk process. However a non-stationary inflation target seemed to create

¹⁷ The first implicit inflation target was set at 14.5% in 1992. By 1995, the beginning of our sample, the target was 9.5%. In 2000 the target was 3.5%, then it was announced that the target would be reduced so that as of 2003 the inflation target would be 2%. It should be noted that in some years there was a point target and in some a range; we always use the point or middle of the range.

some difficulties in the estimation. Our solution was to approximate the random walk by setting the persistence parameter in equation (4.2), δ_π , to be very close to unity – 0.999.

Figure C.1: Annual CPI inflation and the inflation target band, 1986-2008



We set the following long-run values to approximate sample means: domestic per capita annual growth rate (\overline{gr}) – 2.2%, world trade annual growth rate (\overline{gr}^*) – 6.4%, domestic and foreign inflation rate ($\overline{\pi}^T, \overline{\pi}^*$) – 2.0%, foreign exchange risk premium ($\overline{\phi}$) – 2.0%, and the dollar interest rate (\overline{i}^*) – 4.3%. These imply that $\beta = 0.994$, so that the domestic long-run real interest rate is 4.3%. The long-run values of the unemployment rate (\overline{u}) and real unit labor cost (\overline{ulc}) are set at 8.8% and 37.7%. These serve to better identify the output gap.

C-2. Priors

In the choice of priors we lean on the experience from previous studies of the Israeli economy (mainly, Argov and Elkayam, 2007 and Argov et al., 2007a), some great-ratios and judgmental assumptions. Where possible we left the priors rather loose, allowing posterior distribution adjustment where informative data are present (as we will see, this is not always the case). The priors' shapes were chosen in order to match

each parameters' support to its theoretical feasible space. All priors, as well as estimation results, are summarized in table C.1.

For the import weight in consumption our prior is 30%, approximately the weight from input-output tables (unfortunately the last available table is from 1995). We set the prior on rational expectations in the inflation and output gap at 0.5 – for inflation this is close to the results of the previous studies, but for output it is somewhat lower. We set the pass-through to import prices prior at 0.5, which generates a similar pass-through speed to that of previous studies. The prior weight on current exchange rate depreciation in the housing component inflation equation is set at 0.75, similar to estimation results of Argov and Elkayam (2007). The coefficients of investment and government purchases on the output gap reflect their added value weight in output. Therefore we set the prior to the weight of the overall component in uses (16% and 10%). Similarly, the coefficient of world demand on the output gap reflects the added value weight of exports in output. We set the prior at 30% approximately the weight of exports in total uses.

We set the prior on interest rate smoothing to 0.7 somewhat close to that found in Argov et al. (2007a) – 0.8. They found the inflation reaction parameter to be in the range of 1.6-2.5, Elkayam (2001) estimated it to be 1.7 and Barnea and Djivre (2004) estimated 2.0-2.6. We chose a prior of 1.9.

Our prior for the output gap effect on unemployment was set at 0.5, as implied by Okun's law. For the persistence/rational expectations weight in the market based inflation expectations equation we set a uniform (0,1) prior in order derive information solely from the data. The priors for the parameters of the world demand gap equation were set according to the estimation in Argov et al. (2007a) which relied on an HP filter gap. The prior weight of non-fuel input prices in the "model relevant" input price measure was set according to its actual weight in imports of raw materials (87%).

As apparent from Table C.1, for the standard deviations of some shocks we chose a very tight prior. This was done because there is not enough information in the data to pin down the relative variances between all shocks, presumably due to the large amount of unobservable variables. The choice of those almost calibrated standard deviations was made in order to achieve fairly smooth potential variables, i.e, we applied a tight prior on the smoothness of potential variables.

Table C.1: Parameters – Priors and Posterior Estimation Results

Parameter		Prior Distribution			Posterior Distribution				
		Type	Mean	Std	Mode	Std	Mean	5%	95%
Import weight	w_f^c	beta	0.3	0.1	0.315	0.070	0.335	0.228	0.447
Local inflation equation									
Rational expectations	λ_1	beta	0.5	0.1	0.529	0.089	0.470	0.331	0.618
Output gap	λ_2	gamma	0.2	0.1	0.109	0.056	0.138	0.038	0.238
Real price of inputs	λ_3	gamma	0.05	0.025	0.036	0.018	0.038	0.010	0.064
Pass-through to imported inflation	λ_f	gamma	0.5	0.3	0.435	0.195	0.486	0.163	0.813
Current EX on housing	$\eta^{housing}$	beta	0.75	0.15	0.812	0.026	0.812	0.765	0.859
Persistence in housing price shock	$\delta_{Housing}$	beta	0.5	0.2	0.592	0.091	0.577	0.425	0.732
Oil effect on CPI fuel	χ_1	beta	0.25	0.1	0.306	0.042	0.304	0.234	0.373
Current oil on CPI Fuel	χ_2	beta	0.5	0.2	0.796	0.085	0.782	0.652	0.920
Output gap equation									
Rational expectations	b_{11}	beta	0.5	0.2	0.641	0.173	0.497	0.157	0.825
Homogeneity	b_{12}	beta	0.7	0.2	0.875	0.139	0.740	0.495	0.991
Real interest rate	b_2	gamma	0.5	0.2	0.275	0.121	0.318	0.121	0.512
Real exchange rate	b_3	gamma	0.2	0.1	0.099	0.056	0.119	0.028	0.206
LOP gap	b_4	gamma	0.3	0.1	0.169	0.054	0.184	0.093	0.272
World demand	b_5	gamma	0.3	0.1	0.262	0.085	0.299	0.147	0.444
Investment	b_6	gamma	0.16	0.05	0.092	0.022	0.096	0.060	0.131
Government	b_7	gamma	0.1	0.05	0.053	0.029	0.068	0.018	0.115
Persistence in Output gap shock	δ_{u^r}	beta	0.5	0.2	0.802	0.088	0.734	0.529	0.921
EX eq.: rational exp.	$\tilde{\omega}$	gamma	0.5	0.25	0.709	0.306	0.723	0.239	1.179
Monetary policy									
Interest rate smoothing	\mathcal{K}_i	beta	0.7	0.1	0.732	0.042	0.738	0.670	0.808
Reaction to inflation	\mathcal{K}_π	gamma	1.9	0.5	1.217	0.234	1.289	0.872	1.691
Reaction to output gap	\mathcal{K}_y	gamma	0.05	0.02	0.054	0.020	0.058	0.025	0.090
Growth persistence	δ_{gr}	beta	0.5	0.2	0.464	0.224	0.486	0.182	0.776
Potential world demand persistence	$\delta_{y^*,p}$	beta	0.5	0.2	0.604	0.198	0.505	0.246	0.783
Natural relative input price reaction to gap	δ_z	beta	0.3	0.2	0.059	0.061	0.269	0.003	0.561
Natural rate persistence	δ_r	beta	0.7	0.15	0.732	0.111	0.705	0.519	0.901
Natural unemployment persistence	δ_u	beta	0.8	0.1	0.932	0.035	0.885	0.788	0.979

Table C.1: Parameters – Priors and Posterior Estimation Results (cont.)

Parameter		Prior Distribution			Posterior Distribution				
		Type	Mean	Std	Mode	Std	Mean	5%	95%
Unemployment gap persistence	α_1	beta	0.7	0.1	0.711	0.111	0.747	0.593	0.913
Output effect on unemployment	α_2	gamma	0.5	0.1	0.384	0.076	0.422	0.290	0.556
ULC persistence	ζ_1	beta	0.5	0.05	0.574	0.045	0.569	0.493	0.642
Output effect on ULC	ζ_2	gamma	0.2	0.05	0.178	0.039	0.182	0.120	0.246
Persistence in inf. exp.	ν	Unif (0,1)	0.5	0.289	0.557	0.074	0.561	0.438	0.684
5 year yield persistence	$\delta_{r,5}$	beta	0.6	0.15	0.462	0.058	0.476	0.367	0.583
Risk-premium persistence	δ_ϕ	beta	0.8	0.1	0.873	0.069	0.851	0.752	0.955
World demand gap - lag1	$\delta_{y^*,1}$	beta	0.75	0.1	0.799	0.087	0.787	0.653	0.924
World demand gap - lag2	$\delta_{y^*,2}$	normal	0.39	0.2	0.463	0.128	0.466	0.210	0.728
Non-fuel weight in imported input prices	W^{p*z}	beta	0.87	0.1	0.964	0.058	0.880	0.747	0.999
Shocks' std.									
Exchange rate	$\mathcal{E}_t^{\Delta e}$	inv. gamma	10.0	Inf.	11.36	1.14	11.73	9.71	13.63
Effective world CPI	$\mathcal{E}_t^{*TW_CPI}$	inv. gamma	10.0	Inf.	6.27	0.627	6.46	5.37	7.54
Fuel in CPI	\mathcal{E}_t^{Fuel}	inv. gamma	6.0	Inf.	10.38	1.04	10.91	9.04	12.73
Housing in CPI	$\mathcal{E}_t^{Housing}$	inv. gamma	3.5	Inf.	4.27	0.427	4.47	3.68	5.22
Fruits&vegetables in CPI	\mathcal{E}_t^{Veg}	inv. gamma	16.0	Inf.	16.93	1.69	17.37	14.48	20.25
Imported inflation	$\mathcal{E}_t^{\pi^f}$	inv. gamma	0.25	0.05	0.229	0.041	0.250	0.171	0.323
Local inflation	$\mathcal{E}_t^{\pi^h}$	inv. gamma	2.5	Inf.	2.64	0.400	2.95	2.23	3.67
Consumer goods' import price	$\mathcal{E}_t^{*C_IM}$	inv. gamma	7.0	Inf.	6.59	0.658	6.75	5.62	7.86
Oil import price	\mathcal{E}_t^{*oil}	inv. gamma	40.0	Inf.	38.71	3.87	39.72	33.00	46.49
Imported non-oil-input prices	$\mathcal{E}_t^{*z,nonoil}$	inv. gamma	6.0	Inf.	5.22	0.525	5.35	4.47	6.24
Natural relative imported inputs price	$\mathcal{E}_t^{*z^c,p}$	inv. gamma	0.25	Inf.	0.115	0.047	0.206	0.059	0.387
Im. deflator inflation	\mathcal{E}_t^{*M}	inv. gamma	5.8	Inf.	5.62	0.562	5.77	4.80	6.69
Inflation target	$\mathcal{E}_t^{\pi^T}$	inv. gamma	1.0	Inf.	0.668	0.067	0.686	0.573	0.800
US inflation	\mathcal{E}_t^{*US}	inv. gamma	1.3	Inf.	1.24	0.124	1.28	1.06	1.481
World trade prices	\mathcal{E}_t^{*py}	inv. gamma	10.0	Inf.	7.37	0.737	7.57	6.29	8.81
Natural world trade	$\mathcal{E}_t^{*y,p}$	inv. gamma	0.8	0.6	0.566	0.220	0.809	0.404	1.19
Market based inf. exp.	$\mathcal{E}_t^{\pi^c}$	inv. gamma	1.0	Inf.	0.726	0.084	0.756	0.617	0.897
FX risk premium	\mathcal{E}_t^ϕ	inv. gamma	0.6	Inf.	0.642	0.065	0.658	0.545	0.761

Table C.1: Parameters – Priors and Posterior Estimation Results (cont.)

Parameter		Prior Distribution			Posterior Distribution				
		Type	Mean	Std	Mode	Std	Mean	5%	95%
Potential growth rate	\mathcal{E}_t^{gr}	inv. gamma	1.0	0.1	0.959	0.126	1.00	0.787	1.23
Dollar interest rate	\mathcal{E}_t^{ir}	inv. gamma	0.5	Inf.	0.300	0.030	0.307	0.255	0.359
Monetary policy	\mathcal{E}_t^i	inv. gamma	0.5	Inf.	0.719	0.075	0.755	0.621	0.886
LOP gap	\mathcal{E}_t^{LOP}	inv. gamma	0.5	0.1	0.464	0.085	0.516	0.350	0.683
Natural real interest rate	\mathcal{E}_t^r	inv. gamma	0.8	0.01	0.808	0.041	0.810	0.742	0.877
5-year yield	\mathcal{E}_t^{r5}	inv. gamma	0.2	Inf.	0.088	0.033	0.128	0.050	0.207
Government purchases	\mathcal{E}_t^g	inv. gamma	1.5	Inf.	1.944	0.194	1.987	1.65	2.30
Investment	\mathcal{E}_t^{inv}	inv. gamma	8.0	Inf.	5.825	0.581	5.961	4.97	6.91
Unit labor cost	\mathcal{E}_t^{ulc}	inv. gamma	0.8	Inf.	0.729	0.086	0.767	0.610	0.920
Natural unemployment rate	\mathcal{E}_t^{ur}	inv. gamma	0.2	0.01	0.206	0.021	0.207	0.172	0.242
Unemployment gap	$\mathcal{E}_t^{\bar{u}}$	inv. gamma	0.5	Inf.	0.286	0.060	0.312	0.207	0.411
World trade gap	\mathcal{E}_t^{y*}	inv. gamma	1.0	Inf.	0.995	0.169	0.851	0.423	1.21
Output gap	\mathcal{E}_t^y	inv. gamma	0.5	Inf.	0.209	0.068	0.413	0.152	0.694
Potential output	$\mathcal{E}_t^{y^p}$	inv. gamma	1.0	0.01	1.01	0.052	1.02	0.933	1.10

C-3. Main estimation results

The estimation results are reported in Table C.1. We present the mode of the posterior distribution, the mean and the 90% highest probability interval. Figures (C.2a)-(C.2d) depict the prior and posterior distributions of the estimated parameters. The distribution was calculated through the Metropolis-Hasting Monte-Carlo Markov-Chain. For the baseline estimation we conducted two blocks of 600,000 iterations (half of which were burned out). Convergence was monitored through the Brooks and Gelman (1998) procedure. All of these were done using the DYNARE version 4.0.2 application.

The estimation results clearly show that many of the parameters, whose posterior distribution replicates the prior, are weakly identified by the data. However, some results do come up. We start by inflation related parameters. The import weight (w_f^c) is well identified and close to the prior – 0.3. In contrast, Argov and Elkayam (2007) found it higher – 0.45 to 0.55.¹⁸ The data are somewhat indicative of the

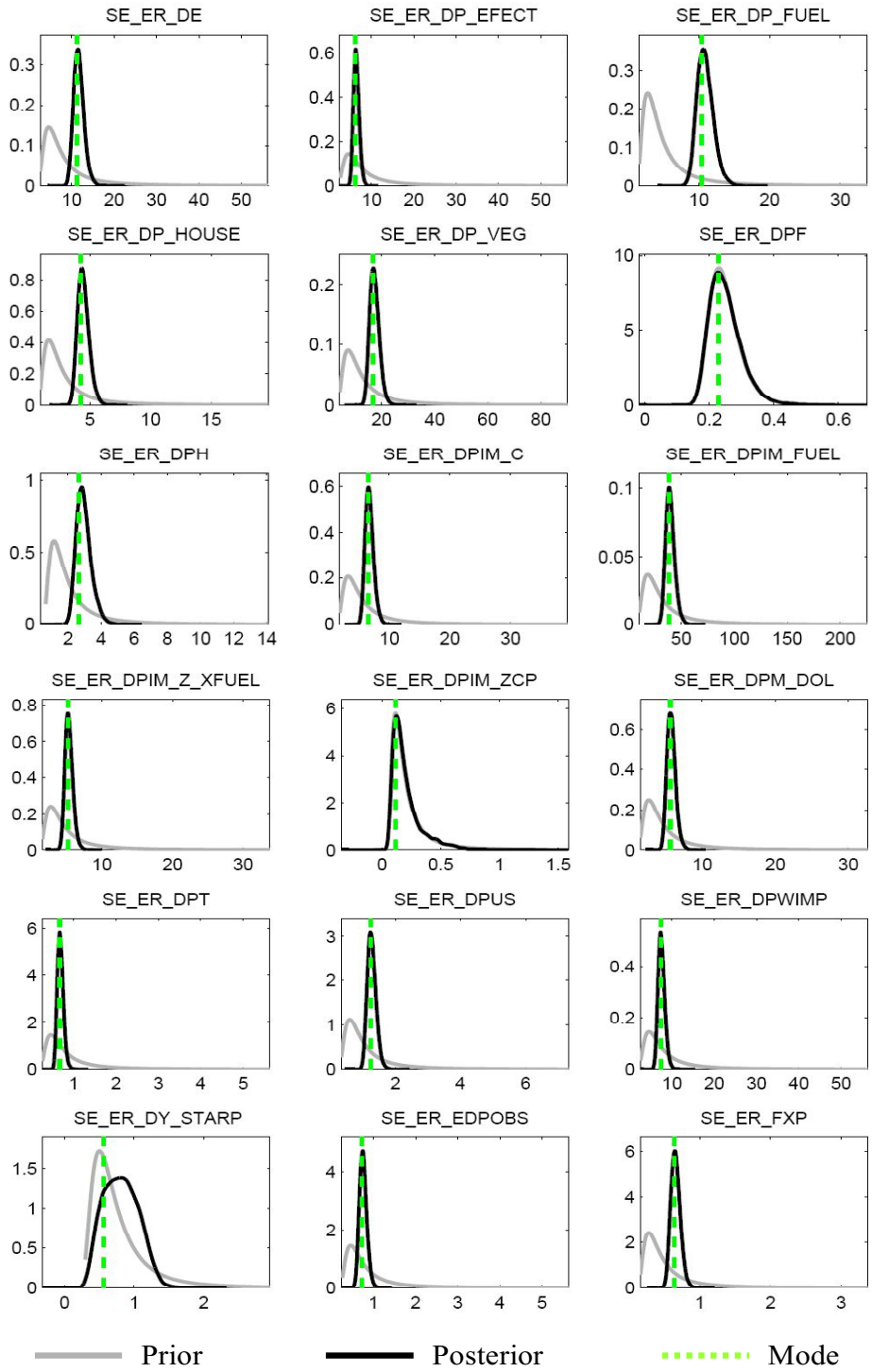
¹⁸ Their "core" inflation measure included fuel, which are mainly imported. However this cannot account for the difference.

coefficients of the output gap (λ_2) and the real price of inputs (λ_3), pointing to a lower value than our prior. Compared to Argov and Elkayam, we estimate a somewhat stronger effect of the output gap on inflation (their estimated coefficient is 0.1 compared to our mean of 0.14). The speed of pass-through to import prices (λ_f) is, unfortunately, identified only weakly. It turns out that the data do not contain enough information to jointly estimate the import weight (w_f^e) and the speed of pass-through, so that, given the estimation of the import weight, the pass-through speed is more of a calibration. Naturally the parameters of the inflation components equation (housing and fuel) are well identified because it contains only observable variables.

In the output gap equation the lead's parameter (b_{11}) and the world trade's coefficient (b_5) are not identified. However, the data turned out to be informative on the remaining parameters. The data support the non-homogeneity of the equation – b_{12} was estimated to be 0.74, somewhat higher than our prior. The coefficient of the real interest rate was estimated to be 0.32 lower than our prior of 0.5 and lower than the results of Argov and Elkayam (2007) – 0.4. The data were also indicative of the coefficients of the real exchange rate (b_3), the L.O.P. gap (b_4), investment (b_6) and government purchases (b_7). They all turned out smaller than our prior and Argov and Elkayam's estimation results. It is also apparent that the data support strong persistence in the demand shock (z_t^y). The posterior mean of δ_{z^y} was estimated at 0.73 and the prior of 0.5 is just below the 90% highest probability interval.

The data were informative regarding the monetary policy reaction function. The interest-rate smoothing (κ_i) was estimated to be 0.74, in the region of our prior (0.7) and Argov and Elkayam's estimation. The aggressiveness regarding inflation (κ_π) was reduced in the estimation to 1.29, in the lower bound of Argov and Elkayam's estimation. The data do not possess information on the degree of reaction to the output gap.

Figure C.2a: Prior and Posterior Distributions



SE_ER_DE - $\mathcal{E}_t^{\Delta e}$

SE_ER_DP_HOUSE - $\mathcal{E}_t^{Hou\ sing}$

SE_ER_DPH - $\mathcal{E}_t^{\pi^h}$

SE_ER_DPIM_Z_XFUEL - $\mathcal{E}_t^{z^*,nonoil}$

SE_ER_DPT - $\mathcal{E}_t^{\pi^f}$

SE_ER_DY_STARP - $\mathcal{E}_t^{y^*,p}$

SE_ER_DP_EFECT - $\mathcal{E}_t^{*TW_CPI}$

SE_ER_DP_VEG - \mathcal{E}_t^{Veg}

SE_ER_DPIM_C - $\mathcal{E}_t^{*C_IM}$

SE_ER_DPIM_ZCP - $\mathcal{E}_t^{z^{c*,p}}$

SE_ER_DPUS - \mathcal{E}_t^{*US}

SE_ER_EDPOBS - $\mathcal{E}_t^{\pi^c}$

SE_ER_DP_FUEL - \mathcal{E}_t^{Fuel}

SE_ER_DPF - $\mathcal{E}_t^{\pi^f}$

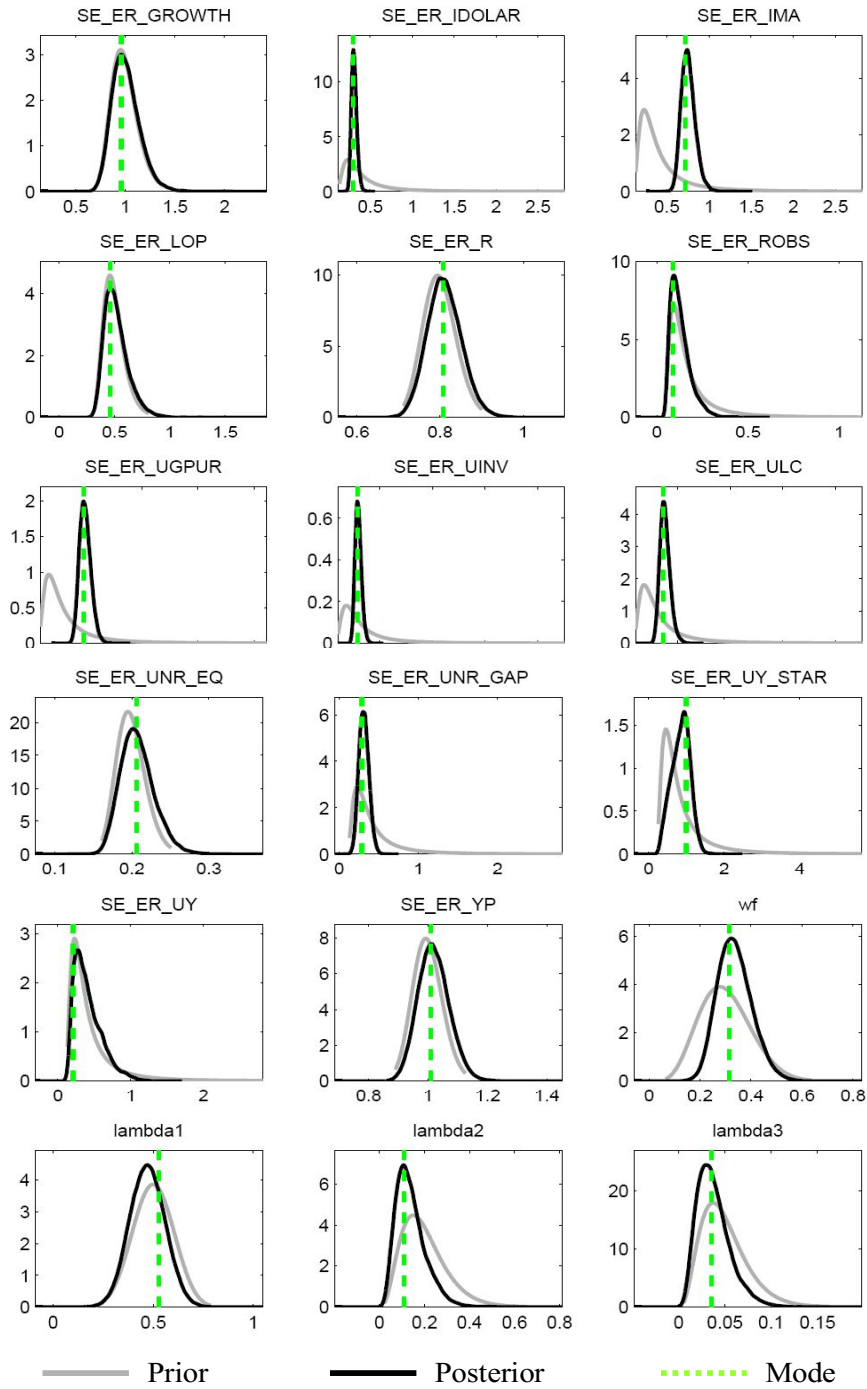
SE_ER_DPIM_FUEL - $\mathcal{E}_t^{*,oil}$

SE_ER_DPM_DOL - \mathcal{E}_t^M

SE_ER_DPWIMP - \mathcal{E}_t^{py*}

SE_ER_FXP - \mathcal{E}_t^ϕ

Figure C.2b: Prior and Posterior Distributions (cont.)

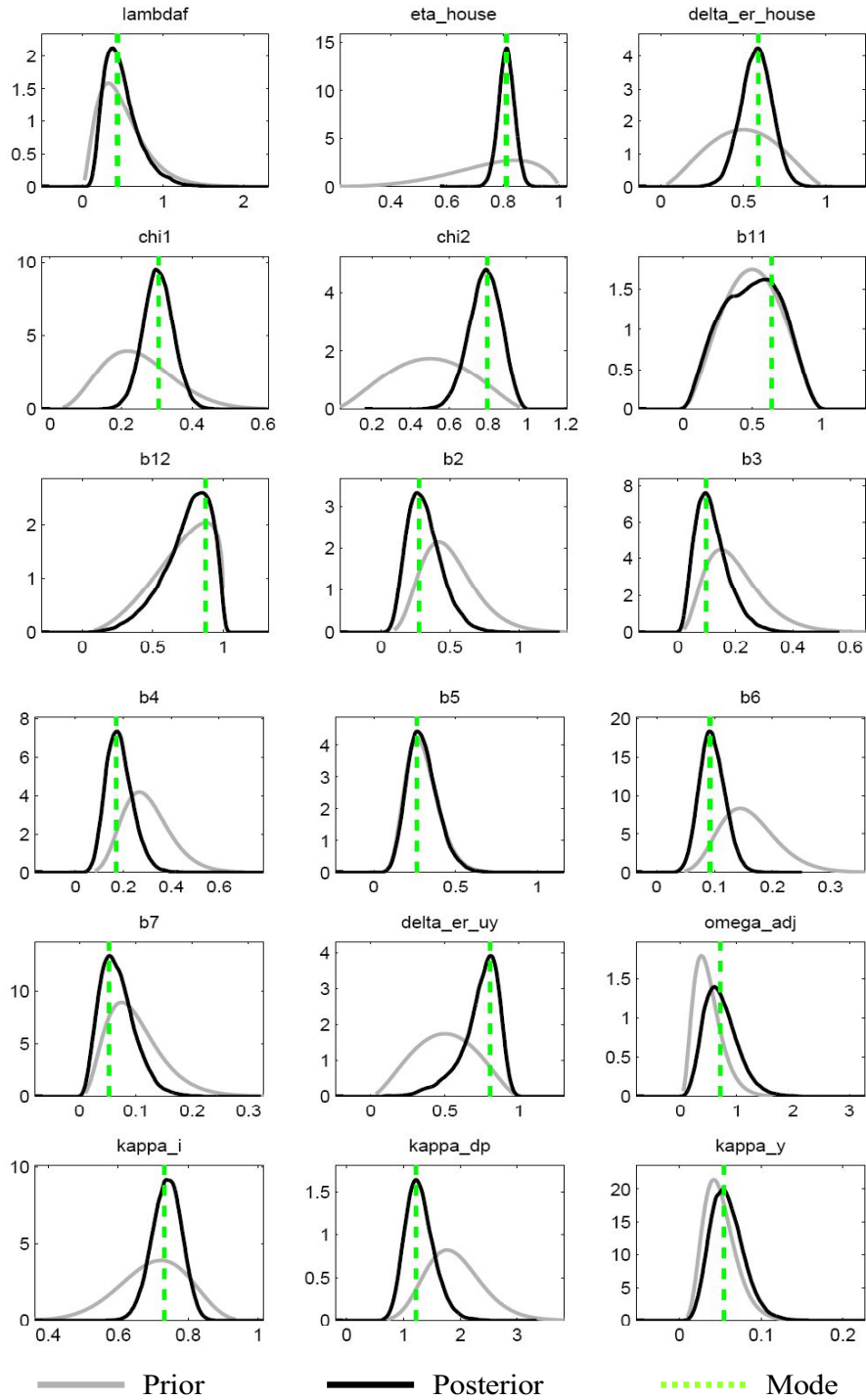


SE_ER_GROWTH - ε_t^{gr}
 SE_ER_DP_LOP - ε_t^{LOP}
 SE_ER_UGPUR - ε_t^g
 SE_ER_UNR_EQ - ε_t^{ur}
 SE_ER_UY - ε_t^y
 lambda1 - λ_1

SE_ER_IDOLAR - ε_t^{is}
 SE_ER_DP_R - ε_t^r
 SE_ER_UINV - ε_t^{inv}
 SE_ER_UNR_GAP - ε_t^{ii}
 SE_ER_YP - ε_t^{yp}
 lambda2 - λ_2

SE_ER_IMA - ε_t^i
 SE_ER_ROBS - ε_t^{r5}
 SE_ER_ULC - ε_t^{ulc}
 SE_ER_UY_STAR - ε_t^{y*}
 wf - w_f^c
 lambda3 - λ_3

Figure C.2c: Prior and Posterior Distributions (cont.)



lambdaf - λ_f

chi1 - χ_1

b12 - b_{12}

b4 - b_4

b7 - b_7

kappa_i - κ_i

eta_house - $\eta^{housing}$

chi2 - χ_2

b2 - b_2

b5 - b_5

delta_er_uy - δ_{u^r}

kappa_dp - κ_π

delta_er_house - $\delta_{Housing}$

b11 - b_{11}

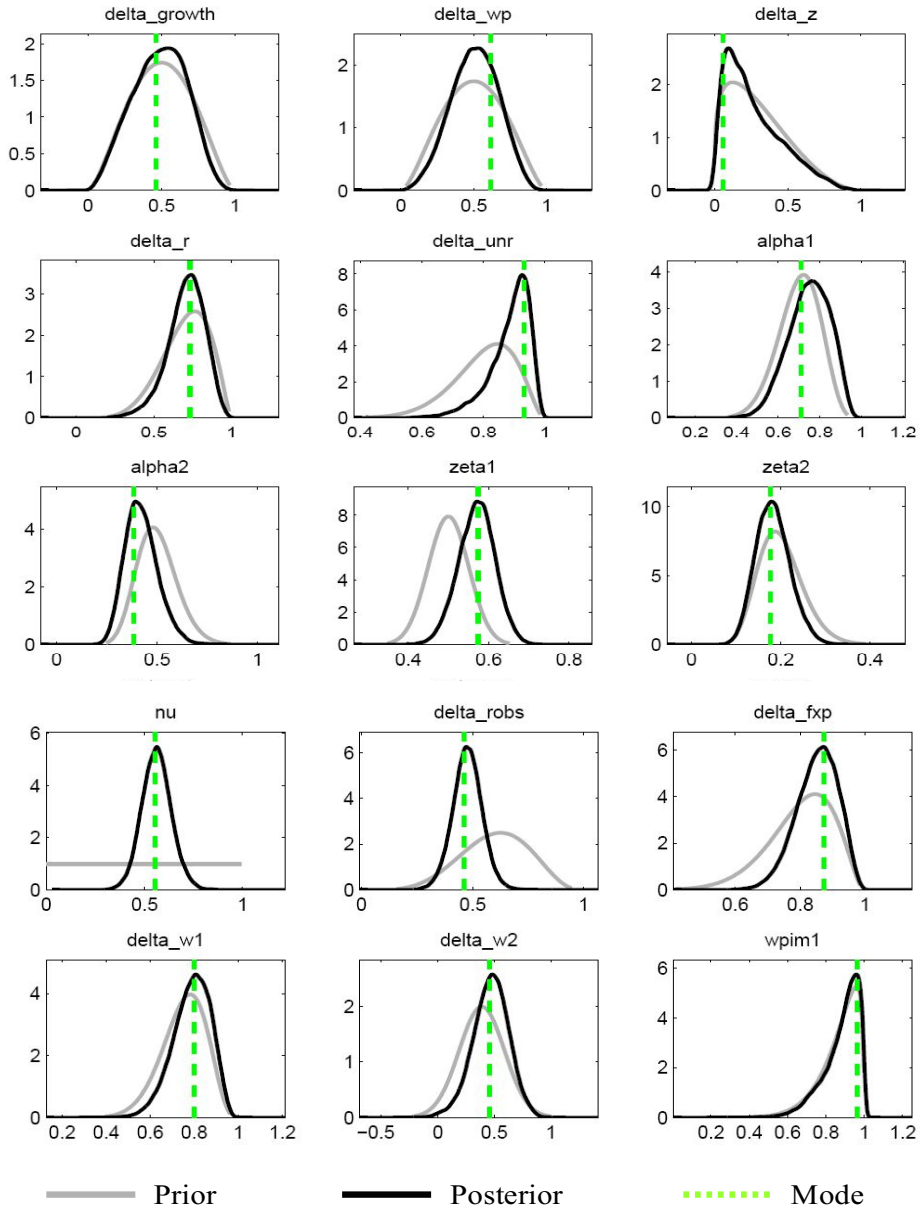
b3 - b_3

b6 - b_6

omega_adj - $\tilde{\omega}$

kappa_y - κ_y

Figure C.2d: Prior and Posterior Distributions (cont.)



delta_growth - δ_{gr}

delta_r - δ_r

alpha2 - α_2

nu - ν

delta_w1 - $\delta_{y^*,1}$

delta_wp - $\delta_{y^*,p}$

delta_unr - δ_u

zeta1 - ζ_1

delta_robs - $\delta_{r,5}$

delta_w2 - $\delta_{y^*,2}$

delta_z - δ_z

alpha1 - α_1

zeta2 - ζ_2

delta_fxp - δ_ϕ

wpim1 - W^{p*z}

Figure C.3a: Impulse Response to 1 Std. Monetary Policy Shock

(0.75 percentage points shock to ε_t^i)

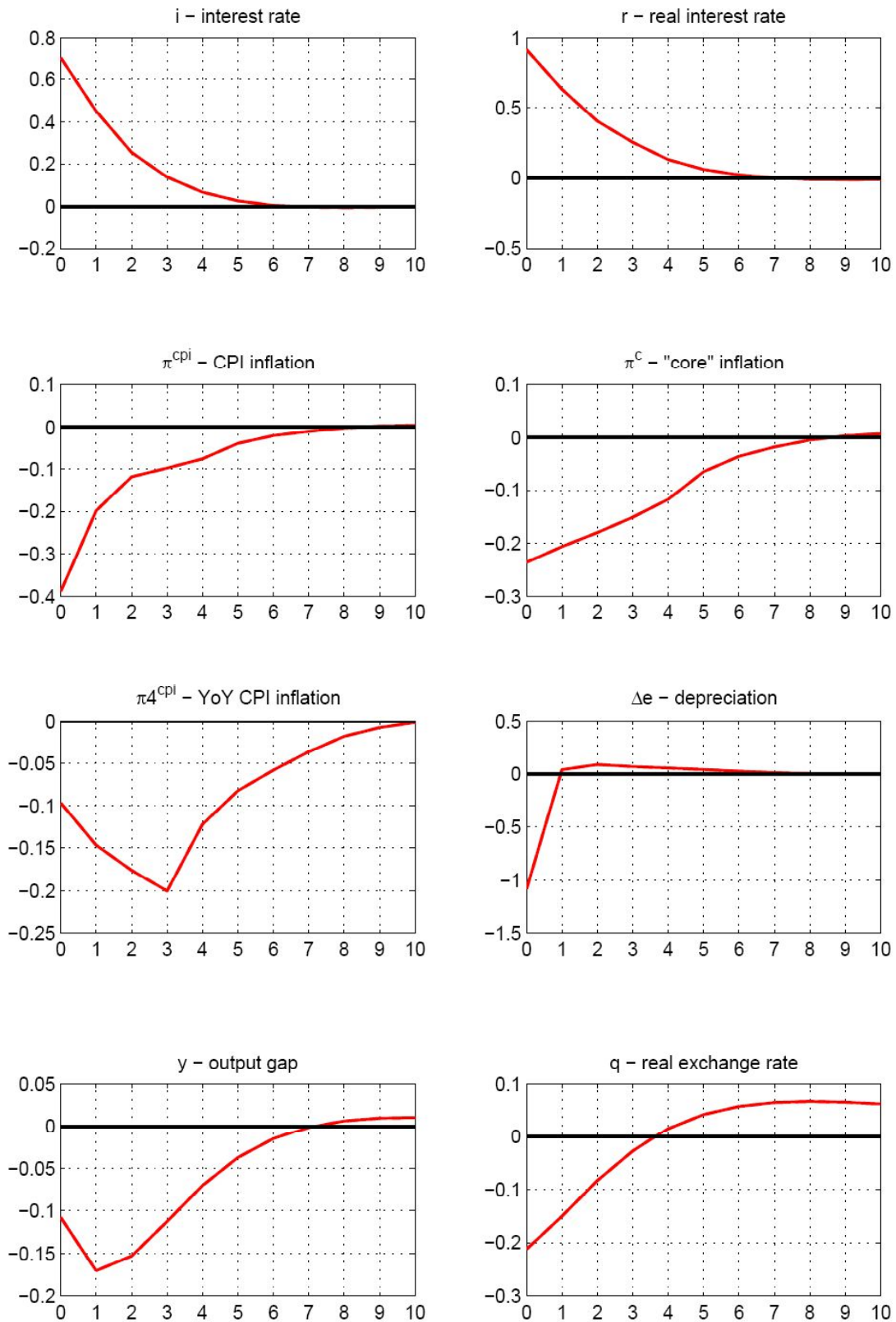


Figure C.3b: Impulse Response to 1 Std. Exchange-rate Shock

(Annualized 11.7% shock to $\varepsilon_t^{\Delta e}$)

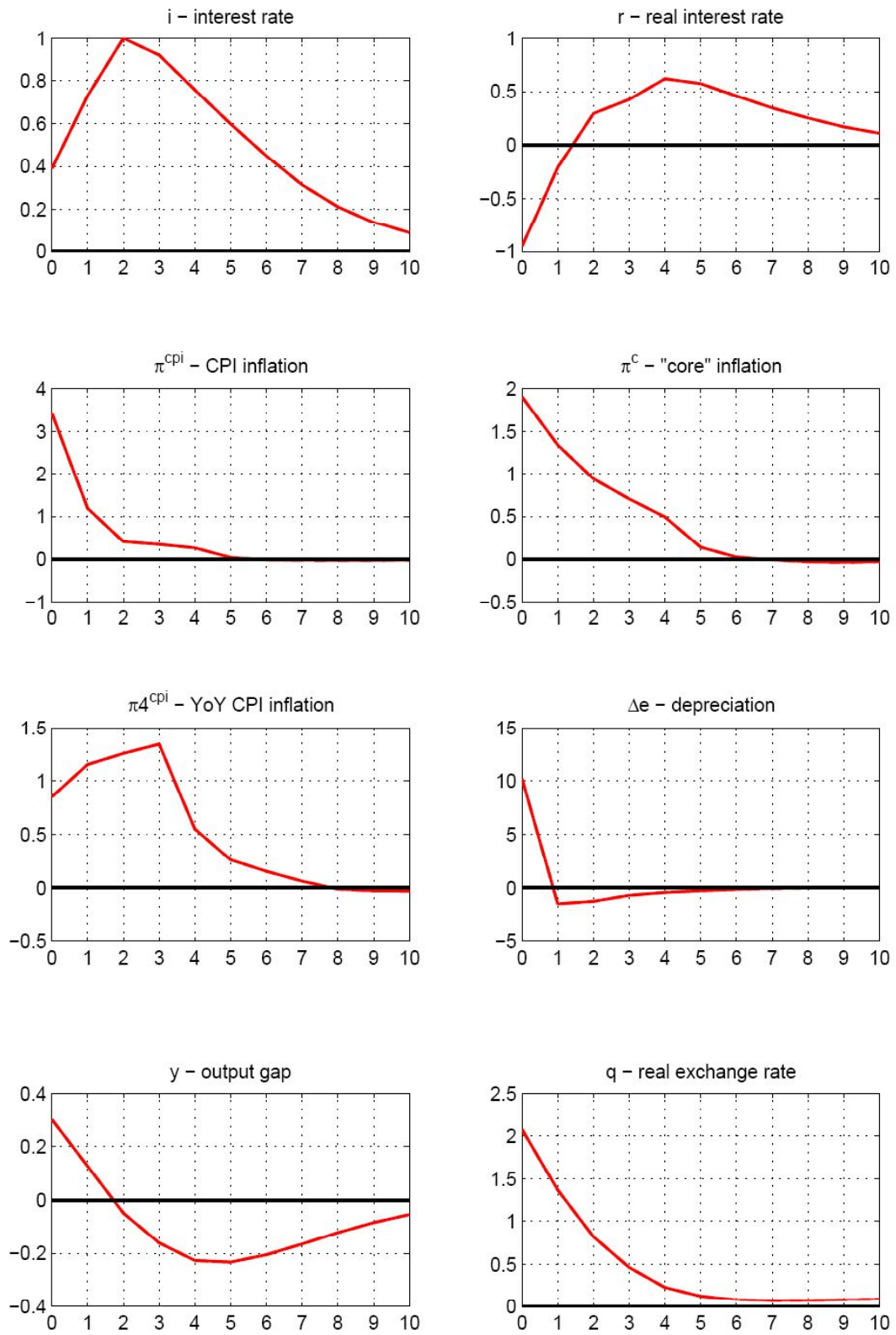
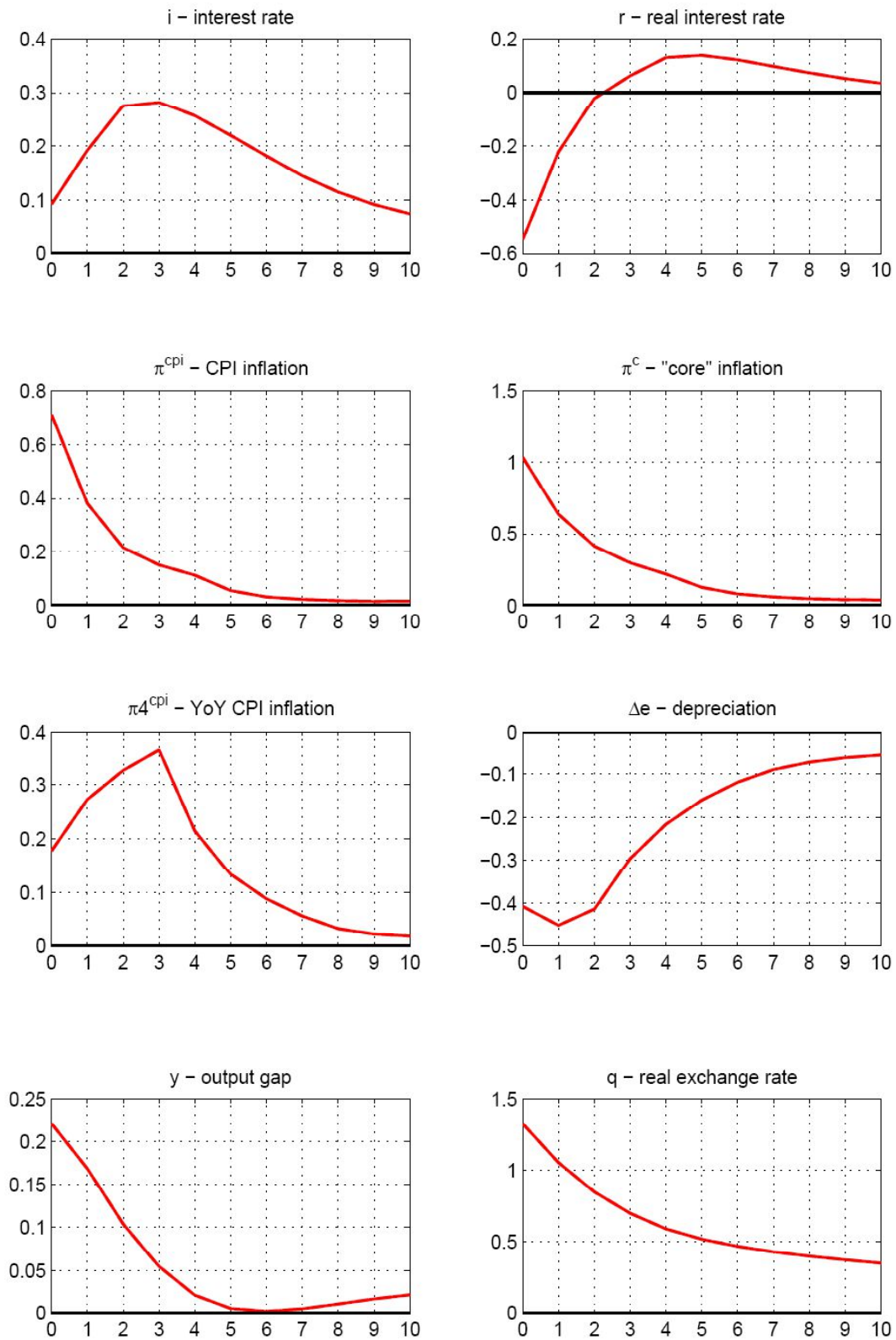


Figure C.3c: Impulse Response to 1 Std. Foreign Price Shock

(Annualized 6.75% shock to ε_t^{*C-IM})



C-4. Impulse response functions

In this section we present dynamic elasticities (impulse responses) of some key endogenous variables, with respect to each of the following shocks: monetary policy, nominal exchange rate and a foreign price shock.

Figure C.3a presents the impulse response with respect to one standard deviation shock to the nominal interest rate (that is a 0.75 percentage point shock to ε^i). Notice that all the endogenous variables are immediately affected by the shock, and for most of them, the immediate response is the largest. For the output gap, we find a mild hump-shape, where the peak of the response is in the second quarter. Usually in estimated models one would expect to find a hump-shaped response of inflation and the output gap to the interest rate shock where the peak effect is after four quarters.¹⁹ The large and quick response of the endogenous variables apparent in our model is partly due to the existence of the exchange rate channel and the fast exchange rate pass-through. The unexpected increase in the interest rate causes an immediate decline of the exchange rate through the UIP condition, which immediately affects inflation and the real exchange rate, and through it – the output gap. The quick response is also due to the relatively large coefficients of expectations in the inflation, output gap and exchange rate equations (that is, the large degree of which the model is forward looking).

In Figure C.3b we present the impulse response with respect to an unexpected one standard deviation shock to the exchange rate (that is an annualized 11.7 percentage points shock to ε^{Ae}). Notice that here as well (as in Figure C.3a) the immediate response is the largest. Due to the concurrent positive response of the interest rate, the 12 p.p. shock ends in only a 10 p.p. depreciation in the first quarter. CPI inflation increases by 3.5 p.p, indicating immediate pass-through of 0.35 with respect to the CPI inflation. The pass-through to core inflation is somewhat smaller, 0.2, but still higher than common in other economies. Due to the inflationary consequences of the depreciation, the nominal interest rate increases immediately by 0.4 p.p. and peaks at 1.0 p.p. above the steady state. The real rate temporarily drops in the first quarter; however, as the nominal rate continues to rise and inflation re-converges, the real rate peaks at 0.6 p.p. (above s.s.) a year after the shock. The output gap shows an interesting feature: The real depreciation induces only a mild expansion

¹⁹ See Smets and Wouters (2003) and Christiano et al. (2005) for a closed economy. See Adolfson et al. (2005) and Brubakk et al. (2006) for an open economy.

of the economy which is followed by a long-lasting reduction of output. This stems from the fast pass-through to prices which mitigates the affect of the nominal depreciation on the real exchange rate, and the fact that monetary policy is tightened in order to offset the strong effect on inflation.

The above simulations highlight the role of the exchange rate in the transmission mechanism of monetary policy in an open economy. The high exchange rate pass-through means high sensitivity of the inflation rate to shocks to the exchange rate. On the other hand, the high exchange rate pass-through also enhances the effectiveness of the nominal interest rate as a tool for stabilizing inflation.

The last figure, C.3c, presents the impulse response with respect to a one standard deviation shock to foreign inflation $-\Delta p_t^{*C-IM}$ (that is an annualized 6.75 percentage points shock to ε^{*C-IM}). Recall that the characterizing equation for the imported consumer good's unit value (foreign inflation in the baseline model) has no persistence; therefore we are describing a one-period increase in foreign inflation. We can see, once again, that the immediate response is the largest. However, the pass-through to CPI inflation is considerably smaller than the exchange rate shock (immediate pass-through of 0.1 compared to 0.35). That is because foreign prices do not affect the housing component, as opposed to the exchange rate which is its main determinant. As a result monetary tightening is moderate and the real exchange rate is under-valued for a few years, so that the output gap is positive for one year and does not overshoot to negative values.

C-5. Variance decomposition

C-5-1. Forecast error variance decomposition

In this section we will decompose the variance of the (infinite limit horizon) forecast error by the various shocks. In order to avoid near non-stationary inflation, we will assume no shocks to the inflation target.²⁰ The results for five key observable variables are reported in Table C.2. We present only shocks that contribute more than 1.0% to one or more of the forecast error variances (the oil price shock is included anyway).

²⁰ Recall that the inflation target was modeled as nearly random walk in order to estimate the model through the last stages of the disinflation process. Under this assumption the variance of the inflation level is infinite and it is all attributed to the inflation target shock. In order to asses the variance decomposition around a stable inflation rate, we set the variance of the inflation target to zero.

Table C.2: Forecast Error Variance Decomposition

Shock \ Variable		CPI inflation	"Core" inflation	Nominal interest rate	Output growth	Depreciation rate
		π_t^{CPI}	π_t^C	i_t	Δy_t	Δe_t
Exchange rate	\mathcal{E}_t^{Ne}	67.8	47.7	50.4	5.5	94.0
Housing in CPI	$\mathcal{E}_t^{Housing}$	5.6	0.4	5.1	0.4	0.6
Fruit&vegetables in CPI	\mathcal{E}_t^{Veg}	2.9	0.1	0.7	0.1	0.1
Local inflation	$\mathcal{E}_t^{\pi^h}$	9.5	24.2	2.2	0.5	0.2
Consumer goods' import price	\mathcal{E}_t^{*C-IM}	3.7	12.3	5.4	1.8	0.7
Oil import price	\mathcal{E}_t^{*oil}	0.5	0.3	0.4	0.0	0.1
Natural world trade	$\mathcal{E}_t^{y^*P}$	0.2	1.1	1.3	0.3	0.2
EX risk premium	\mathcal{E}_t^ϕ	1.7	1.8	3.3	0.1	1.0
Potential growth rate	\mathcal{E}_t^{gr}	0.2	0.4	0.2	2.2	0.0
Dollar interest rate	$\mathcal{E}_t^{i^*}$	5.0	6.1	13.1	0.2	1.3
Monetary policy	\mathcal{E}_t^i	1.1	1.2	10.4	0.7	1.0
Natural real interest rate	\mathcal{E}_t^r	0.8	1.0	2.7	0.0	0.3
Investment	\mathcal{E}_t^{inv}	0.0	0.1	0.1	16.1	0.0
Output gap	\mathcal{E}_t^y	0.3	1.5	3.5	42.0	0.5
World trade gap	$\mathcal{E}_t^{y^*}$	0.0	0.1	0.2	2.8	0.0
Potential output	$\mathcal{E}_t^{y^p}$	0.1	0.5	0.5	26.6	0.1

It is clearly seen that the depreciation shocks play an enormous role in Israel's monetary system. The shock contributes nearly 68% of the variance in CPI inflation. In part, that is due to the housing component which is entirely related to the NIS/dollar exchange rate (see equation 2.2). However, also the "core" inflation (that excludes the housing sector) is largely affected by exchange rate shocks (48%). That is a reflection of the strong and fast pass-through in Israel. As a consequence, an inflation targeting central bank must react to developments in the exchange rate. Apparently, the exchange rate shock contributes 50% of the interest rate variance.

An interesting result is the contribution of the dollar interest rate to the local nominal interest rate, 13%, even higher than its own shock. The channel working here is the uncovered interest rate parity. Changes in the foreign interest rate may cause variation in the exchange rate that would pass through to inflation. However, the table reveals that the dollar interest rate does not contribute much to the variance of the

depreciation rate. That means that the Bank of Israel probably reacted with its nominal rate to changes in the dollar interest rate in order to prevent interest-differential effects on the exchange rate.

The last point that emerges from the table is the minor role of oil price shocks in Israel's inflation, at least based on 1995-2006 data. They contribute only 0.5% to the variance of inflation. The reason might be the fact that for a significant part of the sample oil prices were characterized by large fluctuations around some stable level. In this environment there is no need to adjust domestic prices to a hike in the oil price, for it presumably will drop back in the following quarters. However, at the beginning of the decade oil prices began rising rapidly with a non-reversing trend. We assess that only in 2006-07 was the non-reversing trend internalized in firms' decisions so that oil prices took a major role in the rise of inflation. We can see from Table C.2 that unlike oil prices the unit value consumer import goods (world prices in the baseline specification) did play a significant role in the variance of "core" inflation – 12.3%.

C-5-2. Historical decomposition

To supplement the general forecast-error decomposition above, we discuss here an historical decomposition of inflation by shocks. That is, we will decompose the deviation of inflation from the target though out the decade of 1997-2007 by the contributions of groups of shocks. The decomposition is presented in Figure C.4. In order to make the presentation clearly visible we divided the shocks into five groups: supply shocks (that generate negative correlation between inflation and output),²¹ demand shocks (that generate positive correlation between inflation and output),²² monetary policy shocks,²³ foreign price shocks²⁴ and exchange rate shocks.²⁵ In addition we will present the results for year-on-year inflation (as deviations from the target) by calendar years, for they capture most of the high-low inflation eras.

²¹ The shocks included in the group are: $\varepsilon_t^{y,p}$, ε_t^r , ε_t^{LOP} , ε_t^{gr} , $\varepsilon_t^{\pi^s}$, $\varepsilon_t^{\pi^f}$, ε_t^{veg} , $\varepsilon_t^{Housing}$, ε_t^{Fuel} .

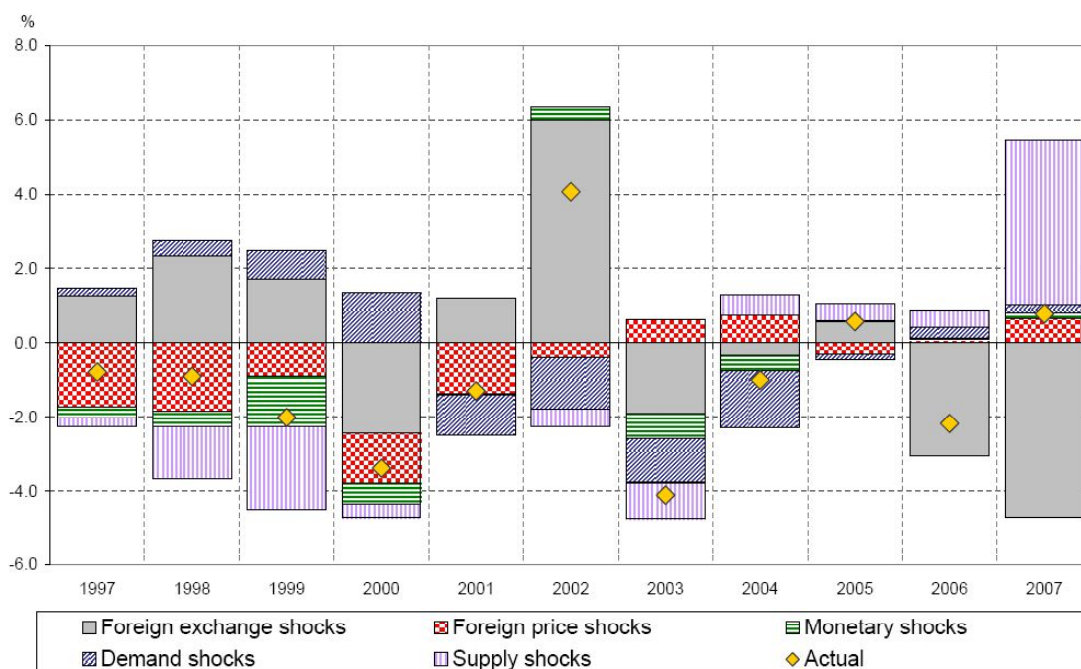
²² The shocks included in the group are: $\varepsilon_t^{y^*}$, ε_t^y , ε_t^{inv} , ε_t^g , $\varepsilon_t^{i^*}$, ε_t^ϕ , $\varepsilon_t^{y^*,p}$.

²³ The shocks included in the group are: ε_t^i , $\varepsilon_t^{\pi^T}$.

²⁴ The shocks included in the group are: $\varepsilon_t^{z^*,p}$, $\varepsilon_t^{z^*,nooil}$, $\varepsilon_t^{*,oil}$, ε_t^{*C-IM} .

²⁵ The shocks included in the group are: $\varepsilon_t^{\Delta e}$.

Figure C.4: Historical Decomposition of Annual Inflation (Deviation from Target), 1997-2007



Once again we can see the significance of exchange rate shocks in inflation determination. They explain a main part of not achieving the inflation target in 2000, 2002, 2003 and 2006. The year 2002 is a special case: in the last week of 2001, the interest rate was reduced unexpectedly by an exceptional two percentage points. The reduction was part of a fiscal-monetary package. This came as a surprise, along with the fact that fiscal policy was not tightened as agreed, and generated a sharp reduction in the credibility of macro-economic policy, that resulted in a large depreciation of the NIS versus the dollar (14% within 2 quarters).²⁶ Due to the strong pass-through the depreciation resulted in high inflation (4 percentage points above the target). Although monetary easing certainly had a significant role in this depreciation, the linear UIP condition cannot attribute it to interest rate differentials. Therefore we can see that the exchange rate shock is the main contributor to missing the target in 2002.²⁷ Negative demand shocks expressing the global fall of the high-tech sector and the deteriorating security situation also contributed. The recession in demand

²⁶ The year was also characterized by sharp deterioration in Israel's security situation in the face of the second Intifada.

²⁷ Argov et al. (2007b) adjust the IMF's resembling model to account for monetary policy credibility. It is calibrated to produce a significant contribution of the erratic interest rate reduction to the hike in inflation.

continued throughout the next two years and were partly responsible for the low inflation in 2003-04. In these years we can see that monetary policy made a negative contribution to inflation. During the 2002 exchange-rate crisis, interest rates were increased sharply from 3.8% at the beginning of the year to 9.1% in the second half. Only a drastic change in policy stance was able to stop the depreciation process. However it seems that rates were kept high for a little too long, causing a negative contribution to inflation.

It can be seen in Figure C.4 that throughout the years 1997-2001 inflation was lower than the target. The first two years were a final stage in the disinflation process (inflation in 1997-08 was around 8%, in 1999 it dropped below 2%). The low inflation was not a result of the exchange rate, on the contrary, it had positive contributions to inflation throughout the first three years. These years were characterized by three main processes that generated the low inflation. (1) Foreign price shocks: the increased globalization and movement of manufacturing to low-cost countries (China, India) brought a global reduction of prices which lowered inflation in Israel through their effect on import prices. (2) Supply shocks: a large part of these shocks are negative inflation (equation) shocks which many models interpret as reduction of mark-ups. Therefore their contribution to low inflation may express increased competition in the Israeli economy. (3) Monetary shocks: it was a common assessment at the time that monetary policy was tight, and interest rates have been reduced slowly. This feeling generated part of the pressure leading to the sharp interest rate reduction in the end of 2001. As can be seen, the model also attributes part of the low inflation to positive interest rate shocks, i.e., interest rates being higher than implied by the monetary policy rule.

As for 2007, when inflation was higher than target by 0.8 percentage points, we can see the model attributes most of the contribution to negative supply shocks (positive inflation shocks). However, it is commonly asserted that the global rise in inflation was due to rising commodity prices in the global markets. In the baseline model we can see foreign inflation shocks contribute only 0.6 percentage points to inflation. We will return to the issue of 2007 in section D when comparing the baseline estimation to alternatives.

C-6. Filtered unobserved variables

The original model of Argov and Elkayam (2007) relied crucially on univariate HP filtered trends. That is, the gaps that appeared in the theoretical model were deviations from HP filter trends calculated prior to the estimation procedure. This was essential as they used limited information GMM estimation. In our case, we took advantage of our full information system estimation and specified had hoc equations for the trends and gaps (see Section B-5). Therefore, through the Kallman filter, we are able to smooth out the model consistent trend and gap series, which are based on all the observables and the structure of the model. In this section we report the obtained smoothed output gap (Figure C.5), the natural real interest rate (Figure C.6) and the potential real exchange rate (Figure C.7) for the estimation and out-of-sample period of 1995 through 2007.

Figure C.5: Output Gap – Model Derived and HP Filtered, 1995-2007

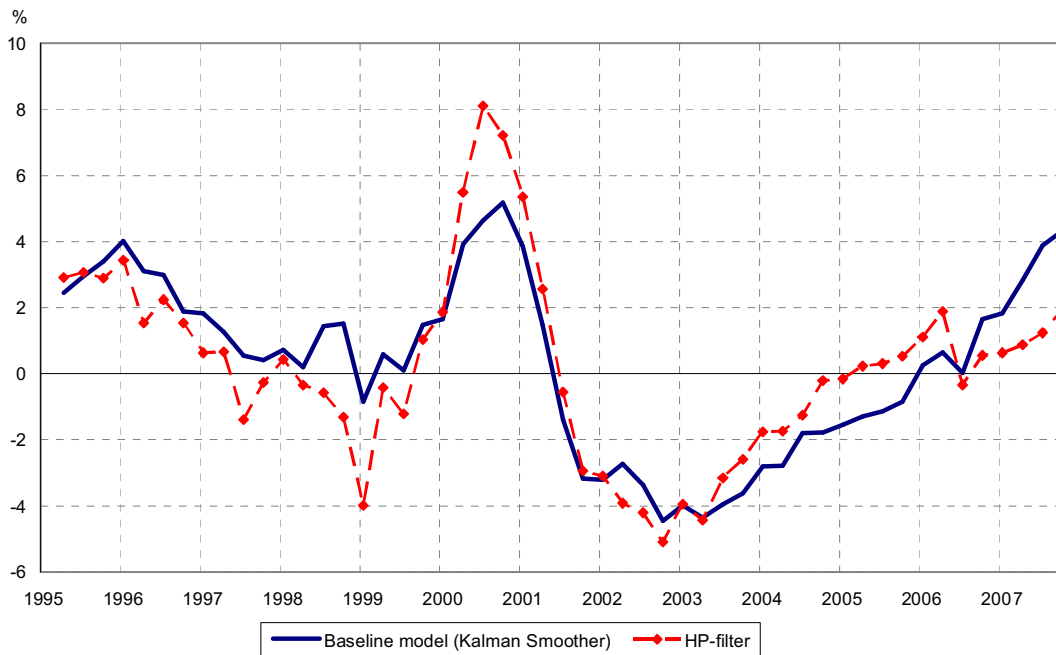


Figure C.5 reports the model derived output gap. For comparison we added an HP filtered gap. Overall the series are similar. The main differences are in 2000 and 2007. In 2000 the output gap is notably positive (output above potential). This result is derived from strong growth figures in the data, reflecting, in part, the high-tech boom. In addition, the real interest rate of above 6% and the historically appreciated real exchange rate are consistent with demand shocks that pushed up the output gap.

However, the output gap peaks at 5% rather than 8% calculated from the univariate HP filter. In part that is a result of the observed low inflation (three percentage points below mid-target) which implies that demand-side effects on prices could not have been too strong. In fact, it is evident from the historical decomposition that demand shocks were the sole positive contributors to inflation, whereas negative exchange rate shocks and low import prices drove inflation down.

Also, in 2007 the model consistent gap is very positive with a peak of 4.5%, once again consistent with high growth figures and an appreciated real exchange rate that can be generated from demand side shocks. However, as is apparent from the historical decomposition in Figure C.4, demand shocks made only a minor contribution to inflation in 2007. How is this consistent? As it turns out from the model, local direct output gap shocks (ε_t^y) have only a limited inflationary effect. In 2000 the demand shocks included high foreign interest rates and risk premiums which, ceteris paribus, are inflationary through their depreciative pressure on the exchange rate.

Figure C.6: Real Interest Rate – Natural Rate, Ex-Ante Rate and 5-Year Yield on Government Bonds, 1995-2007

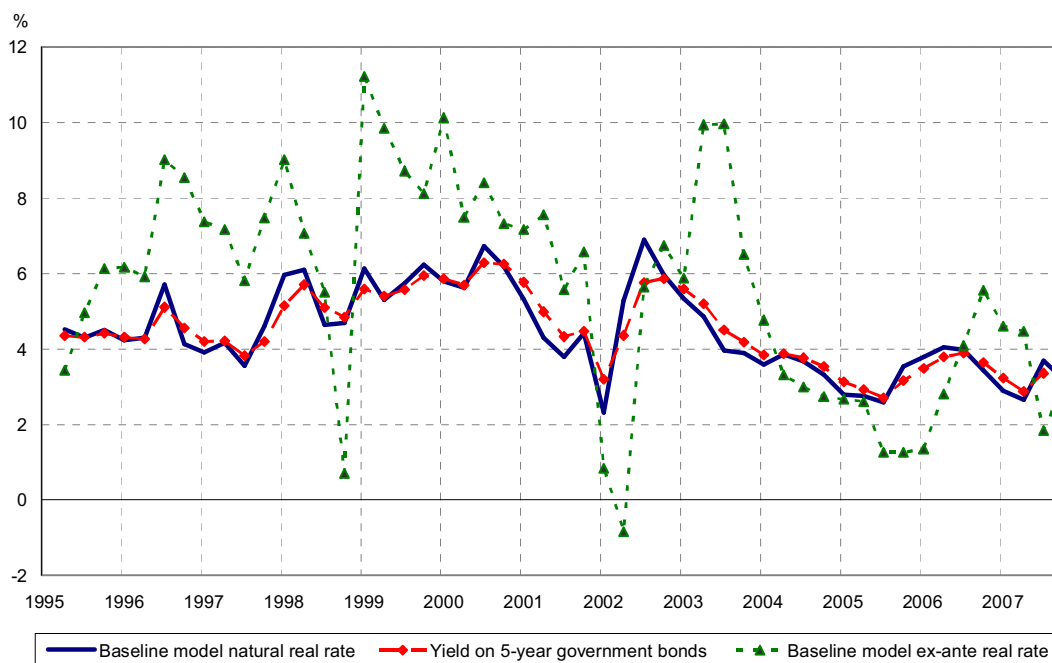


Figure C.6 depicts the smoothed natural real interest rate (r_t^p), the observed yield on 5-year CPI-indexed government bonds (r_t^{5year}) which serves as a proxy for the natural rate, and the smoothed ex ante real interest rate ($i_t - \pi_{t+1}^c$). It is clear that the smoothed natural rate is almost identical to the observed 5-year yields. This can result if the 5-year yield is a very good indicator of the natural rate in the context of our model, or, alternatively if the data contain little information on the natural rate – the Kallman filter will return the proxy as the smoothed series. We re-estimated the model with the 5- to 10-year forward real rate serving as a proxy instead of the 5-year yield. In this case too the smoothed natural real rate turned out close to the proxy. Therefore we conclude that the data contain little information on the natural real rate, so that, de-facto we *assumed* that the natural real rate is (to some approximation) the 5-year yield.

As we can see from the figure, throughout a decade ending in 2004 the ex ante real rate was held above the natural one. This may explain, in part, the deep recession Israel experienced once the high-tech boom exploded and the security situation deteriorated in year 2001.

Figure C.7: Real Exchange Rate – Actual and Potential, 1995-2007

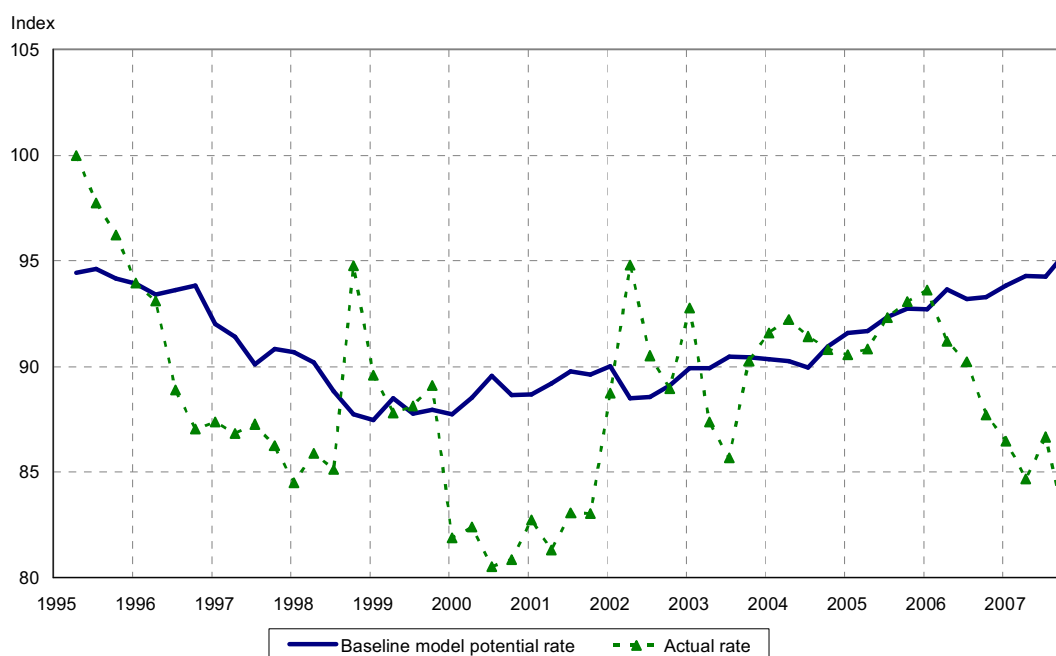


Figure C.7 plots the observed real exchange rate (defined as the foreign price measure relative to the local "core" inflation), and the smoothed potential rate. We can see the significant negative gaps around years 2000 and 2007, consistent with the positive output gaps. It can be seen that the potential rate appreciated from 1997-99 mainly due to excess world trade growth in the face of globalization. The potential rate was rather stable until 2004; in the recession year of 2001 this reflected a balanced reduction of world trade and local potential output growth. As of mid-2004 the potential real exchange is depreciating, even when the observed rate started appreciating in mid-2006. The potential depreciation is mainly a result of the high potential output growth during those years, and to some extent a reduction in world trade growth.

C-7. Goodness of fit

C-7-1. Forecasting errors

In order to assess the model's forecasting ability we will inspect its root mean square forecast errors (RMSE) for various horizons. To render interpretability, we will compare the RMSE to four alternatives: two statistical VAR models and two naive models.

We estimate 1-lag and 2-lag VAR models with the following variables: quarterly CPI inflation (π_t^{Cpi}), quarterly business sector GDP growth (Δy_t), quarterly depreciation (Δe_t) and the nominal interest rate (i_t); we also added to each equation lags of the dollar interest rate (i_t^*), quarterly change in the imported consumer goods' unit value (Δp_t^{*C-IM}), world trade growth (Δy_t^*), foreign exchange risk premium (ϕ_t), 5-year real yields (r_t^{5year}) and the inflation target (π_t^T).²⁸ The VARs were estimated for the same sample used in the baseline structural model estimation above (1995:Q2-2006:Q4). To calculate forecasts (and forecast errors) we used the same characterizing AR(1) equations for the exogenous variables (i_t^* , Δp_t^{*C-IM} , Δy_t^* , ϕ_t , r_t^{5year} , π_t^T). Since the equations for the world trade growth and 5-year real yield are determined within the model in the structural baseline case, we estimated simple auto-regressive equations for them.

²⁸ The number of lags corresponded to the VAR length. However, in both cases we included only one lag of the inflation target.

We also compare the RMSE results to two naive models. The first is a random walk model (in which the forecast is always the last data point). The second is a "steady state" forecast model. That is, for inflation the forecast is the last known inflation target, for the interest rate the forecast is the 5-year real yield plus the inflation target, for the growth rate the forecast is the mean growth rate, and, for the depreciation rate the forecast is the inflation target differential. Although both models are naive they represent two distinct projections. The random walk model assumes that inflation (or any other variable) will stay at its current level regardless of the monetary authority's efforts, whereas the "steady state" model assumes inflation will revert quickly to the desired target.

**Table C.3: Comparison of RMSE:
Baseline Model vs. Alternative VARS and Naive Models**

Variable	Forecast Horizon	Sample	Baseline model	VAR (1)	VAR (2)	RW model	SS model
Inflation (π_t^{Cpi})	1	95:Q2-06:Q4	3.92	3.06	2.80	4.73	3.97
		00:Q1-07:Q4	3.16	2.50	2.17	3.36	3.47
Inflation (π_t^{Cpi})	2	95:Q2-06:Q4	4.35	4.03	3.94	5.66	4.10
		00:Q1-07:Q4	3.65	2.94	2.87	4.36	3.49
YoY Inflation ($\pi 4_t^{Cpi}$)	4	95:Q2-06:Q4	2.89	2.46	2.32	4.68	2.55
		00:Q1-07:Q4	2.66	1.74	1.63	3.85	2.48
Interest rate (i_t)	1	95:Q2-06:Q4	1.50	1.62	1.67	1.19	1.77
		00:Q1-07:Q4	1.02	1.19	1.28	1.06	1.33
Interest rate (i_t)	2	95:Q2-06:Q4	1.74	1.76	1.77	1.88	1.90
		00:Q1-07:Q4	1.22	1.28	1.27	1.78	1.66
Interest rate (i_t)	4	95:Q2-06:Q4	2.26	2.15	2.17	2.60	2.17
		00:Q1-07:Q4	2.00	1.64	1.68	2.73	2.13
Output growth (Δy_t)	1	95:Q2-06:Q4	1.55	1.29	1.11	1.91	1.57
		00:Q1-07:Q4	1.37	1.13	1.21	1.43	1.54
Output growth (Δy_t)	2	95:Q2-06:Q4	1.56	1.41	1.21	1.74	1.57
		00:Q1-07:Q4	1.55	1.35	1.43	1.65	1.54
Output growth (Δy_t)	4	95:Q2-06:Q4	1.53	1.55	1.45	2.55	1.57
		00:Q1-07:Q4	1.43	1.31	1.24	2.26	1.54
Depreciation rate (Δe_t)	1	95:Q2-06:Q4	11.24	8.56	7.87	16.7	11.55
		00:Q1-07:Q4	12.11	9.81	9.67	16.09	12.14

Table C.3 summarizes the RMSE for two samples, the first is the estimation sample 1995:Q2-2006:Q4. The second sample covers a shorter and more recent era, 2000:Q1-2007:Q4. This sample starts after disinflation was achieved around low levels. Notice it includes 2007, which is not part of the estimation periods.²⁹

The general result arising from the table is that our baseline model does a better forecasting job than the naive models (especially the random walk) but falls behind the VARs. In terms of inflation forecast, we can see the VARs ultimately do better. Our baseline model is level with the "steady state" model and performs much better than the naive random walk. This is probably a result of the large shocks characterizing the exchange rate and the strong pass-through to inflation. As a result, in many points in time inflation jumped above and fell below the inflation target. That is why the no-change random walk model performs so poorly. That can explain why such a naive model as the "steady state" is similar to and for some horizons better (in term of forecast) than the structural baseline model. Whereas the latter predicts a typically gradual reversion to the inflation target, the naive "steady state" model predicts an immediate return (in many cases, the data show oscillations to the counter side of the target). Part of the explanation for the superior forecasting properties of the VARs is related to the exchange rate. As we can see, the VARs outperform other models, including the "steady state" model which is no other than a classical random-walk model in the level of the nominal exchange rate. It may be that the VAR is a reduced form of a structural model that is able to forecast the exchange rate, in contrast to the general finding of Meese and Rogoff (1983). However, it may also just be the case that in the limited observation model, the VARs are able to produce a linear combination that incidentally explains the exchange rate's in-sample variation better than the random walk or structural model.

In terms of interest rate predictions, we can see that all models are in the same neighborhood, where our baseline model is somewhat better than others for short horizons (1 and 2 quarters). Interestingly, at the 1-quarter horizon the random walk model seems to do relatively well. That might symbol the strong interest rate smoothing applied by the Bank of Israel during the sample, in which case a short-run no-change forecast will perform well. In terms of output growth the baseline model

²⁹ The estimation of the baseline model or the VARs is the same for both samples. Only the sample of the forecast errors is different.

performs worse than the VAR models, similar to the "steady state" model and better than the random walk.

It can be summarized that for pure forecasting purposes, statistical models might be more adequate, though they do not generate a coherent story as structural models do, demand additional identifying assumptions in order to conduct risk analysis, and are not fit for policy exercises.

C-7-2. Cross-correlations test

To test the dynamics of the model, in this section we present a test comparing the observed cross-correlations (across variables and time) of key model variables to those implied by the model. A significance test can be performed by constructing confidence intervals to the model's cross-correlations. The step-by-step description of the test is available in Argov et al. (2007a); we will mention that a similar procedure was originally taken in Smets and Wouters (2003).³⁰

In Figure C.8 we present a comparison of the observed cross-correlations in the sample period 1994:Q2-2007:Q4 (including the initialization period 1994Q:2-1995:Q1 and the out-of-sample year – 2007) to those produced by the baseline model. We present the test for the following variables: quarterly depreciation rate (DE), quarterly CPI inflation (DCPI), quarterly "core" inflation (DP) and nominal interest rate (IMA). The vertical axis of each diagram represents the correlation coefficient between the variable x_t and the variable z_{t-k} , that is, between two variables separated by k periods. The horizontal axis represents k . Thus, for example, the far-left diagram in the second row, titled $\rho(\text{DCPI}_t, \text{DE}_{t-k})$, presents the coefficients of cross-correlation between the rate of CPI inflation (DCPI) and each of the first five lags of the nominal depreciation (DE), as well as its contemporaneous rate. The continuous line is the observed correlation, whereas the broken lines are the model's correlations (5%, 50% and 95% confidence interval).

We can see that almost all correlations are within the confidence interval, meaning (in a somewhat over-stated manner) that we cannot reject the hypothesis that the true data were generated by our model. The outliers are the auto-correlation of the interest rate with its fifth lag and the cross-correlation of the depreciation rate with the fourth and fifth lag of the interest rate. The first outlier is an expression of the strong

³⁰ The author thanks Alon Binyamini for providing the Matlab programs used to compute and present the results.

interest rate smoothing observed in the data; we do not attribute any special meaning to the second.

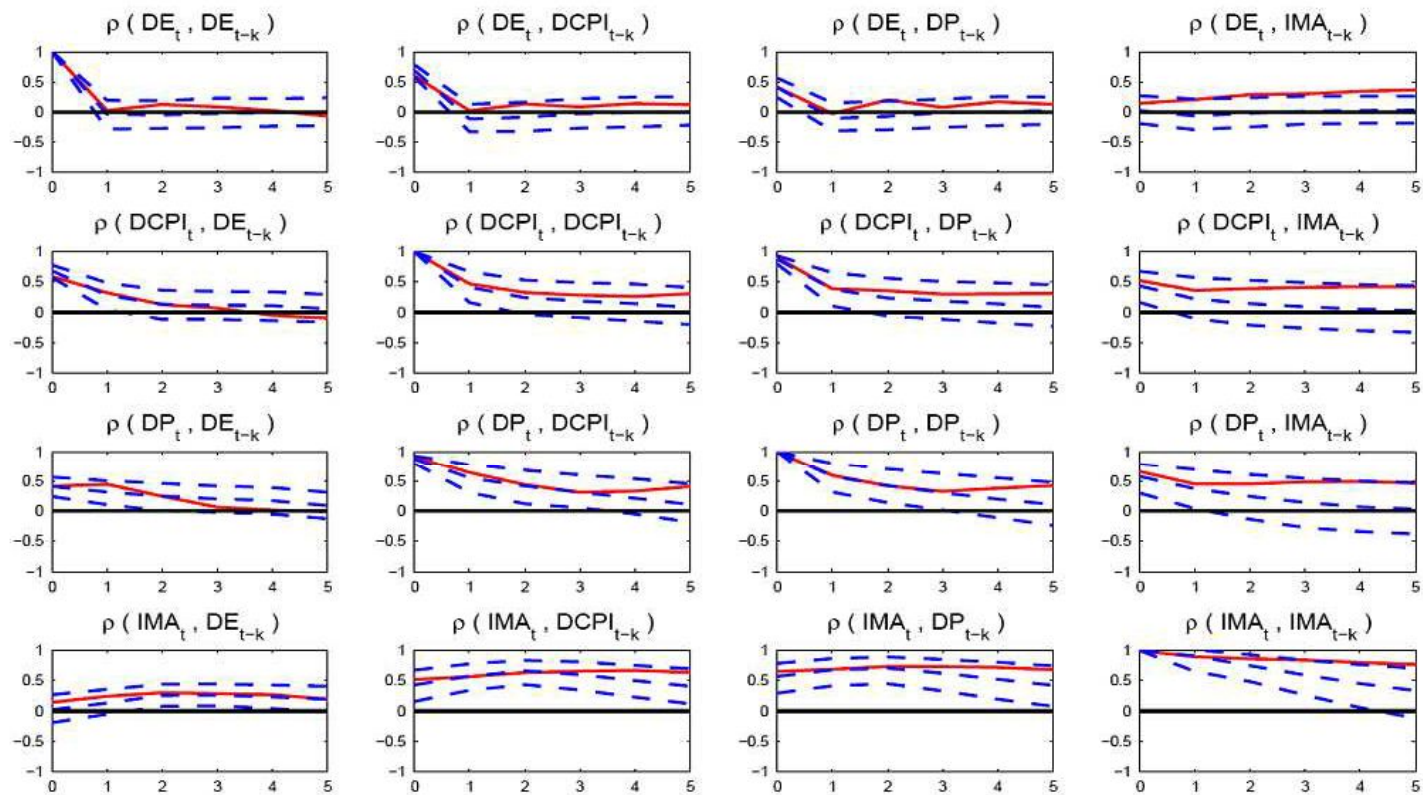
These results might be positively biased due to the disinflation process (in the model it is expressed by a nearly random walk of the inflation target). Therefore in Figure C.9 we will present the test for the sample following the stabilization of inflation (1999:Q1-2007:Q4). In that period there is no clear trend in inflation. The model was adjusted by assuming a constant inflation target. As expected, the results in this case are somewhat less definitive; however, most of the cross-correlations are still within the confidence interval. For the exchange rate (first row), we can see that the data, as well as the model, show lack of correlations with lagged variable. This result is not surprising given highly liquid and perfect market characteristics familiar in exchange-rates markets. In the second row for CPI inflation, we can see that the model captures the contemporaneous correlation with the exchange rate; however, it does not reproduce the strong observed cross-correlation with the first lag of the depreciation. From the third row we can learn that this is a result of the fact that the model does not explain the correlation of the lagged depreciation rate with "core" inflation. This might mean that the pass-through to import prices is somewhat slower than implied by the model. (Remember that the parameter of the speed of pass-through was not well identified in the data, and therefore was calibrated de-facto.)

In the last diagram of the second row we can see that the data show slight negative correlation between inflation and the contemporaneous interest rate; however, the model implies a positive correlation. This means that in the model the effect of inflation on the interest rate is stronger than the effect of the interest rate on prices. The data do not support this. In the last row of the figure we can see that the model captures most of the remaining correlations with the interest rate.

To conclude this section, it can be said that the model is able to reproduce most of the correlations observed in the data. When looking at the post-disinflation era, some work might be needed to calibrate the speed of pass-through.

Figure C.8: Observed Cross-Correlations vs. Model Confidence Interval, 1994:Q2-2007:Q4

— Observed - - - 5,50,95 percent confidence interval



DE – Quarterly depreciation (Δe)

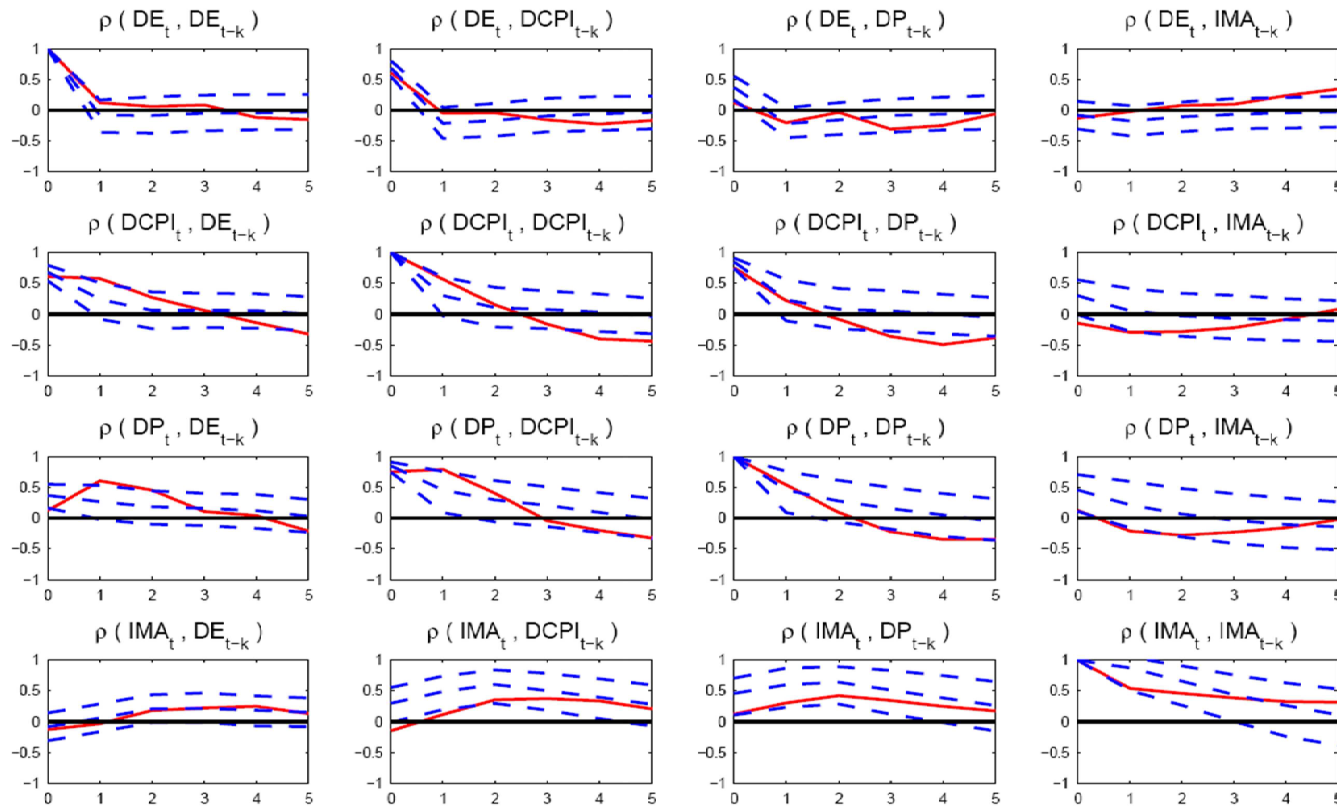
DCPI – Quarterly CPI inflation (π^{CPI})

DP – Quarterly “core” inflation (π^C)

IMA – Nominal interest rate (i)

Figure C.9: Observed Cross-Correlations vs. Model Confidence Interval, 1999:Q1-2007:Q4

— Observed - - - 5,50,95 percent confidence interval



DE – Quarterly depreciation (Δe)

DCPI – Quarterly CPI inflation (π^{CPI})

DP – Quarterly “core” inflation (π^C)

IMA – Nominal interest rate (i)

D. Alternative foreign price measures

A troubling fact that emerged from the historical decomposition (Section C-5-2) is that our baseline model attributes most of the high inflation in 2007 to domestic supply shocks, where it has been widely accepted that inflation rose in Israel, as well as world wide, due to high commodity prices (mainly raw food and energy prices) in the global markets. Why does the model misinterpret that year? One conjecture is an ill choice of the foreign price measure. Following Argov and Elkayam (2007), we used the unit value of imported consumer goods as the main foreign price measure. However its development in the last years did not reflect the rise in global commodity prices for it does not contain raw food and oil.³¹ Therefore the model interpreted the rise in inflation as domestic inflation shocks (categorized as supply shocks). In this part we will check whether the choice of this foreign price measure was wrong a priori, and try to determine which observable inflation measure best describes the *foreign* inflation in the model (π_t^*). We will test the following alternatives:

- (B) Baseline: Using the unit value of imported consumer goods.
- (1) Using the trade weighted foreign CPI inflation, translated to dollar terms.
- (2) Using the CPI inflation in the United states.
- (3) Using the world trade unit value.
- (4) Using the national accounts imports deflator in dollar terms.

To get a better sense of the results, we will also estimate the model with the following controlling assumptions:

- (5). Assuming the world inflation rate is constant. This will tell us whether using any of the price indices contribute to the explanation of the inflation process.
- (6) Reversing the roles of imported input prices and imported consumer prices. In this alternative we will test whether the separation of input and consumer prices is identifiable. We will reverse the baseline specification so that the change in the unit value of imported consumer goods (Δp_t^{*C-IM}) is the price of

³¹ Raw food and fuel are categorized by the Central Bureau of Statistics as production inputs. This price measure is used in the model within the local inflation Phillips Curve, but has a limited role.

inputs (π_t^{*z}), and that the weighted average of imported input prices ($\Delta p_t^{z*,nonoil}$) and oil price (Δp_t^{*oil}) is the general world price inflation (π_t^*).

For each alternative, we re-estimated the whole model. (Note that all estimations are based on the same set of observable variables, the only difference is which observable price measure is equal to world inflation – see equation 8.7). Table D.1 summarizes the estimated log marginal density of the various alternatives. This statistic is mainly a measure of the one-step-ahead forecasting properties of the model. A higher value (less negative) is attributed to better forecasting properties.³²

Table D.1: Log Marginal Density of Alternative Models

			Number of iterations and blocks (after 50% burn-out)	Log marginal density (modified harmonic mean)	Log marginal density (Laplace approximation)
(B)	Baseline	$\pi_t^* = \Delta p_t^{*C-IM}$	300,000 x 2	-2543.0	-2546.8
(1)	Trade-weighted CPI	$\pi_t^* = \Delta p_t^{*TW-CPI}$	300,000 x 2	-2543.3	-2547.0
(2)	CPI – US	$\pi_t^* = \Delta p_t^{*USI}$	--	--	-2556.9
(3)	World trade price	$\pi_t^* = \Delta p_t^{*w}$	--	--	-2553.6
(4)	Import deflator	$\pi_t^* = \Delta p_t^{*M}$			-2552.3
(5)	Constant inflation	$\pi_t^* = 2.0$	--	--	-2554.2
(6)	Reverse roles	$\pi_t^* = w^{p^{*z}} \Delta p_t^{z*,nonoil} + (1 - w^{p^{*z}}) p_t^{*oil}$ $\pi_t^{*z} = \Delta p_t^{*C-IM}$	--	--	-2550.6

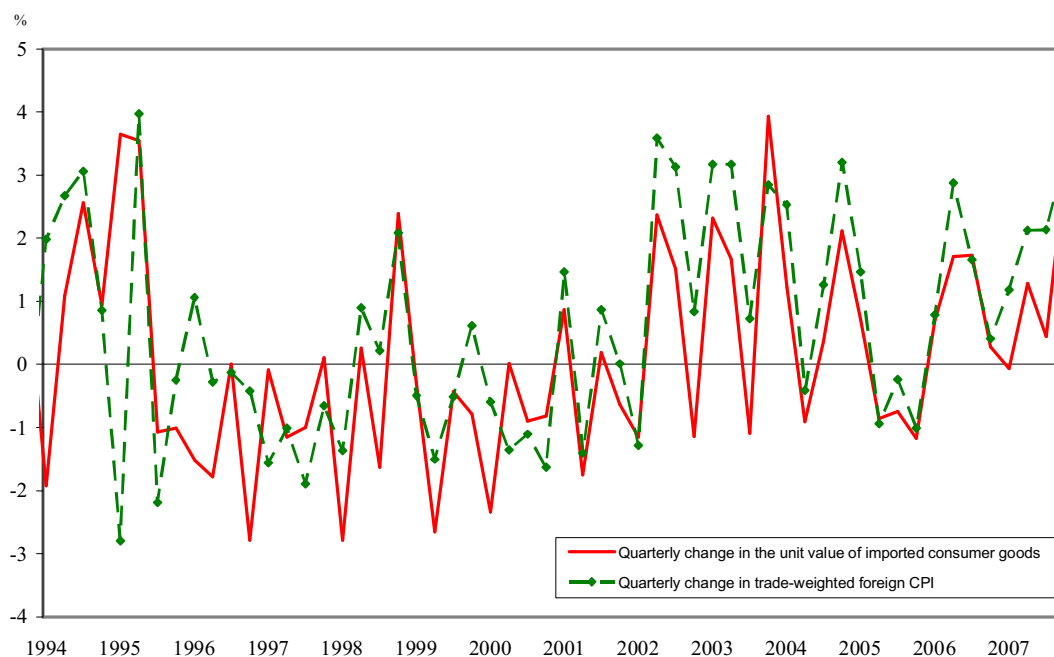
It turns out that our baseline specification in which we use the unit value of imported consumer goods delivers the best results, although this price includes only a subset of the imported consumer goods basket. Equal in rank is the trade weighted world CPI inflation (alternative 1). The estimation results using the trade weighted CPI are also similar to the baseline in terms of parameter values.³³ This stems from the fact that until 2006 the series behaved very similarly (see figure D.1). The

³² For the better performing models according to the Laplace approximation, we calculated the modified harmonic mean using the Metropolis Hasting algorithm.

³³ Appendix 2 reports the estimation results under alternative 1, including some of the main applications presented earlier for the baseline case. The main reported results hold under this alternative.

coefficient of correlation between the two inflation measures is 0.65. Therefore, on an econometric basis, it is not possible to determine some preference. However, comparing the forecasting results of the model for 2007, using the two world inflation series gives different results. Figure D.2 depicts the model's forecast of inflation for 2007 conditional on the realization of all shocks except those of the domestic inflation block ($\varepsilon_t^{Housing}, \varepsilon_t^{Fuel}, \varepsilon_t^{Veg}, \varepsilon_t^{\pi^h}, \varepsilon_t^{\pi^f}, \varepsilon_t^{LOP}$). That is, we include the realization of the foreign inflation shocks so as to see how the use of each foreign inflation measure changes the predictions of the model. We compare the forecast of the baseline model and alternative 1 model to the ex post realization.

**Figure D.1: World Price Inflation:
Unit Value of Imported Consumer goods vs. Trade-Weighted CPI**

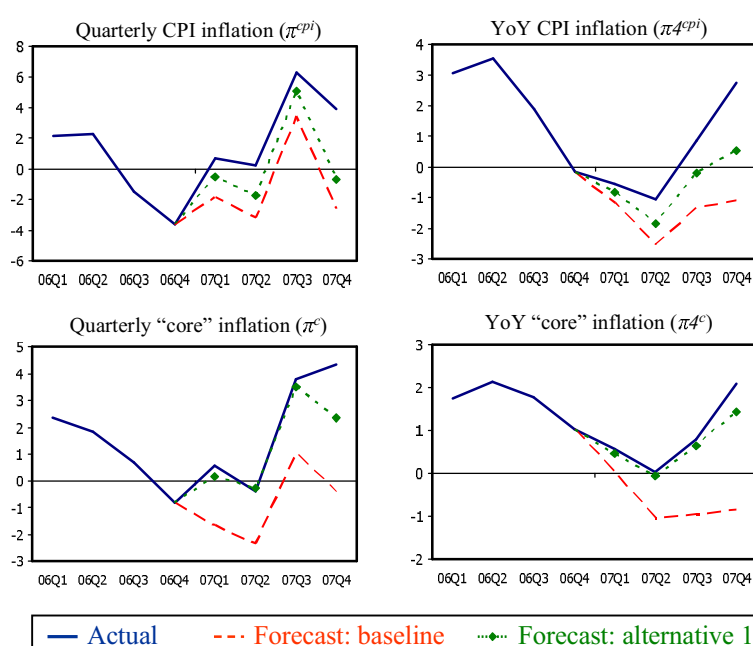


Comparing the forecast results of the models in Figure D.2 it is clear that using the CPI foreign trade-weighted inflation better explains Israel's 2007 inflation, especially "core" inflation which is most affected by foreign inflation. Contrary to the baseline model, using the trade-weighted CPI alternative would have predicted the rise in core inflation in the second half of 2007.³⁴ The different results we get for 2007 lie in the fact that the behavior of the foreign inflation measures were different: while

³⁴ It should be clarified that these forecasts are conditional on using some ex post smoothed shocks, so it does not mean the model could have predicted 2007 only on the basis of data known before 2007. The purpose of this exercise is to see which inflation measure fits better the outcomes of 2007.

the trade-weighted world CPI inflation was 9.0% in 2007, due to the weakness of the dollar and the rise in raw food and energy prices, the unit value of imported consumer goods rose by only 4.6%, which is mainly due to the first reason. The imported consumer goods unit value does not include energy and raw food, and therefore is not predictive of the 2007 rise of inflation in Israel.

Figure D.2: Dynamic Simulation of the Model for 2007 Conditional on the Realization of Shocks Excluding Local Inflation Shocks

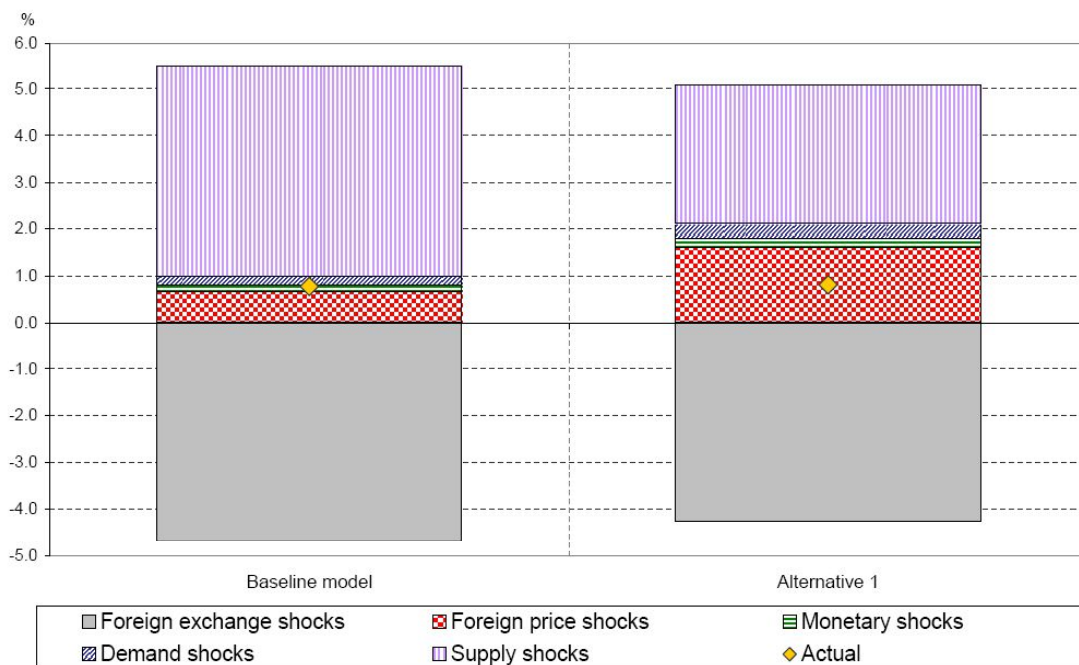


A different perspective on the 2007 issues can be seen by returning to the historical data decomposition presented in section C-5-2. We re-computed the historical decomposition based on alternative-1 model, that is, using trade-weighted foreign CPI inflation. Figure D.3 depicts the decomposition of 2007 inflation according to the baseline model and alternative 1. As mentioned before, counter to common perception, the baseline model attributes only a small contribution to foreign inflation shocks in the high 2007 inflation. However, the alternative model more than doubles the contribution of foreign price shocks from 0.7 to 1.6 percentage points. As a result, the local inflation shocks, classified as supply shocks, are smaller. For that reason the alternative model's conditional forecasting of 2007 inflation is superior (as was presented in figure D.2).

Can we conclude that the trade-weighted foreign CPI inflation is a better measure than our baseline unit value of imported consumer goods? No, it may very well be coincidental that its 2007 forecasting performance is better. In the future, the foreign CPI inflation might reflect developments not relevant to Israel. However it does possess a few more advantages. First, CPI indices are better measured in most countries than unit values. Second, the publication time-lag is shorter. Taking those into account may very well justify the future use of the trade-weight foreign CPI inflation as the main foreign price index.

Figure D.3: Decomposition of 2007 Inflation:

Unit Value of Imported Consumer Goods (Baseline) vs. Trade-Weighted CPI (Alternative 1)



Returning to Table D.1, it is apparent that using either the unit value of world trade or the US CPI inflation rate does no better than not using any inflation measure. Using the import price deflator does somewhat better than those two, but still worse than our baseline unit value or the alternative trade weighted CPI. In terms of parameters, all three estimations deliver somewhat smaller share of imports in consumption (25% compared to 32% in the baseline estimation), due to lower relevance of their foreign prices to the Israeli CPI. Table D.1 also confirms our separation between general foreign inflation and input prices. Reversing their roles, as was done in alternative 6, worsens the baseline's results.

E. Conclusions

The small approximate DSGE model outlined in Argov and Elkayam (2007) is regularly used for monetary analysis at the Bank of Israel. We have taken the model one step further by applying full-information Bayesian techniques to evaluate its parameters and likelihood. The estimation results seem fair – some, though not all, parameters are well identified from the data, particularly the share of imports in consumption (30%) and the interest rate's effect on the output gap. To some extent, the estimation confirms our prior on the output gap's effect on prices. Unfortunately, the data were not informative on the speed of pass-through from world prices or the exchange rate to import prices. Prior empirical evidence hints that it is relatively fast in Israel, but a comparison of the model's cross-correlation with the observed shows that it might be somewhat slower than estimated in the past. In general the cross-correlation analysis shows that most data moments are replicated by the model. However, the model's forecasting ability is weak compared with that of statistical models that do not impose structure (VARs). This calls for future research in order to improve forecasting ability while maintaining a structural model that enables consistent forecasting and monetary analysis.

The full-information Bayesian estimation inherits some advantages over the limited information GMM approach taken by Argov and Elkayam (2007). It enables more internally consistent analysis by deriving model consistent trends and unobservables via the Kalman filter. From that we have learned that by the end of 2007 the output gap in Israel was significantly positive, mainly due to demand shocks which were accommodated by real interest rates below potential. However, the historical decomposition shows that high inflation in that year (approximately one percentage point above mid-target) was not due to demand shocks. This is a result of the minor effect the output gap has on locally produced prices in Israel. The historical decomposition attributes the high inflation to negative supply shocks (direct inflation shocks). This could be interpreted as increases in desired mark-ups triggered by the positive output gap. However, it is more common to assess that local factors were not the main reason behind rising inflation, but the global boom in commodity prices. In

this paper we tried to tackle the presumption that an erroneous choice of a foreign price measure caused this misinterpretation. Our baseline price measure, the unit value of imported consumer goods, did not rise dramatically in 2007, as it does not contain direct energy products or raw food. Re-estimating the model with various other foreign price measures which are affected by the global rise in energy and food prices shows that no alternative clearly outperforms our baseline choice. On the contrary, during our sample period it seems energy prices have a minimal effect on consumer prices. Why did the economy react differently in 2007? We raise the possibility that only in 2006-07 was the positive trend of oil prices internalized in firms' decisions, whereas for a significant part of the sample oil prices were characterized by large fluctuations around some stable level. In such an environment there is no need to adjust domestic prices to a hike in the oil price, for it most presumably will drop back in the following quarters. As a result, the estimation delivers a minor effect of oil prices on inflation. Explaining this shift endogenously by some state-dependent pricing model could be an interesting research program.

One price measure is comparable in its performance to our baseline choice – the trade-weighted CPI inflation rate. In estimation, it delivers the same log-marginal likelihood because in the past it behaved similarly to our baseline unit value of imported consumer goods. However, it does possess some fundamental advantages: (1) It better explains 2007 inflation because foreign CPI rates rose for the same reason as in Israel; (2) CPI data are usually better measured than unit values, and therefore contain smaller measurement errors; (3) Finally its publication time-lag is shorter than foreign trade unit values or national accounts data. Due to all these, the adoption of the trade-weighted CPI as the model's main foreign price measure should be considered for regular use in concrete monetary policy analysis.

Appendix 1 – Description of the Data

For the estimation of the model, 24 data series were used, of which 16 were rates of change. In general, interest rates and quarterly rates of change of nominal variables (prices and exchange rates) were annualized. However, in the estimation procedure we adjusted all equations so the variables are expressed in the same terms (divide or multiply by 4), thus allowing the direct interpretation of the estimated parameters.

1-1. Quarterly rates of change

1-1-1. Nominal variables (annualized)

The percentage rate of change in nominal variable X , denoted by Δx (or π^x), is calculated as follows:

$$(A.1) \quad \Delta x = (\log(X) - \log(X_{-1})) * 100 * 4,$$

Multiplying by 100 transforms the rate of change into percent and multiplying by 4 annualizes it. Except for the exchange rate and the inflation target, price levels were seasonally adjusted by the multiplicative X-12 procedure. Data with higher than quarterly frequency were averaged prior to seasonal adjustment or percentage change transformation. Following is a description of the nominal change variables included in the model:

π_t^{Cpi} – inflation in headline consumer price index (CPI). Source: Central Bureau of Statistics (CBS).

$\pi_t^{Housing}$ – inflation in the CPI housing component. Source: CBS.

π_t^{Fuel} – inflation in the CPI fuel components (fuel and oil for cars, fuel for home heating). Source: CBS and Bank of Israel calculations.

π_t^C – inflation in the CPI excluding housing, fuel, fruit and vegetables components. Source: CBS and BoI calculations.

Δe_t – depreciation in the nominal NIS/dollar exchange rate. Source: BoI database.

Δp_t^{*C-IM} – percent change in the unit value (Fisher's price index) of imported consumer goods (in dollar terms). Source: BoI database.

$\Delta p_t^{z*,nonoil}$ – percent change in the unit value (Fisher's price index) of imported inputs.

Based on a weighted average of imported production inputs, excluding fuel and

diamonds, and investment goods (in dollar terms). Source: CBS and author's calculations.

$\Delta p_t^{*,oil}$ – percent change in the unit value (Fisher's price index) of imported fuels (in dollar terms). Source: CBS.

Δp_t^{*US} – percent change in United States headline CPI index (in dollar terms). Source: IFS database.

$\Delta p_t^{*TW-CPI}$ – percent change in a trade-weighted average of CPI indices in 34 of Israel's main trading partners, translated into dollar terms. Source: IFS database, and BOI and author's calculations.

Δp_t^{*M} – percent change in the National Account's import deflator, translated into dollar terms. Source: CBS.

Δp_t^{y*} – percent change in the price of world trade, based on the unit value of industrialized countries' imports. Source: IFS database.

π_t^T – the announced *year-ahead* inflation target (in terms of total CPI). Source: BoI database.

π_t^e – *one-year-ahead* break-even inflation expectations derived from the capital markets. The expectations are based on the difference between nominal and real yields to maturity on government bonds. Source: BoI database.

1-1-2. Real variables (non-annualized)

The percentage rate of change in real variable X, denoted by Δx , is calculated as follows:

$$(A.2) \quad \Delta x = (\log(X) - \log(X_{-1})) * 100,$$

Following is a description of the nominal change variables included in the model:

Δy_t – per capita business sector GDP growth (seasonally adjusted GDP at fixed prices divided by working-age population). Israel's official GDP data contain a break in 1995 due to definition changes. A continuous series was built by chaining the old definition series according to their percent changes. Source: CBS and author's calculations.

Δy_t^* - world trade growth, based on the industrialized countries' imports divided by their unit value. World trade was seasonally adjusted by the multiplicative X-12 procedure prior to percent change transformation. Source: IFS database and author's calculations.

1-2. HP filtered gaps

We denote the smoothing of (real, per capita, seasonally adjusted) series X using the HP filter as $HP(X)$. The HP filtered gap of series X denoted by \hat{x} is calculated as follows:

$$(A.3) \quad \hat{x} = [\log(X) - HP(\log(X))] * 100.$$

The term in square brackets is the deviation rate of X from its trend. Multiplying by 100 expresses the gap in percent. All series are seasonally adjusted by the multiplicative X-12 procedure and expressed in per capita terms prior to smoothing. Following is a description of the gaps included in the model:

\hat{g}_t^h – the public consumption gap which is based on the real purchases component of the public sector (G_t^h). Note this is supposed to be based on added value series which unfortunately do not exist. Therefore we approximate it by the whole component. Source: CBS and author's calculations.

\hat{inv}_t – the investment gap which is based on real gross investment (INV_t^h). Note this is supposed to be based on added value series which unfortunately do not exist. Therefore we approximate it by the whole component. Source: CBS and author's calculations.

1-3. Interest rates

The interest rates are annualized quarterly averages. i_t is the effective Bank of Israel interest rate and i_t^* is the one-month LIBID dollar interest rate. The yield to maturity on 5-year government CPI-linked bonds, denoted as r_t^{5year} , serves to help identify the natural real interest rate. The source of all interest rates: BoI calculations.

For the foreign exchange risk premium, ϕ_t , we use a quarterly average of the computation developed and presented in Hecht and Pompushko (2006). It nests on NIS/dollar options traded in the Tel-Aviv stock exchange. Source: BoI calculations.

1-4. Labor market data

u_t – the official seasonally adjusted unemployment rate. Source: CBS and author's calculations.

ulc_t – the unit labor cost, is calculated according to:

$$(A.4) \quad ulc_t = \frac{(3 * W_t) * L_t}{P^Y_t Y_t},$$

where:

W_t – average monthly wage per employee post in the business sector.

L_t – number of employee posts in the business sector.

$P^Y_t Y_t$ – nominal business sector GDP output.

Multiplying by 3 converts the monthly wage to quarterly wage. Seasonal adjustment by the multiplicative X-12 procedure was done after the ratio calculation given by (A.4). Source of all data: CBS and author's calculations.

Appendix 2 – Estimation results and applications using the trade weighted foreign CPI index

Table C.1.A: Parameter Sensitivity to Choice of Foreign Inflation Measure

Parameter		Prior Distribution			Posterior Mode	
		Type	Mean	Std	Baseline	Alternative 1
Import weight	w_f^c	beta	0.3	0.1	0.315	0.326
Local inflation equation						
Rational expectations	λ_1	beta	0.5	0.1	0.529	0.516
Output gap	λ_2	gamma	0.2	0.1	0.109	0.144
Real price of inputs	λ_3	gamma	0.05	0.025	0.036	0.026
Pass-through to imported inflation	λ_f	gamma	0.5	0.3	0.435	0.423
Current EX on housing	$\eta^{housing}$	beta	0.75	0.15	0.812	0.812
Persistence in housing price shock	$\delta_{Housing}$	beta	0.5	0.2	0.592	0.608
Oil effect on CPI fuel	χ_1	beta	0.25	0.1	0.306	0.306
Current oil on CPI Fuel	χ_2	beta	0.5	0.2	0.796	0.797
Output gap equation						
Rational expectations	b_{11}	beta	0.5	0.2	0.641	0.561
Homogeneity	b_{12}	beta	0.7	0.2	0.875	0.813
Real interest rate	b_2	gamma	0.5	0.2	0.275	0.255
Real exchange rate	b_3	gamma	0.2	0.1	0.099	0.083
LOP gap	b_4	gamma	0.3	0.1	0.169	0.188
World demand	b_5	gamma	0.3	0.1	0.262	0.266
Investment	b_6	gamma	0.16	0.05	0.092	0.089
Government	b_7	gamma	0.1	0.05	0.053	0.053
Persistence in Output gap shock	δ_{u^y}	beta	0.5	0.2	0.802	0.862
EX eq.: rational exp.	$\tilde{\omega}$	gamma	0.5	0.25	0.709	0.533
Monetary policy						
Interest rate smoothing	κ_i	beta	0.7	0.1	0.732	0.727
Reaction to inflation	κ_π	gamma	1.9	0.5	1.217	1.192
Reaction to output gap	κ_y	gamma	0.05	0.02	0.054	0.055
Growth persistence	δ_{gr}	beta	0.5	0.2	0.464	0.456
Potential world demand persistence	$\delta_{y^*,p}$	beta	0.5	0.2	0.604	0.604
Natural relative input price reaction to gap	δ_z	beta	0.3	0.2	0.059	0.041
Natural rate persistence	δ_r	beta	0.7	0.15	0.732	0.723
Natural unemployment persistence	δ_u	beta	0.8	0.1	0.932	0.930

Table C.1.A: Parameter Sensitivity to Choice of Foreign Inflation Measure (cont.)

Parameter		Prior Distribution			Posterior Mode	
		Type	Mean	Std	Baseline	Alternative 1
Unemployment gap persistence	α_1	beta	0.7	0.1	0.711	0.690
Output effect on unemployment	α_2	gamma	0.5	0.1	0.384	0.370
ULC persistence	ζ_1	beta	0.5	0.05	0.574	0.571
Output effect on ULC	ζ_2	gamma	0.2	0.05	0.178	0.162
Persistence in inf. exp.	ν	Unif (0,1)	0.5	0.289	0.557	0.592
5 year yield persistence	$\delta_{r,5}$	beta	0.6	0.15	0.462	0.462
Risk-premium persistence	δ_ϕ	beta	0.8	0.1	0.873	0.866
World demand gap - lag1	$\delta_{y^*,1}$	beta	0.75	0.1	0.799	0.794
World demand gap - lag2	$\delta_{y^*,2}$	beta	0.39	0.2	0.463	0.455
Non-fuel weight in imported input prices	W^{p*z}	beta	0.87	0.1	0.964	0.978
Shocks' std.						
Exchange rate	$\mathcal{E}_t^{\Delta e}$	inv. gamma	10.0	Inf.	11.36	11.40
Effective world CPI	$\mathcal{E}_t^{*TW_CPI}$	inv. gamma	10.0	Inf.	6.27	6.26
Fuel in CPI	\mathcal{E}_t^{Fuel}	inv. gamma	6.0	Inf.	10.38	10.38
Housing in CPI	$\mathcal{E}_t^{Housing}$	inv. gamma	3.5	Inf.	4.27	4.26
Fruits&vegetables in CPI	\mathcal{E}_t^{Veg}	inv. gamma	16.0	Inf.	16.93	16.93
Imported inflation	$\mathcal{E}_t^{\pi^f}$	inv. gamma	0.25	0.05	0.229	0.229
Local inflation	$\mathcal{E}_t^{\pi^h}$	inv. gamma	2.5	Inf.	2.64	2.598
Consumer goods' import price	$\mathcal{E}_t^{*C_IM}$	inv. gamma	7.0	Inf.	6.59	6.597
Oil import price	\mathcal{E}_t^{*oil}	inv. gamma	40.0	Inf.	38.71	38.69
Imported non-oil-input prices	$\mathcal{E}_t^{z^*,nonoil}$	inv. gamma	6.0	Inf.	5.22	5.197
Natural relative imported inputs price	$\mathcal{E}_t^{z^*,p}$	inv. gamma	0.25	Inf.	0.115	0.115
Im. deflator inflation	\mathcal{E}_t^{*M}	inv. gamma	5.8	Inf.	5.62	5.62
Inflation target	$\mathcal{E}_t^{\pi^T}$	inv. gamma	1.0	Inf.	0.668	0.668
US inflation	\mathcal{E}_t^{*US}	inv. gamma	1.3	Inf.	1.24	1.24
World trade prices	$\mathcal{E}_t^{py^*}$	inv. gamma	10.0	Inf.	7.37	7.36
Natural world trade	$\mathcal{E}_t^{y^*,p}$	inv. gamma	0.8	0.6	0.566	0.598
Market based inf. exp.	$\mathcal{E}_t^{\pi^m}$	inv. gamma	1.0	Inf.	0.726	0.749
FX risk premium	\mathcal{E}_t^ϕ	inv. gamma	0.6	Inf.	0.642	0.641

Table C.1.A: Parameter Sensitivity to Choice of Foreign Inflation Measure (cont.)

Parameter		Prior Distribution			Posterior Mode	
		Type	Mean	Std	Baseline	Alternative 1
Potential growth rate	\mathcal{E}_t^{gr}	inv. gamma	1.0	0.1	0.959	0.959
Dollar interest rate	\mathcal{E}_t^{i*}	inv. gamma	0.5	Inf.	0.300	0.300
Monetary policy	\mathcal{E}_t^i	inv. gamma	0.5	Inf.	0.719	0.722
LOP gap	\mathcal{E}_t^{LOP}	inv. gamma	0.5	0.1	0.464	0.459
Natural real interest rate	\mathcal{E}_t^r	inv. gamma	0.8	0.01	0.808	0.807
5-year yield	\mathcal{E}_t^{r5}	inv. gamma	0.2	Inf.	0.088	0.088
Government purchases	\mathcal{E}_t^g	inv. gamma	1.5	Inf.	1.944	1.94
Investment	\mathcal{E}_t^{inv}	inv. gamma	8.0	Inf.	5.825	5.83
Unit labor cost	\mathcal{E}_t^{ulc}	inv. gamma	0.8	Inf.	0.729	0.741
Natural unemployment rate	$\mathcal{E}_t^{u^p}$	inv. gamma	0.2	0.01	0.206	0.206
Unemployment gap	$\mathcal{E}_t^{\hat{u}}$	inv. gamma	0.5	Inf.	0.286	0.278
World trade gap	\mathcal{E}_t^{y*}	inv. gamma	1.0	Inf.	0.995	0.971
Output gap	\mathcal{E}_t^y	inv. gamma	0.5	Inf.	0.209	0.211
Potential output	$\mathcal{E}_t^{y^p}$	inv. gamma	1.0	0.01	1.01	1.01

Figure C.4.A: Historical Decomposition of Annual Inflation (Deviation from Target) Under Alternative 1, 1997-2007

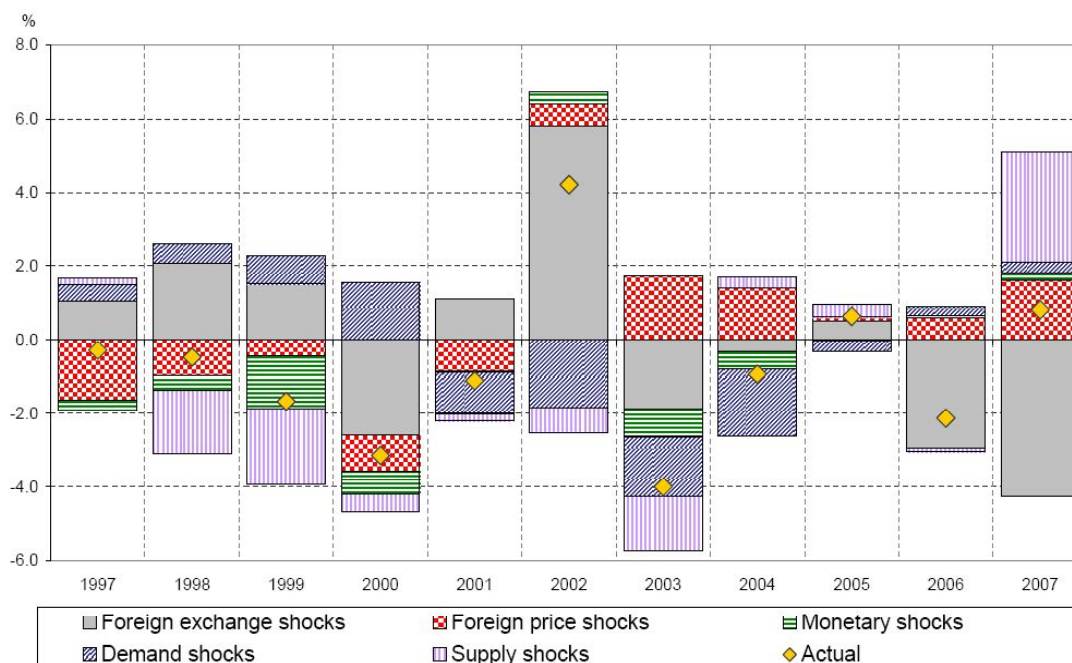


Table C.3.A: Comparison of RMSE:**Alternative 1 vs. Baseline Model, Alternative VARS and Naive Models**

Variable	Forecast Horizon	Sample	Alternative 1	Baseline model	VAR (1)	VAR (2)	RW model	SS model
Inflation (π_t^{Cpi})	1	95:Q2-06:Q4	3.94	3.92	3.06	2.80	4.73	3.97
		00:Q1-07:Q4	3.22	3.16	2.50	2.17	3.36	3.47
Inflation (π_t^{Cpi})	2	95:Q2-06:Q4	4.37	4.35	4.03	3.94	5.66	4.10
		00:Q1-07:Q4	3.68	3.65	2.94	2.87	4.36	3.49
YoY Inflation (π_t^{4Cpi})	4	95:Q2-06:Q4	2.90	2.89	2.46	2.32	4.68	2.55
		00:Q1-07:Q4	2.73	2.66	1.74	1.63	3.85	2.48
Interest rate (i_t)	1	95:Q2-06:Q4	1.50	1.50	1.62	1.67	1.19	1.77
		00:Q1-07:Q4	1.03	1.02	1.19	1.28	1.06	1.33
Interest rate (i_t)	2	95:Q2-06:Q4	1.73	1.74	1.76	1.77	1.88	1.90
		00:Q1-07:Q4	1.26	1.22	1.28	1.27	1.78	1.66
Interest rate (i_t)	4	95:Q2-06:Q4	2.28	2.26	2.15	2.17	2.60	2.17
		00:Q1-07:Q4	2.10	2.00	1.64	1.68	2.73	2.13
Output growth (Δy_t)	1	95:Q2-06:Q4	1.55	1.55	1.29	1.11	1.91	1.57
		00:Q1-07:Q4	1.33	1.37	1.13	1.21	1.43	1.54
Output growth (Δy_t)	2	95:Q2-06:Q4	1.54	1.56	1.41	1.21	1.74	1.57
		00:Q1-07:Q4	1.49	1.55	1.35	1.43	1.65	1.54
Output growth (Δy_t)	4	95:Q2-06:Q4	1.52	1.53	1.55	1.45	2.55	1.57
		00:Q1-07:Q4	1.40	1.43	1.31	1.24	2.26	1.54
Depreciation rate (Δe_t)	1	95:Q2-06:Q4	11.16	11.24	8.56	7.87	16.7	11.55
		00:Q1-07:Q4	11.94	12.11	9.81	9.67	16.09	12.14

Figure C.8.A: Observed Cross-Correlations vs. Model Confidence Interval Under Alternative 1, 1994:Q2-2007:Q4

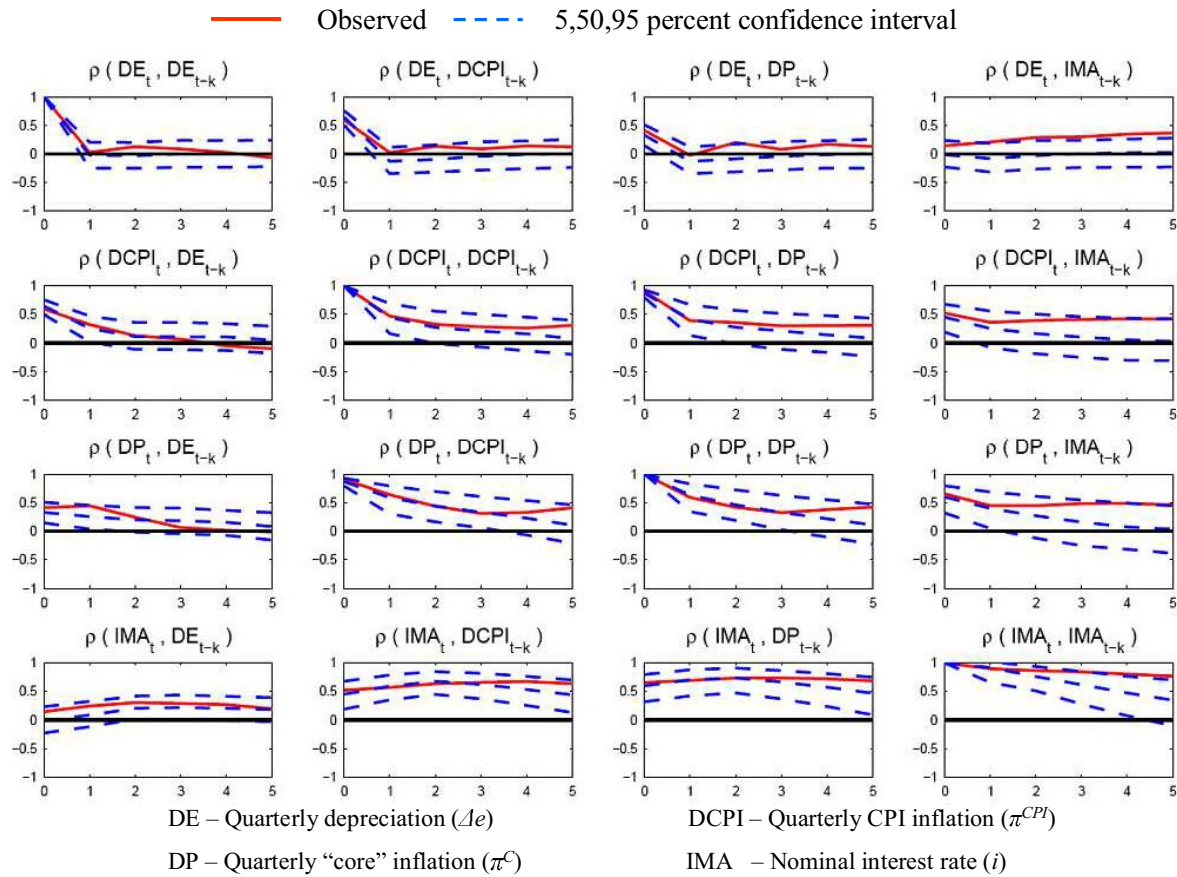
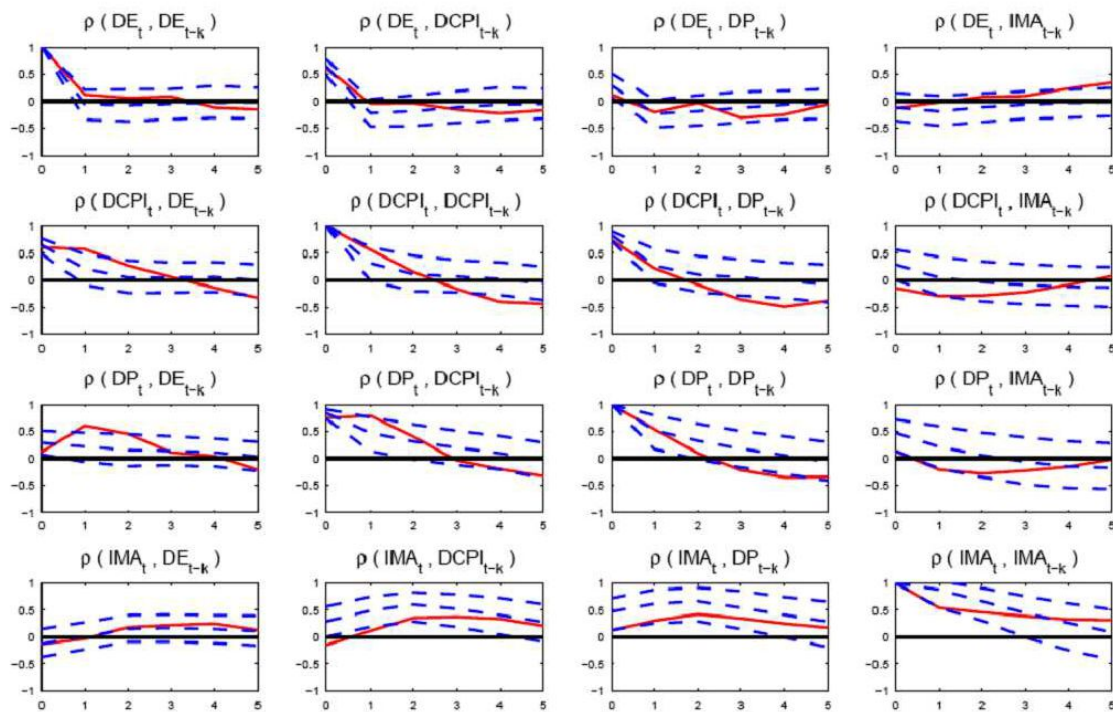


Figure C.9.A: Observed Cross-Correlations vs. Model Confidence Interval Under Alternative 1, 1999:Q1-2007:Q4

— Observed - - - 5,50,95 percent confidence interval



DE – Quarterly depreciation (Δe)

DCPI – Quarterly CPI inflation (π^{CPI})

DP – Quarterly “core” inflation (π^C)

IMA – Nominal interest rate (i)

References

- Adolfson, M. (2001). *Monetary policy with incomplete exchange rate pass-through*, Sveriges Riksbank Working Paper No. 127.
- Adolfson, M. (2007). "Incomplete Exchange Pass-Through and Simple Monetary Policy Rules," *Journal of International Money and Finance* 26, pp. 468-494.
- Adolfson, M., S. Laseen, J. Linde and M. Villani (2005). *Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through*, Sveriges Riksbank Working Paper No. 179.
- Argov, E., A. Binyamini, D. Elkayam and I. Rozenshtrom (2007a). *A small macroeconomic model to support inflation targeting in Israel*, Bank of Israel, Monetary Department.
- Argov, E. and D. Elkayam (2007) *An estimated New-Keynesian Model for Israel*, 2007.08, Discussion Paper Series, Monetary Department, Bank of Israel.
- Argov, E., N. Epstien, P. Karam, D. Laxton and D. Rose (2007b). *Endogenous monetary policy in a small macro model of Israel*, IMF working paper 07/207.
- Bank of Israel (2007). *Bank of Israel Annual Report – 2007, Chapter 3*.
- Barnea, A. and J. Djivre (2004). *Changes in Monetary and Exchange Rate Policies and the Transmission Mechanism in Israel, 1989.IV – 2002.I*, 2004.13, Discussion Paper Series, Research Department, Bank of Israel.
- Binyamini, A. (2007). "Small Open Economy New Keynesian Phillips Curve: Derivation and Application to Israel," *Israel Economic Review* Vol. 5, No. 1, pp. 67-92.
- Brooks, S. and A. Gelman (1998). "General Methods for Monitoring Convergence of Iterative Simulations," *Journal of Computational and Graphical Statistics*, volume 7, number 4, pp. 434-455.
- Brubakk, L., T. A. Husebo, J. Maih, K. Olsen and M. Ostnor (2006). *Finding NEMO: Documentation of the Norwegian Economy Model*. Norges Bank Staff Memo 2006/6.
- Calvo, G.A. (1983). "Staggered pricing in a utility-maximizing framework," *Journal of Monetary Economics* 12, pp. 383-398.
- Christiano, J., M. Eichenbaum and C. Evans (2005). "Nominal rigidities and the dynamic effects of a shock to monetary policy," *Journal of Political Economy* 113 (1), pp. 1-45.
- Christoffel, K., G. Coenen and A. Warne (2008). *The New Area-Wide Model of the Euro Area – A Micro-Founded Open-Economy Model for Forecasting and Policy analysis*, ECB working paper No. 994, October.
- Elkayam, D. (2001). *A Model for Monetary Policy Under inflation Targeting: The Case of Israel*, 2001.03, Discussion Paper Series, Monetary Department, Bank of Israel.

- Erceg, C., D. Henderson and A. Levin (2000). "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics* 46, pp. 281-313.
- Elkayam, D. (2003). *The long road from adjustable peg to flexible exchange rate regimes: the case of Israel*, 2003.04, Discussion Paper Series, Monetary Department, Bank of Israel.
- Gali, J. (2003) "New Perspectives on Monetary Policy, Inflation, and the Business Cycle," in *Advances in Economic Theory*, M. Dewatripont, L. Hansen, and S. Turnovsky ed. vol. III, pp. 151-197, Cambridge University Press.
- Hecht, Y. and H. Pompushko (2006). *RND*, 2006.01, Discussion Paper Series, Monetary Department, Bank of Israel. (Hebrew).
- Linde, J., M. Nessen and U. Söderström (2004). *Monetary policy in an estimated open-economy model with imperfect pass-through*, Sveriges Riksbank Working Paper No. 167.
- Meese, R. A. and K. Rogoff (1983) "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?" *Journal of International Economics* 14, pp. 3-24.
- Monacelli, T. (2005). "Monetary policy in a low pass-through environment," *Journal of Money, Credit and Banking* 37 (6), 1047-1066.
- Murchison, S. and A. Rennison (2006). *ToTEM: The Bank of Canada's New Quarterly Projection Model*. Bank of Canada Technical Report No. 97. Ottawa: Bank of Canada
- Prachowny, M. (1993), "Okun's Law: Theoretical Foundations and Revised Estimates," *The Review of Economics and Statistics*, Vol. 75, No. 2, pp. 331-336.
- Rotemberg, J. (1982). "Monopolistic price adjustment and aggregate output," *Review of Economic Studies* 49 (4), pp. 517-531.
- Rotemberg, J. and M. Woodford (1998). *An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy: Expanded Version*, NBER Technical Working Paper 233.
- Segal, G. (2007). *An Optimal Discretionary Policy Rule Under Rational Expectations Applied to Israel*, 2007.05, Discussion Paper Series, Monetary Department, Bank of Israel. (Hebrew).
- Smets, F. and R. Wouters (2003). "An estimated stochastic dynamic general equilibrium model of the euro area," *Journal of the European Economic Association* 1 (5), pp. 1123-1175.
- Svensson, L.E.O. (2000). "Open-economy inflation targeting," *Journal of International Economics* 50, pp. 155-183.