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A New Phillips Curve for Israel*

by

Sigal Ribon**

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** Bank of Israel, Research Department. e-mail: sigalr@bankisrael.gov.il. http://www.boi.gov.il.

מחלקת המחקר, בנק ישראל ת״ד 780, ירושלים 91007
Research Department, Bank of Israel, POB 780, Jerusalem 91007, Israel

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Abstract

The paper offers an alternative description of a Phillips curve for the Israeli economy in the last decade. We use a structural model, based on the micro-founded "New Keynesian" relationship between marginal costs and inflation along the lines of the approach presented in Gali and Gertler (1999) and Sbordone (2001) and following the extension for an open economy by Balakrishnan and Lopez-Salido (2002).

The estimation results show that the frequency of price adjustments in Israel was relatively high—updating prices every 2 to 3 quarters on average, but in the magnitude of the results for other countries. We also found that the share of price adjustments which is based on backward looking considerations is, on the background of Israel's inflationary history, low - only about 0.2 to 0.5 of price updates.

1 Introduction

The relationship between inflation and real economic activity has been long and extensively researched. This relationship is commonly labeled and referred to as the Phillips Curve, owing its name to A. W. Phillips who in 1958 published a paper examining the relationship between unemployment and nominal wages in the United Kingdom. Since then theoretical developments and empirical difficulties stimulated modifications and adjustments to the basic idea, leading to the inclusion of expectations in the reaction function of wages and prices to changes in activity. A brief summary of the

*Bank of Israel, Research Department. e-mail: sigalr@bankisrael.gov.il. A first version of this paper was written while the author was a visiting fellow at Princeton University, which she thanks for their kind hospitality. The author also thanks Zvi Hercowitz and the participants of the Bank of Israel Research Department seminar for their useful comments and suggestions.

conceptual developments in the perception of the Phillips curve appears in Romer (1996).

For the Israeli economy, the relationship between the inflationary process and real activity, whether it is measured by output, the output gap or unemployment has been studied by several researchers, with or without explicit reference to monetary policy, and sometimes in the framework of a wider model. Estimation of a Phillips curve for the Israeli economy has been carried out by Sussman (1990) for the period 1960-87, and more recently by Yotav-Solberg (1997) who estimated a NAIRU relationship, and by Lavi and Sussman (1999). Lavi and Sussman (1999) concentrate on the short-run relationship between inflation and unemployment and find that supply factors are important in explaining the changes in this relationship in the last 3 decades. Their empirical specification is not drawn explicitly from a micro-founded model, as is also the case for the other empirical investigations mentioned above. Some examples of the examination of this relationship in the Israeli economy within a broader framework are Beenstock et al. (1994), Azoulai and Elkayam (1999) and Djivre and Ribon (2000).

This paper attempts to follow the footsteps of the recent Phillips curve literature in which micro-founded behavioral models for the economic agents in the economy - usually firms and households - are incorporated in order to derive from them the relationship between price dynamics and other variables indicating supply side conditions. This is usually done in a monopolistic competition price setting environment and with constraints on the firms' ability to update their prices, which means prices are not fully flexible. This approach is usually referred to as the"New Keynsian Phillips Curve" (NKPC) and it is part of what is related to as a synthesis between the Keynesian approach in which the demand side has a central role in an environment of sticky adjustment of wages and prices, and the Real Business Cycle models in which prices are fully flexible and supply side factors are central to changes in the real activity[1]. Goodfriend and King (1997) call it the "New Neoclassical Synthesis" (see also Gali, 2000).

The main features of the basic NKPC are the micro-founded framework that assumes sticky prices, the inclusion of marginal costs instead of measures of real activity (output gap or unemployment) and a forward-looking component of inflation expectations. The literature in recent years deals mainly with the empirical validity of these assumptions. The central issue

[1] Clarida, Gali and Gertler (1999) base their extensive discussion of monetary policy on the "New Keynesian" framework - assuming nominal rigidities that evolve explicitly from the optimization process of households and firms.

is to what extent forward- or backward looking price setting characterizes the inflation process. Other strands of this research branch investigate alternative production functions (to the basic Cobb-Douglas assumed in the original formulation), analyze econometric issues related to the estimation of the NKPC and explore the role of open-economy elements in the specification of the inflation equation.

The theoretical framework presented in this paper is based on previous work by Gali and Gertler(1999), Gali, Gertler and Lopez-Salido (2000) and Sbordone (2001), among others. The basic models are modified following the approach presented in Balakrishnan and Lopez-Salido (2002) in order to incorporate open economy elements in the model.

The main contribution of this paper is the formulation and estimation of a "new" Phillips curve for the Israeli economy, which is based on microeconomic foundations and therefore allows to attribute an economic interpretation to the estimated parameters.

The paper is organized as follows: the next section describes the theoretical framework of the basic and extended models, the third section includes the empirical evidence and the fourth concludes.

2 The Theoretical Framework

2.1 The Basic Model

We derive a Phillips curve relationship between the inflation rate and an indicator for real activity, based on the optimization process of firms and households in a monopolistic competition environment with sticky prices. Doing this, we follow the recent line of literature interested in formulating and estimating the "New (Keynesian) Phillips Curve", including Roberts (1995), Gali and Gertler(1999), Gali, Gertler and Lopez-Salido (2000) and Christiano, Eichenbaum and Evans (2000), Sbordone (2001), and others.

Our model assumes monopolistic competition between firms that produce differentiated goods. The demand for the differentiated goods, indexed i, at time t is in the Dixit-Stiglitz (1977) form:

$$Y_{it} = (P_{it}/P_t)^{-\theta} Y_t \tag{1}$$

P_{it} is the price of good Y_i at time t. Y is the aggregate good and P is the price index which minimizes the expenditure on one unit of aggregate consumption good. They are defined by:

$$Y_t = \left[\int_0^1 \left(Y_{it}^{\frac{\theta-1}{\theta}} di \right) \right]^{\frac{\theta}{\theta-1}} \quad ; \quad P_t = \left[\int_0^1 \left(P_{it}^{1-\theta} di \right) \right]^{\frac{1}{1-\theta}} \tag{2}$$

We assume a staggered price model along the lines of the Calvo (1983). Firms may adjust their prices only upon receiving a random signal. This signal is received by each firm with probability $(1-\delta)$ and its distribution is identical and independent among the firms. It is also independent of the firm's history of price adjustment. Assuming the number of firms is large enough, a fraction $(1-\delta)$ of the firms is expected to adjust its prices each period. The expected time interval between price adjustments of a firm is $1/(1-\delta)$. The Calvo model assumes that the frequency of price changes is fixed and given exogenously and therefore does not depend on the state of the economy, and in particular on the business cycle or the rate of inflation. It differs from the class of models in which price adjustments are state-dependent (see Caplin and Leahy, 1991 and Dotsey, King and Wolman, 1999). However, this kind of random price adjustments is consistent with empirical findings, as they are summarized in Taylor (1998), that price adjustments are heterogenous among products and industries and are not synchronized among price setters. Lach and Tsiddon (1996) find for Israel in the years 1978-1984 that price changes are not synchronized across price setters.[2]

A firm that is able to change its prices at time t will choose P_{it}^m in order to maximize its profits, discounted by the probability that it will not be able to revise its prices in the next periods and by the discount factor β. The firm's problem is to maximize:

$$profits_i = \sum_{j=0}^{\infty} (\beta\delta)^j E \left[P_{it}^m Y_{it+j} - Costs(Y_{it+j}) \right] \tag{3}$$

Assuming that the prices of the inputs are given, and using the demand function in equation (1), the first order conditions are:

$$\sum_{j=0}^{\infty} (\beta\delta)^j E \left[P_{it}^m - \frac{\theta}{1-\theta} mc_{it+j} P_{t+j} \right] = 0 \tag{4}$$

[2]Lach and Tsiddon (1992) find price setting is staggered, but do not distinguish between changes in product prices within a store or across stores. Lach and Tsiddon (1996) make this distinction and find that staggering occurs between stores and not between products within a store.

with mc_t being the *real* marginal cost at time t.

Dividing by P_t we get:

$$\sum_{j=0}^{\infty}(\beta\delta)^j E\left[p_{it}^m - \frac{\theta}{1-\theta} mc_{it+j}\prod_{k=1}^{j}\pi_k\right] = 0 \tag{5}$$

where $p_{it}^m = P_{it}^m/P_t$ and π is the gross inflation rate of the aggregate price index. In the steady state (denoted by $*$), $p_{it}^* = 1$ and the real marginal cost is the inverse of the (constant) mark-up, $mc_i^* = \frac{\theta-1}{\theta}$.[3] In addition, we assume the steady state gross inflation rate is $\pi^* = 1$. Because all firms are identical we may suppress the subscript i. Log-linearizing the above equation around the steady state we get:

$$\widehat{p}_t^m = (1-\beta\delta)\sum_{j=0}^{\infty}(\beta\delta)^j E\left[\widehat{mc}_{t+j} + \sum_{k=1}^{j}\widehat{\pi}_k\right] \tag{6}$$

with $\widehat{\ }$ denoting the deviation from the log-linearized steady state. The optimal price a firm will choose to set is a function of the expected path of both real marginal costs and inflation, i.e. expected nominal marginal costs.

According to the definition of the aggregate price index in (2) we can write P_t as a weighted sum of prices which were adjusted and prices that remained unchanged, $P_t = \left[(1-\delta)(P_t^m)^{1-\theta} + \delta(P_{t-1})^{1-\theta}\right]^{\frac{1}{1-\theta}}$. Dividing by P_t and log-linearizing around the steady state defined above we get:

$$\widehat{\pi}_t = \frac{1-\delta}{\delta}\widehat{p}_t^m \tag{7}$$

Substituting (7) into (6) and calculating the difference $\widehat{\pi}_t - \beta\delta\widehat{\pi}_{t+1}$ we get:

$$\widehat{\pi}_t = (1-\beta\delta)\frac{(1-\delta)}{\delta}\widehat{mc}_t + \beta\gamma E\widehat{\pi}_{t+1} \tag{8}$$

This expression, derived from the optimization problem of the firms, given the market structure, relates the current rate of inflation to the marginal cost and to the expected rate of inflation for the next period (all in terms of the deviation from steady state). According to equation (8), when the labor market is frictionless current inflation depends only on forward-looking expectations. Inertia in the inflationary process may only result from stickiness

[3] According to the monopolistic competition setup specified in equation (1), the first order condition for P_{it} in order to maximize profits when prices may be updated every period is $(1-\theta) - \theta\frac{MC}{P_{it}} = 0$ or $\frac{MC}{P_{it}} = mc_i = \frac{\theta-1}{\theta}$

in the labor market, but does not evolve directly from the price updating mechanism. Solving equation (8) forward results in

$$\widehat{\pi}_t = (1-\beta\delta)\frac{(1-\delta)}{\delta}\sum_{k=1}^{\infty}\beta^k \widehat{mc}_{t+k} \tag{9}$$

implying that current inflation is a function only of current and future marginal costs and does not depend at all on past inflation.[4]

2.2 Backward Looking Price Setting

One of the basic features of the NKPC in its original formulation is that the evolution of inflation does not depend directly on past inflation. This is a result of the assumption that all the producers, who are able to change their prices (after receiving a random signal) follow an optimization procedure when they update prices. But the implications of this model - that current inflation depends only on expected inflation - do not necessarily agree with the empirical evidence on inflation dynamics and on the costs of disinflation.

In order to resolve part of this inconsistency we allow some of the producers to act according to a simple rule - changing their prices, when possible, by updating the existing price level by the known, one-period lagged, inflation rate. This is similar to the specification in Gali and Gertler (1999) and many others who followed their suggestion for an ad hoc amendment of the basic model. This assumption of pricing by rule of thumb may be reasonable if some of the producers are too small to incur the costs associated with the optimization process. Let us assume that only a fraction $(1-b)$ of the firms sets its prices optimally according to equation (6) and the remainder, a fraction b, sets prices by using the rule:

$$P_t^b = P_{t-1}^m + \pi_{t-1} \tag{10}$$

Backward looking firms see the prices that are updated in the previous period (they do not distinguish between backward- and forward-looking

[4] A refinement of the expression in (8), taking into account the difference between the marginal costs of a *single* firm and the *average* marginal costs in the economy, using the transformation of marginal costs $\widehat{mc}_t^{avg} = \widehat{mc}_t + h(\widehat{p}^m - \sum_{k=1}^{j}\widehat{\pi}_{t+k})$ (See Gagnon and Kahn (2001) for the calculation details.) results in the expression: $\widehat{\pi}_t = (1-\beta\delta)\frac{(1-\delta)}{\delta}\frac{1}{1+h}\widehat{mc}_t^{avg} + \beta E\widehat{\pi}_{t+1}$ with $\widehat{mc}_t^{avg}$ the (deviation from steady state of the) average marginal costs and the adjustment term $\frac{1}{1+h}$ which depends on the production function assumed. See Sbordone (2001) for the calculations for a Cobb-Douglas production function and Gagnon and Kahn (2001) for the derivation of the average marginal costs for alternative production functions, among them the CES function which will be presented later in the paper.

firms), and correct them according to the rate of inflation, as it is proxied by past inflation. (See also Gali and Gertler, 1999 and Gali, Gertler and Lopez-Salido, 2001). The average price level at time t is now:

$$P_t = \left[(1-\delta)\left((1-b)(P_t^m)^{1-\theta} + b(P_{t-1}^m + \pi_{t-1})^{1-\theta}\right) + \delta(P_{t-1})^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{11}$$

Proceeding in a similar fashion as before, using the definitions above we get:[5]

$$\widehat{\pi}_t = \frac{(1-b)(1-\delta)(1-\beta\delta)}{\Psi}\widehat{mc}_t + \frac{\beta\delta}{\Psi}E\widehat{\pi}_{t+1} + \frac{b}{\Psi}\widehat{\pi}_{t-1} \tag{12}$$

with $\Psi = \delta + b(1-\delta+\beta\delta)$.

Current inflation (or its deviation from the steady state) depends not only on expectations concerning future inflation, but also on past inflation. Therefore there is some inertia in the inflationary process, and even if expectations are altered substantially, following a credible disinflationary process, actual inflation will react only gradually. The speed of adjustment to the new inflationary environment will be faster as $(1-b)$ - the fraction of forward-looking firms is larger. This variation on the optimal price setting process does not emerge directly from some other optimization process, tastes or costs. Its main benefits are empirical, allowing us to test for a backward looking component in the inflationary process, which we tend to believe exists empirically.

Most of the papers that test the empirical validity of the NKPC include a backward looking component in the specification, and all find that there is some weight to backward looking considerations in the inflation process. Rudd and Whelan (2001) disagree with such results and claim that the findings of Gali and Gertler (1999) suffer from significant econometric problems and therefore their conclusion that backward looking price adjustments are important is erroneous. Gali, Gertler and Lopez-salido (2003) respond to the accusations and show that their estimates are robust and indicate an essential role for the backward component. Amato and Gerlach (2000) show that forward-looking models do fit the data relatively well, but most of the research shows that the coefficient of lagged inflation is significantly greater than zero, usually between 0.3 and 0.5.[6]

[5] See the Appendix (p. 26) in Jondeau and Le Bihan (2001) for a detailed description of the calculations.

[6] For example, Gali and Gertler (1999) get a coefficient of about 0.2, Gali, Gerler and

2.3 The NKPC in an Open Economy

In the analysis in previous sections no assumptions were made about the degree of openness of the economy. The specification of the Phillips curve was composed of two main components: inflation (expected and past) and marginal costs. The explicit specification of marginal costs (MC) will depend on the assumptions concerning the production function. If it is assumed that the elasticity of output with respect to labor is constant, then the labor share in the output is constant, but once we depart from this assumption, for example assuming a CES production function, the share of labor will depend on its price relative to other inputs. In particular, in an open economy, such as Israel's, labor share will depend on labor's price relative to the price of imported intermediate goods, and marginal costs will be a function of these prices. A small number of studies refer to this issue and expand the specification of the NKPC: Gali and Lopez-Salido (2001) incorporated imported input prices in a New Phillips Curve for Spain and calculated alternative measures of marginal costs assuming different production functions. Following them Balakrishnan and Lopez-Salido (2002) employed basically the same methods for the UK and showed that the incorporation of open-market factors in the Phillips curve improves its fit to UK data. Leith and Malley (2002) estimated the NKPC for the G7, but found that generally the open economy factors do not significantly change the results for most countries studied, including the US, which is usually referred to as a closed economy. Genberg and Pauwels (2003) show for Hong-Kong that empirical results are consistent with the theory only when open economy components are included in the model.

Following Gali and Lopez-Salido (2001) and Balakrishnan and Lopez-Salido (2002) we incorporate imported input prices in the NKPC assuming a CES production function:

$$Y = \left(\alpha_n (ZN)^{1-\frac{1}{\sigma}} + \alpha_m (M)^{1-\frac{1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{13}$$

where N is labor input and M stands for (imported) intermediate goods. σ is the elasticity of substitution. Because the production function includes intermediate goods, Y should represent *gross output* instead of *GDP* in the

Lopez-Salido (2000) have 0.27 to 0.36, and in their updated paper in 2003 - 0.4 to 0.6. McAdam and Williams (2003) show for Europe a coefficient of 0.3 to 0.5. The same magnitude of coefficient is obtained by Jondeau and LeBihan (2001) for Europe and the US.

customary specification.[7]. This is also consistent with the specification of the demand for products in equation (1), that includes in an open economy, an imported component.[8]

From cost minimization we get that the relative proportion of inputs is a function of their relative prices:

$$\frac{N}{M} = \left(\frac{\alpha_n}{\alpha_m}\frac{P_{im}}{W}\right)^{\sigma} \tag{14}$$

P_{im} is the price of imported goods and W is the nominal wage rate. Real marginal costs may be written as

$$MC = \frac{W}{MPN} = \frac{\frac{WN}{Y}}{\frac{\partial Y}{\partial N}\frac{N}{Y}} = \frac{s}{\eta_{N,Y}} = \frac{s}{1-\alpha_m\left(\frac{Y}{M}\right)^{\frac{1-\sigma}{\sigma}}} \tag{15}$$

with s standing for the labor share in output.

Substituting (14) in (15), log-linearizing around steady state and recalling that $\eta_{N,Y} = \frac{s}{MC}$ with $\frac{1}{MC} = \frac{\theta}{\theta-1} = \mu$, we get:

$$\widehat{mc} = \widehat{s} + \frac{1-\mu s}{\mu s}(\sigma-1)(\widehat{p_{im}-w}) \tag{16}$$

In the special case when $\eta_{N,Y}$ is constant, this expression collapses to $\widehat{mc} = \widehat{s}$, which is the customary specification in many studies. Substituting $\widehat{mc}$ with the expression in equation 16, equation (8) becomes:

$$\widehat{\pi}_t = (1-\beta\delta)\frac{(1-\delta)}{\delta}\left(\widehat{s} + \frac{1-\mu s}{\mu s}(\sigma-1)(\widehat{p_m-w})\right) + \beta E\widehat{\pi}_{t+1} \tag{17}$$

In the hybrid model, with backward-looking price setting we get:

$$\widehat{\pi}_t = \frac{(1-b)(1-\delta)(1-\beta\delta)}{\Psi}\left(\widehat{s} + \frac{1-\mu s}{\mu s}(\sigma-1)(\widehat{p_m-w})\right) + \frac{\beta\delta}{\Psi}E\widehat{\pi}_{t+1} + \frac{b}{\Psi}\widehat{\pi}_{t-1} \tag{18}$$

$\Psi = \delta + b(1-\delta+\beta\delta)$

[7]Gali and Lopez-Salido (2001) and Balakrishnan and Lopez-Salido (2002) do not address this issue.

[8]We assume imports of only intermediate goods. We refer only to domestically consumed goods and exclude exported goods because we assume exports' prices are determined in the markets abroad.

As is expected and may also be seen in equation (18), a larger share of firms that is unable to update there prices each period (a larger value for δ) will result in a higher weight for expected inflation, while a larger share of firms that tend to update their prices using a backward looking rule of thumb (a larger b) will result in more weight for past inflation in the inflationary process. Larger values of δ and b will also reduce the importance of marginal costs in the determination of price changes. As the elasticity of substitution in the production function, σ, grows the importance of deviations in the relative price of imported intermediary goods to wages in the determination of price changes also grows.

3 Empirical Evidence

3.1 The Data

The estimation is based on quarterly data for the period 1990:1 to 2003:3, a total of 55 observations. This is a relatively short time span, but as the reader may be aware, the Israeli economy experienced many structural changes in the past decades - changes that make it implausible to assume that a longer period will be sufficiently homogenous to be treated as characterized by the same structural relationships. Following the Stabilization Program in 1985, which was designed to treat hyperinflation during the first half of the 1980's, inflation decreased initially to a low double-digit rate of about 20 percent, and gradually arrived at low single digit inflation, and price stability at the end of the 1990's. Against the background of this major structural change in the Israeli economy, I chose to concentrate in the analysis on the inflationary environment which resembles more the current conditions of the economy. Even this short period may be found hard to characterize as uniform and therefore to estimate, due to the substantial capital and trade liberalization during the last decade.[9] Further research may investigate the changes in the Phillips curve relationship induced by principal changes in the rate of inflation and other major structural changes in the economy during the last decade.

The analysis refers to the business sector. For the estimation of the closed economy version of the NKPC, which is based on a Cobb-Douglas production function, the price index is the business-sector GDP deflator, and wages are the average rate of nominal wages in the business sector. Import prices

[9] For a fuller description of the inflationary process in Israel and other structural changes, see Djivre and Tsiddon (2002).

Change in prices of	Mean	Std
Business sector GDP	.019	.019
Domestically produced uses	.017	.022
Domestically produced domestic uses	.022	.023

Table 1: Mean and standard deviation of different measures of inflation

are the dollar-denominated prices of imported intermediate goods multiplied by the local-currency exchange rate vis-à-vis the dollar. The share of labor income in business sector GDP is computed using the national accounts data for labor compensation in the business sector, which is the sum of compensation for employees and the self-employed.[10]. In the open economy version of the NKPC, the CES production function with intermediate imported goods relates to gross output, so the price index should measure the prices of this aggregate. Unfortunately we do not have a price index for the gross output of the business sector, therefore, we use two alternative measures of uses to approximate the prices of this aggregate. The first one is the sum of uses that are generally domestically produced and include: private consumption of non-durables, civilian purchases of the government, investment excluding imported machinery and equipment and vehicles (which are all imported) and exports. An alternative measure aggregates only domestic uses (domestically produced), leaving out exports from the previous list, based on the assumption that exports' prices are generally set in the international market.[11] The share of labor share in gross output is computed by dividing the sum of compensation for employees and the self-employed (as before) by gross output, which is the sum of business sector GDP and imported intermediate goods. Average share of labor compensation in business sector GDP is about 0.65, compared to about 0.50 in gross output.

As may be seen in Table 1 the rate of change of the of the prices according to the two definitions of uses is more volatile than that of the GDP deflator. From Figure 2 it is easy to see that it is also larger than the volatility of the ratio of import prices to wages and of unit labor costs. Therefore, we may expect that fit of the estimated model explaining the rate of change of the

[10]This data is annual. It was transformed into quarterly data using the quarterly distribution of the total wage bill in the business sector as reported by the National Insurance Institute.

[11]A shortcoming of the GDP deflator in the closed economy version of the model is that, for the Israeli economy, which is an open economy, it includes GDP intended for export. Therefore, the aggregate GDP deflator includes prices which are set internationally and to a lesser extent according to producers' decisions.

prices of uses (as a proxy for gross output) will be only partial.

In the theoretical model, all variables are defined as the deviation of the log variable from the steady state. Therefore the steady state must be defined empirically. Unlike the case in empirical studies of the European or the US economy, the presence of a clear downward trend in the rate of inflation in Israel during the previous decade makes the assumption that actual inflation represents a deviation from a constant (zero) steady-state inflation less reasonable. Two alternative approaches are adopted in the estimation. The first is estimation of the (log of) actual values of inflation, wage share and prices of imports relative to wages. The second approach uses the HP filter in order to detrend these variables. A conventional view of the disinflationary process in the 1990's relates to it as a step process (see Liviatan and Melnick, 1998). Therefore an alternative definition of detrended inflation may be the residuals from a simple regression of the inflation from its steps.[12] The residuals from both processes are fairly similar, and are shown in Figure 1. We chose to use the HP filtered series in the estimation.

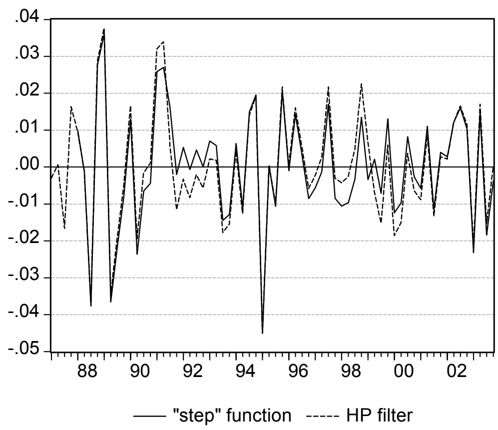

Figure 1: Residuals of business-sector GDP price inflation

The path of labor share, import prices relative to wages and price inflation and the HP filtered trend of these series are shown in Figure 2

[12]The regression is LDPYB = 0.042 - 0.018*D912AFT -0.020*D991AFT. LDPYB is the quarterly change in the log of business sector prices, D912AFT and D991AFT are dummy variables with value 1 beginning in the third quarter of 1991 and the second quarter of 1999 respectively.

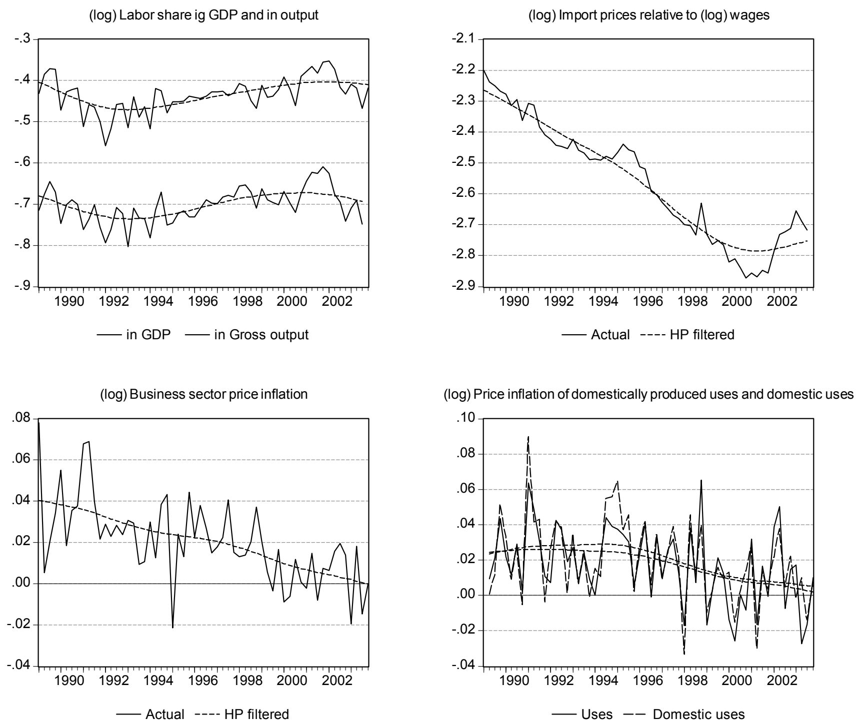

Figure 2: Actual and detrended data

3.2 Estimation

Equation (18) provides a general theoretical framework for the empirical estimation and nests in it the basic formulations of the NKPC presented in the first parts of the theoretical chapter. The customary original models of the NKPC assume a Cobb-Douglas production function with no substitution between labor and other inputs. In that case marginal costs consist only of labor costs, specifically, $mc_t = W_t/MPN_t = \frac{1}{(1-\alpha)}\frac{W_t}{P_t}\frac{N_t}{Y_t}$ and $\widehat{mc}$ represents the labor share in GDP (which is also a measure for unit labor cost). In the terms of equation (18) this means assuming $\sigma = 1$. The basic formulation of the NKPC that is derived from micro-founded considerations includes only marginal costs and forward-looking inflation expectations, as in equation (8). This means b is assumed to be zero - all firms set their prices optimally. In the hybrid models b may be greater than zero. Although equation (18) nests these partial models, and their validity may be tested directly by testing the estimated coefficients of σ and b, I chose to estimate the partial models and the full model separately. The estimation uses the original values of the (log) variables and alternatively, their deviations from a HP trend.

The equations are estimated using the GMM procedure.[13] This method does not require information of the exact distribution of the disturbances. The parameters are estimated so that the sample correlations between the instruments and the estimated equation are as close to zero as possible. The procedure orthogonalizes the basic expression to the set of instruments. The instrumental variables that are used are four lags of the inflation variable and the other explanatory variables. In some specifications four lags of the central bank's nominal interest rate, the (log of) business-sector wage inflation and quarterly dummy variables to account for the seasonality in the inflation rate were also included. The validity of over-identification (when the number of instruments is larger than the number of parameters to estimate) is checked using the J-statistic. A constant is also allowed in the structural estimation although it does not appear in the theoretical formulation, to account for measurement errors and for a structural rate of inflation, higher than zero, corresponding to fundamental characteristics of the economy.

3.2.1 The Closed Economy NKPC

The basic formulation of the NKPC includes only the labor share in output, as an indicator for marginal costs (assuming a Cobb-Douglas production function) and forward looking inflation expectations as presented in equation (8). The hybrid version includes also lagged actual inflation, as shown in equations (12). These basic formulations are estimated, although examining the data it is evident that, in contrast to the large economies in Europe and the US[14], there does not exist a simple positive correlation between inflation and unit labor costs (Figure 3).

Clearly, other factors affecting the evolution of prices are missing in such a specification. Ad hoc dummy variables for downward steps in inflation in 1991 and 1999 were added to the estimation of the level of inflation, and improve the results to some extent. Generally, the contribution of unit labor costs (ULC) to the description of the evolution of inflation is not stable, and in most cases it is insignificant. The coefficient of expected inflation, in the base model, which is expected to be around one, is significantly smaller than

[13] Which is included in the E-Views 4 econometric software.

[14] See Figures 2 and 3 in Gali, Gertler and Lopez-Salido (2001).

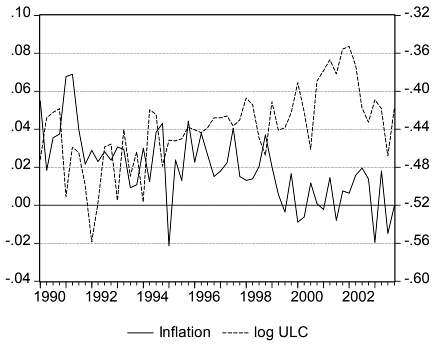

Figure 3: Business sector GDP price inflation and log unit labor cost

one. The results are presented in Tables 2 and 3. Definitions of the variables appear in the Appendix.

The results for specification no. 3 in table 2 are the most reasonable, with all coefficients (except the dummy for the second quarter) positive and plausible. Deriving the structural parameters from the estimated coefficients, assuming $\beta = 0.99$, we get δ, the probability that a firm is *not able* to update its price, or in other words price stickiness is equal to about 0.77. This means that the expected interval between price adjustments of an average firm is $1/(1-\delta) = 4.3$ quarters. The fraction of firms that update prices using a backward looking rule, b, is about 0.6 to 0.8.

3.3 The Open Economy Hybrid NKPC

In this section the basic NKPC model is expanded to a broader model that includes the additional factor of an open-economy NKPC, which is the price of imported goods relative to the wage rate. The evolution of this relative price and the relative proportion of imported inputs to labor, as seen in Figure 4, seems to support the assumption that the share of imported goods and labor in the production function is variable and depends, among other factors, on the relative price of these inputs.[15]

The downward trend of the relative prices, which resembles the downward trend of the rate of inflation, hints, before any further analysis that this factor may assist in describing the evolution of inflation in the 1990's.

[15]Bentolila and Saint-Paul (2003) show for the OECD that the labor share in output depends on, among other factors like technology changes, the relative price of imported inputs.

Equation	**1**	**2**	**3**	**4**
	Base model		Hybrid model	
Dependent var.	ldpyb	ldpyb	dlpyb	dlpyb
constant	0.013	0.031	0.027	0.031
	0.24	0.00	0.01	0.01
ldpyb(+1)	0.816	0.657	0.585	0.487
	0.00	0.00	0.00	0.00
ldpyb(-1)			0.564	0.121
			0.00	0.23
lulc	0.015	0.031	0.065	0.027
	0.58	0.18	0.01	0.26
dumq2	−0.011	−0.012	−0.008	−0.009
	0.00	0.00	0.04	0.00
d912aft		−0.006		−0.008
		0.13		0.06
d991aft		−0.010		−0.010
		0.00		0.00
J-stat	11.0	11.0	11.1	13.0
	0.39	0.39	0.48	0.33
* Second row values are p-values.				

Table 2: Reduced form estimation for closed economy models

The open-economy model was estimated structurally to allow the identification of the structural parameters. Although, according to the model, it is gross output inflation that should be estimated, we present specifications in which the GDP deflator is the dependent variable in the open economy model, as was done in the model for a closed economy. (Columns 5 and 6 in Table 4)

According to equation (18), the parameters to be identified are β—the discount rate, δ—the price stickiness, b—the rate of backward looking firms, σ—the rate of input substitution in the production function, and $\frac{1-\mu s}{\mu s}$ where s is (average) labor share in output and $\mu = \frac{\theta}{\theta - 1}$ is the markup.

Due to limitations of the estimation only a subset of the parameters may be identified. We chose to assume $\beta = 0.99$ and substitute $s = 0.65$ or $s = 0.50$ according to the average value of labor share in GDP or gross output, respectively. A proxy for σ was set according to a simple estimation of the CES production function in equation (13)[16]. The point estimate for σ derived from the results of this estimation is about 1.3. Analysis of the sensitivity of the results to this assumption was performed and will be presented below. The structural coefficients δ and b and the markup μ are remained to be estimated. The results of the structural estimation are shown

[16] The dependent variable is the log of domestically produced uses (as specified above), excluding α_m which was insignificant. I did not find any previous estimations of a CES production function for Israel, to use as a benchmark.

Equation	**1**	**2**
	Base model	Hybrid model
Dependent var.	dlpyb_res	dlpyb_res
constant	0.000 0.57	0.001 0.21
ldpyb_res(+1)	0.304 0.04	0.321 0.05
ldpyb_res(-1)		0.117 0.23
lulc_res	0.163 0.00	0.173 0.003
dumq2	−0.004 0.18	−0.004 0.18
J-stat	10.1 0.10	9.9 0.13
* Second row values are p-values.		

Table 3: Reduced form estimation for closed economy models - deviations from trend

in Tables 4 and 5. Definitions of the variables are in the Appendix.

The proportion of firms that, according to the estimation results, is unable to change their price each period (δ) is about 0.47 to 0.60. This means that the average length of period between price updates is about 2 to 3 quarters.

This velocity of price changes is relatively high compared with findings for the US and the Euro area, but still in the same magnitude as found for these countries. Gali and Gertler (1999) who base their estimation on a similar theoretical background estimate δ to be around 0.8-0.87 for both the base model and the hybrid model, which is equivalent to price change duration of about 5 to 8 quarters. They get a slightly lower value (0.73-0.77) when estimating the Phillips curve for the 1960's through the 1980's (excluding the 1990's). Gali, Gertler and Lopez-Salido (2001 and 2003a), using the same methodology, obtain lower values, about 0.5 - 0.6 for the US and 0.67-0.8 for the Euro area. Christiano, Eichenbaum and Evans (2000) present a value of 0.76 which is equivalent to price duration of 4 quarters and Sbordone (2001) attains price inertia in a range of 2.5-3.5 quarters. Amato and Gerlach (2000) find the duration of price updates is 2-3 quarters in the US and 6 quarters in Spain. McAdam and Willman (2003) find the duration in Europe is 4.5-6 quarters and Leith and Malley (2002) show that the duration for the US, the UK and Italy is about 2 quarters and in Canada, France and Japan about 3 quarters. An extensive overview by Taylor (1998) of the earlier literature examining price adjustment in the US concludes that the average frequency of price changes is about one year.

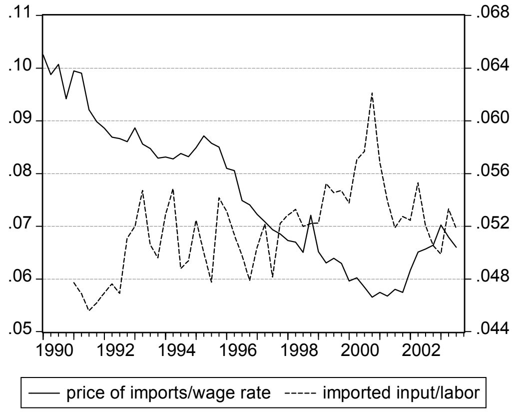

Figure 4: Realtive quantities and prices of imported goods and labor

Nonetheless, our findings are not unreasonable against the background of moderate double-digit inflation (10-20 percent annually) during the first half of the sample period, and specifically, the hyperinflationary history of the Israeli economy which induced the development of sophisticated mechanisms for continuous updating of prices during that era. Lach and Tsiddon (1992, 1996) find for Israeli data from the relatively high inflationary environment of the beginning of the 1980's[17] that stores updated their prices at an average rate of about once every 1.5-2.2 *months*. Eden (2001) finds for similar micro-data for the period 1991-1992 that prices are updated every 2.2-2.6 months - a relatively minor reduction from the frequency observed in the earlier periods which were characterized by a significantly higher rate of inflation.[18]

Taylor (1998) mentions in his summary of the survey that it has been found that "The frequency of wage and price changes depends on the average rate of inflation" and it is "one of the most robust empirical findings in the studies reviewed here." An alternative model for price adjustments which is state-dependent instead of time-dependent (and exogenous) as is the Calvo model we assume, suggested by Dotsey, King and Wolman (1999), generates price adjustment frequencies that vary with the business cycle and in particular are higher for higher inflation rates. All these findings support the possibility that lower values of δ, meaning higher frequency of price ad-

[17]The *monthly* inflation rate in the period they examine ranges from 3.9% in 1978 to mid 1979 to 7.3% in 1982.

[18]Average monthly inflation rate was about 1.4% in 1991 and 0.8% in 1992.

justments, are expected for the Israeli economy, relative to other economies with lower and more stable inflation.

Among the firms that can update their prices, the proportion of firms that uses a backward looking rule (b) is 0.4-0.5 in the specifications that estimate the log of the rate of change of prices (Table 4) and is about 0.16 to 0.24 for the specifications that estimate using the deviations from the log-run trend of price changes (Table 5), meaning that most of the firms do update their prices optimally using a forward-looking rule. The estimated values for the mark-up μ vary in a relatively wide range between 1.02 and 1.7 depending on the specification and set of instrumental variables. The lower range of these estimates is consistent with findings for other economies.[19]

Equation	**1**	**2**	**3**	**4**	**5**	**6**
Dependent var.	ldpu	ldpu	ldpdu	ldpdu	ldpyb	ldpyb
Constant	0.257	0.122	0.093	0.093	0.162	0.162
	0.00	0.00	0.22	0.22	0.00	0.00
δ	0.472	0.479	0.585	0.585	0.576	0.576
	0.00	0.00	0.00	0.00	0.00	0.00
b	0.370	0.528	0.539	0.539	0.298	0.298
	0.00	0.00	0.00	0.00	0.00	0.00
μ	1.194	1.496	1.134	1.507	0.816	1.116
	0.00	0.00	0.00	0.00	0.00	0.00
σ	**1.3**	**1.3**	**1.3**	**1.7**	**1.3**	**1.7**
J-stat	10.5	11.4	11.0	11.0	8.8	8.8
	0.35	0.42	0.39	0.39	0.22	0.22
* Second row values are p-values.						
** Different results in columns 1,2 due to different instrumental vars.						
Derived coefficients						
Equation	**1**	**2**	**3**	**4**	**5**	**6**
dep.var.(+1)	0.55	0.47	0.51	0.52	0.65	0.65
dep.var.(-1)	0.43	0.52	0.48	0.48	0.34	0.34
lulc	0.21	0.13	0.07	0.07	0.15	0.15
lpmi-lwgb	0.04	0.01	0.02	0.02	0.06	0.07

Table 4: Structural estimation of the open economy model

According to these estimated values of the structural parameters, the coefficient of future inflation in the inflation equation is around 0.50 to 0.75 and of lagged inflation about 0.25 to 0.50, which is consistent with the common results for the US and Europe. (See footnote 6). This means that there exists only moderate inertia in the inflation process as a result of the up-

[19] A value of 1.33 in Erceg, Henderson and Levin (2000), 1.11 in Rotemberg and Woodford (1997). Balakrishnan and Lopez-Salido (2002) assume 1.2; Leith and Malley (2002) use 1.1.

Equation	**1**	**2**	**3**	**4**
Dependent var.	ldpu_res	ldpdu_res	ldpdu_res	ldpdu_res
δ	0.495	0.521	0.533	0.533
	0.00	0.00	0.00	0.00
b	0.243	0.214	0.158	0.158
	0.00	0.04	0.08	0.08
μ	1.748	1.139	1.016	1.413
	0.02	0.00	0.00	0.00
σ	**1.3**	**1.3**	**1.3**	**1.7**
J-stat	8.69	9.02	8.69	8.69
	0.15	0.12	0.15	0.15
* Second row values are p-values.				
** Different results in columns 2,3 due to different instrumental vars.				
Derived coefficients				
Equation	**1**	**2**	**3**	**4**
dep.var.(+1)	0.66	0.70	0.76	0.76
dep.var.(-1)	0.33	0.29	0.22	0.22
lulc	0.26	0.25	0.27	0.27
lpmi-lwgb	0.01	0.06	0.08	0.08

Table 5: Structural estimation of the open economy model - deviations from trend

dating process of prices and may also indicate that economic policy enjoyed fairly high credibility, allowing price updates based on future expectations and to a lesser extent on past developments. This result is somewhat surprising in light of the high correlation between inflation expectations for the next 12 months, as they are derived from the financial markets, and past CPI inflation.

An additional source of inertia in the inflationary process is the stickiness in the wage determination process. This factor is expressed in the inflation equation through marginal costs and the relative price of wages to import prices. But, even if *past* prices or inflation have some weight in determining of *current* nominal wages, the relatively small size of coefficients on both the unit labor costs and the relative prices in the inflation equation means that overall importance of wage stickiness in inflationary inertia is, according to our results, minor.

The coefficient of the price of imported goods relative to wages is about 0.02 to 0.08 in different specifications, and the coefficient of (log) ULC is about 0.1 to 0.3.

The actual annual inflation of the prices of domestic uses and the estimated values according to equation 3 in table 4 are shown in Figure 5.

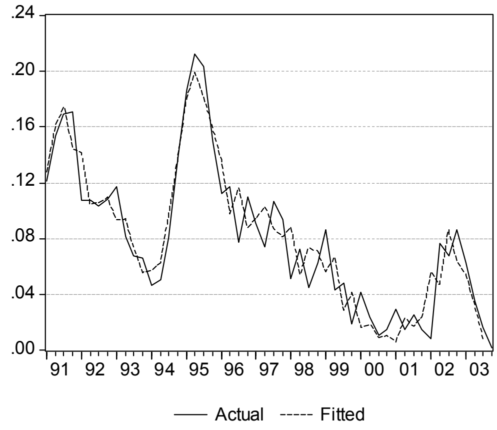

Figure 5: Actual and estimated values of annual inflation in the prices of domestically produced domestic uses.

Generally, the fitted values follow the path of actual inflation. The significant weight of future (expected) inflation in the determination of current inflation is apparent in the shift of fitted values relative to actual values one period ahead during part of the sample period.

4 Concluding Remarks

The paper presents a "New Keynesian" Phillips curve for the Israeli economy and evaluates its empirical relevance. The model essentially resembles the approach presented in Gali and Gertler (1999) and Sbordone (2001), among others, and is expanded along the lines of Balakrishnan and Lopez-Salido (2002) for an open economy. It provides a micro-founded framework linking between marginal costs of production and inflation dynamics. The formulation of the NKPC, according to a theoretical framework allows us to identify the structural parameters that characterize the product market, under the assumption of monopolistic competition and some stickiness in prices. We find that the empirical characteristics of the Phillips curve do not differ qualitatively from those of other countries (in Europe, Canada and the US), although Israel's inflation history is substantially different from that of those countries and includes past periods of high inflation and hyperinflation (not in the sample) that may have had an effect on the behavior of economic agents.

One of the main findings is that the average frequency of price updates by firms is every 2 to 3 quarters, much lower than the frequency in the 1980's—about 1-3 months. The share of firms that update their prices according to a backward looking rule is only 1/4-1/3, suggesting that over the sample period the credibility of the policy as targeting for price stability and the volatility of prices were such that allowed firms to set their prices, giving substantial weight to expected developments. The value of these two parameters generated reduced form coefficients of about 0.3-0.5 on past inflation and 0.5-0.7 on future inflation, meaning inflation inertia due to backward looking in price adjustment is moderate.

The inertia in marginal costs, due to stickiness in the wage determination has not been investigated directly in this paper. According to Lavi and Sussman (2001), although in the long run wages are cointegrated with unit elasticity with labor productivity, in the short run wages deviate from marginal productivity due to short-run rigidities such as unexpected inflation, the cost-of-living adjustments, and other institutional rigidities. Therefore, it is plausible to assume that inertia in prices is higher than that caused directly by the mechanism of price updates. However, due to the relatively small quantitative effect of marginal costs on current price changes, the overall relevance of wage stickiness to inflationary inertia is, according to our results, minor.

As Israel is an open economy, affected by foreign prices and the exchange rate, it is seems reasonable to include open economy components in the model. We find that the price of imported goods relative to wages does influence the inflation process and improves the estimation results, although not dramatically.

Although Israel underwent a disinflationary process in the last decade, parameters were estimated as constant for the whole period. An extension of this research may be a refinement of the estimation by allowing the structural parameters to change over time. However, the possibility to do so is doubtful due to the lack of a sufficiently long period, required in order to allow changes in the coefficients during the sample period. It is very customary in this field of research to adjust the basic NKPC by adding an assumed ad hoc backward component, as is done by Gali and Gertler (1999) and others, trying to incorporate this component via a structural model of the labor market[20] may improve our understanding of the forces behind price inertia. Another expansion of the current framework may be the inclusion of open economy

[20] Erceg, Henderson and Levin (2000) proceed in this direction.

parameters in the consumption function side also by allowing substitution between domestically produced and foreign produced goods[21].

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[21] As is done in Leith and Malley (2002).

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6 Appendix: Variable definitions

d912aft - Dummy variable =1 starting from 1991 III. Zero otherwise.

d991aft - Dummy variable =1 starting from 1999 II. Zero otherwise.

dumq2 - Dummy variable = 1 in the second quarter of each year.

ldpdu - Log difference of the prices of domestically produced domestic uses.

ldpu - Log difference of the prices of domestically produced uses.

ldpyb - Log difference of the business sector GDP deflator.

lpmi - Log Shekel prices of imported inputs.

lulc - Log unit labor costs.

lwgb - Log real wage in business sector.

lyb - Log business sector GDP.I.

Suffix

_res - Residual from trend according to HP filter starting in 1987.