



Persistent Undershooting of the Inflation Target During Disinflation in Israel: Inflation Avoidance Preferences or a Hidden Target?

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Abstract

The paper attempts to determine whether persistent undershooting of the inflation target – particularly during a disinflation process – is a result of inflation avoidance preferences (IAP), namely asymmetric monetary policy with respect to inflation, or a hidden target that is lower than the announced one.

This analysis introduces a Linex-form central bank behavior function into a New Keynesian (NK) framework, which makes it possible to explicitly distinguish between the two hypotheses. Using data for Israel for the period 1994-2007, the model is empirically tested using three different regression techniques – OLS, Non-Linear OLS (NLS) and instrumental variables (IV) using the GMM method. It is shown that a hidden target was indeed adopted during the 1990s – the main period of the disinflation process - and that it equaled about 4 percent on average in comparison to the average announced inflation target of 8 percent. At the same time, an asymmetric policy was also conducted, thus suggesting that the policies – hidden target and IAP – had different motives, with the former perhaps being aimed at manipulating the public's expectations of inflation. During the 2000s, on the other hand, the evidence is inconclusive as to whether a hidden target *or* asymmetric policy was adopted, thus suggesting that one or the other was used to implement IAP policy. It emerges that when the CB plays a repeated game in determining monetary policy and the public goes through a learning process to understand central bank behavior, a *hidden target* that is lower than the announced one may be a practical way of manipulating expectations even under discretion.

החטאת יעד האינפלציה מלמטה בתהליך הדיסאינפלציה בישראל:

אסימטריה או יעד סמוי?

ויצמן נגר*

תמצית

עבודת התיזה בוחנת האם החטאה עקבית מלמטה של יעד האינפלציה בישראל – ובפרט בתקופת תהליך דיס-האינפלציה – היא תוצאה של מדיניות מוניטרית אסימטרית ביחס לאינפלציה (inflation avoidance preferences-IAP) או תוצאה של יעד סמוי (hidden target) שהוא נמוך מיעד האינפלציה הרשמי. ההבדל בין שני המקרים הוא שמדיניות אסימטרית מכוונת להשגת היעד הרשמי; ואולם, שמרנות ביחס לאינפלציה יחד עם אי-הודאות ביחס לתנאים הכלכליים במשק יכולים להביא לזהירות יתר שתוצאתה היא החטאת היעד מלמטה. לעומת זאת, יעד סמוי מטרתו להשיג יעד שהוא נמוך יותר מהיעד הרשמי.

פונקצית המטרה של הבנק המרכזי היא מסוג לינקס (linex) הלוקחת בחשבון את אי-הוודאות, ואליה מתווספים פרמטרים המאפשרים להבחין בין שתי ההשערות של אסימטריה ויעד סמוי. המודל הכלכלי הוא ניאוקונסיאני עם פונקצית ביקוש מצרפי (AD) ופונקצית היצע (עקומת פיליפס), ובו משתלבת פונקצית המטרה. האופטימיזציה נעשית תחת מדיניות של שיקול דעת (discretion) לפיה הציפיות האינפלציוניות הן אקסוגניות ונתונות לבנק המרכזי, והאופטימיזציה נעשית לתקופה אחת קדימה בלבד. המשוואות הנגזרות מהאופטימיזציה של המערכת נאמדו אמפירית לגבי ישראל בתקופה 1994-2007 בשלוש שיטות אקונומטריות שונות: OLS, Non-Linear OLS (NLS), ושימוש במשתני עזר (IV) בשיטת GMM. התוצאות מראות כי במהלך שנות התשעים, שהתאפיינה בתהליך דיס-האינפלציה, אכן אומץ יעד אינפלציה סמוי על ידי בנק ישראל והוא נאמד בכ-4 אחוזים במוצע לעומת 8 אחוזים במוצע של יעד האינפלציה הרשמי. בד בבד, בתקופה זו אומצה גם מדיניות אסימטרית ביחס לאינפלציה. נראה לכן כי המניעים לביצוע המדיניות האסימטרית היו שונים מהמניעים של יעד סמוי, כאשר האחרון נועד להשפיע על הציפיות האינפלציוניות. לעומת זאת, בשנות האלפיים התוצאות מצביעות על אסימטריה או יעד סמוי, אך לא שניהם יחד, ומכאן ניתן להסיק ששניהם היו אמצעים חילופיים לביצוע מדיניות אסימטרית (IAP).

תוצאות אלו מצביעות על האפשרות שנקיטת מדיניות מוניטרית של יעד סמוי שעקבית לאורך זמן, יחד עם תהליך למידה של הציבור, מהווה דרך מעשית לעצב את הציפיות האינפלציוניות אפילו תחת מדיניות של שיקול דעת.

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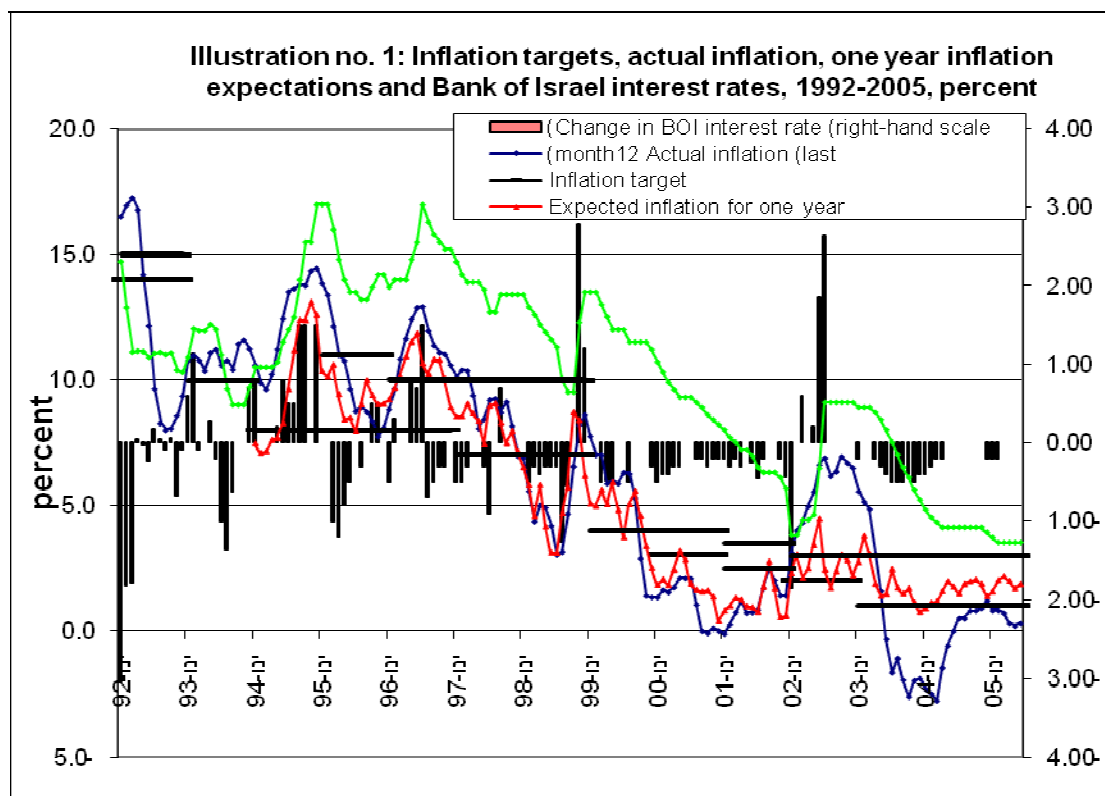
עבודה זו היא חלק מעבודת התיזה לדוקטורט באוניברסיטת תל-אביב. אני אסיר תודה לאלכס צוקרמן שהנחה ואיתגר אותי לאורך כל הדרך. תודות לאסף רזין ולפרנציסקו רוחה-מורסיה (Francisco J. Ruge-Murcia), שהיו המתדיינים על עבודה זו ועל הערותיהם מועילות. קיבלתי הערות מועילות גם מסמינר הדוקטורנטים באוניברסיטת תל-אביב, מדינאל לוי וסמינר הדוקטורנטים באוניברסיטת בר-אילן, וכן מעמי ברנע וממשתתפי סמינר חטיבת המחקר של בנק ישראל, ואני מודה לכולם.

1. Introduction

The seminal work of Kydland & Prescott (1977) and Barro & Gordon (1983) (hereafter: KPBG) demonstrated that the employment or short-run Phillips curve motive leads to inflation bias due to time inconsistency. Based on their work and the research that followed, inflation target regimes were widely adopted among central banks (whether explicitly or implicitly) from the 1990s onwards. McCallum (1995, 1997) and Blinder (1998) argued against KPBG's explanation of *inflation bias*. Moreover, empirical evidence was found of *deflation bias* which tended to indicate an asymmetric policy with respect to inflation. Cukierman (2000b, 2002) argued that under two conditions, i.e. if the central bank (CB) is uncertain about the prevailing economic conditions and if it is more sensitive to below-normal employment than above-normal, then inflation bias may exist even if KPBG's argument does not hold, i.e. even when the CB targets the normal level of output. Similarly, deflation bias may arise if the CB is more sensitive to above-target inflation than to below-target. Cukierman and Muscatelli (2008) labeled these types of asymmetry as *Recession Avoidance Preferences* (RAP) and *Inflation Avoidance Preferences* (IAP), respectively. This hypothesis was empirically tested using US and UK data for various periods and it was concluded that asymmetry varies with the regime adopted and what is viewed as the most pressing macroeconomic problem at the time.

However, undershooting of the inflation target may also be due to the CB's intentional adoption of a hidden target that is lower than the announced one, rather than asymmetric policy. Figure 1 shows actual inflation versus the announced inflation target and demonstrates that while actual inflation (in blue) often overshoot the target up until 1996, from 1997 onward undershooting of the inflation target (in bold) was prevalent. This is especially true for the following periods: mid-1997 to mid-1998, the end of 1999 to 2001 and from 2003 onward. It can also be seen that apart from the normal gradual interest rate changes, there were substantial shifts during these periods in the response of the interest rate (the level of the interest rate is represented by the green line and its changes as bars).

Although this phenomenon can be viewed as IAP, it may also be due to the adoption by the CB of a hidden target that is lower than the announced one. Sussman (2007), in interpreting the Israeli experience during the 90's, claimed that a hidden target level of zero had been adopted since 1995. His conclusion, however, was not based on an explicit study of this question.



But is there any difference in motivation between a hidden target and asymmetric policy? It can be claimed that a hidden target policy reinforces credibility and is beneficial in dealing with uncertainty and therefore it is only *a different technique* used to apply IAP. In this case, we should find empirical evidence for either asymmetry *or* a hidden target. However, in the case that there is evidence for the existence of both during the same period, then a hidden target policy would have a different motive, perhaps to manipulate the public's inflation expectations, even in a discretionary regime.

This paper aims to explicitly differentiate between asymmetry and a hidden target by introducing a Linex function to describe CB behavior within a New Keynesian (NK) framework. Using Israeli data for the period 1994-2007, it is shown that a hidden target of about 4 percent was adopted during the 90s in contrast to the average announced target of 8 percent. At the same time, an asymmetric policy was also adopted, suggesting different motives for each. In contrast, during the 2000s it cannot conclusively be shown whether a hidden target *or* an asymmetric policy was adopted, suggesting that one or the other was used to implement IAP policy.

The rest of the paper is organized as follows: Section 2 reviews the relevant literature and Section 3 briefly introduces the Linex function. Section 4 introduces the model for the

economy and derives two optimized equations for estimation. Background on the Israeli disinflation process is presented in Section 5 and in Section 6 the equations are econometrically estimated using three different regression techniques – OLS, Non-Linear OLS (NLS) and GMM using Instrumental Variables (IV). The results are discussed in Section 7 and Section 8 presents a summary and conclusions.

2. Review of the Literature

The dominant explanation for inflation in the 1970s has been the employment or short-run Phillips curve motive,¹ as presented in the seminal KPBG articles. They showed that under rational expectations, the CB's attempt to achieve employment above its natural level leads to a persistent inflation bias and that in fact employment does not rise above its natural level (i.e. which would prevail at zero inflation). This explanation also formed the basis for the idea of "dynamic inconsistency" (which was coined by Kydland and Prescott) and led to the perception that inflation bias could be reduced if CB policy were to be time-consistent. Consequently, a vast body of literature examined methods of reducing inflation bias. These included the nomination of a conservative CB governor (Rogoff, 1985); enhancing the independence, reliability, credibility and accountability of the CB (Cukierman, 1992, 2000a); and considering the use of discretion as opposed to commitment (rules).²

Against this backdrop, many developed economies adopted inflation target regimes during the 1990s as a practical way of committing themselves to reducing inflation and a

¹ Chapter 2 in Cukierman (1992) offers four possible reasons for an inflation bias under perfect information, all of which lead to dynamic inconsistency: the employment or short-run Phillips curve motive; the fiscal (seigniorage) revenue motive; the interest rate smoothing and financial stability motive; and the balance of payment motive (under a fixed exchange rate regime) which is also referred to as the employment motive. However, the seigniorage motive (which had been noted in Keynes (1924), p46) does not appear to be an appropriate explanation for the inflation bias in the 1970s for several reasons: first, seigniorage in the developed economies was a relatively small share (around 1%) of GNP; second, the developed economies have a sophisticated tax system; and finally there is a clearly-defined separation between the Government (or Treasury) and the CB.

Another related explanation for the inflationary trend in the 1960s and 1970s is the use of a nominal interest rate target without a nominal anchor, which results in the CB automatically accommodating any shock to money demand. However, as Fischer (1994, p. 29) noted, this argument encountered some difficulties since a closer examination showed that nominal interest rate targeting leads to determinacy under rational as opposed to adaptive expectations and because introducing any nominal anchor keeps the price level determinate. This argument can be traced back to Wicksell ([1898] 1965), whose idea was later developed by Friedman (1968).

² For further discussion, see for example Walsh (1995) and Persson & Tabellini (1993) who proposed optimal incentive contracts for central bankers and Svensson (1997) who showed that such contracts can be implemented by means of a simple inflation target. See also Clarida, Gali & Gertler (1999) (hereafter: CGG).

strand of literature developed which focuses on their methods and degree of success in implementing this policy. Since the Governors are judged by their success in combating inflation, Fischer (1994, pp. 293) suggested the possible outcome of *deflation bias*. Evidence to support asymmetry with respect to inflation was offered by Laxton & Rose (1995) for the US, Mishkin and Posen (1997) for Canada and the UK, Clarida and Gertler (1997)³ and Dolado et al. (2000).⁴ Ruge-Murcia (2001, 2003a)⁵ also found deflation bias in Canada, Sweden and UK.

As CBs became more independent, some studies raised doubts as to the realism of KPBG's theory of inflation bias. McCallum (1995, 1997) argued that CB's refrain from systematically stimulating output even under discretion because they understand its futility. On the basis of institutional evidence, Blinder (1998) argued against the KPBG theory by asserting that Fed policymakers do not systematically try to maintain employment above its natural level. (He also argued that from a political point of view, tightening monetary policy is more difficult than easing it).

In view of the claims that a KPBG inflation bias mechanism disappeared to a large extent under the new enhanced CB autonomy, Cukierman (2000b, 2002) made the argument that an inflation bias may arise even when the CB targets the natural level of output, as a result of uncertainty regarding the future state of the economy⁶ and a greater sensitivity to below-normal employment than above-normal. Along the same lines, deflation bias may appear when policymakers are more averse to a positive inflation gap than to a negative one of the same magnitude, which may occur for example during periods of inflation stabilization. Such asymmetric behavior was labeled by Cukierman and Muscatelli (2008) as Recession Avoidance Preferences (RAP) and Inflation Avoidance Preferences (IAP), respectively. Ruge-Murcia (2003) tested this hypothesis empirically and found that it provided a better

³ Clarida & Gertler (1997) reviewed Germany's monetary policy (prior to the creation of the European monetary union) within the context of a Taylor rule policy and found evidence of asymmetry with a deflation bias.

⁴ Dolado et al. (2000) examined this question by comparing four countries: the US, Germany, France and Spain. They found evidence of deflation bias of various intensities (with Germany showing the strongest). With regard to output, they found symmetry in the three European countries, while the US showed a more aggressive response to recession. These studies used a quadratic objective function which is common in the literature (see the discussion below).

⁵ Ruge-Murcia used the Linex Objective Function for CBs as suggested by Nobay and Peel (1998, 2000) who were the first to apply the Linex function to monetary policy objectives .

⁶ Uncertainty about the condition of the economy, the nature of the shocks and the long and variables lags of policy impact (see also Goodhart, 1999). CGG (1999) and Blinder (1997) also discuss the lack of monetary models that include uncertain behavior formulation.

explanation for the behavior of US inflation than the KPBG model.⁷ Using a non-quadratic model, Cukierman & Muscatelli (2008) empirically tested the question of asymmetry for the US and UK and found that the asymmetry properties vary with the regime and according to what is viewed as the main macroeconomic problem at that point in time. Sussman (2007) interpreted the Israeli experience during the 1990s as implying that the Bank of Israel pursued a hidden target that was lower than the announced one, which is the issue to be investigated in this paper.

Uncertainty and asymmetric behavior are also relevant to the related issue of the theoretical form of the CB objective function. While a quadratic form is widely used due to its convenient properties, it embodies the certainty-equivalence property, i.e. it ignores the uncertainty surrounding inflation.⁸ Therefore, such a behavior function may be unrealistic since in the real world CBs are not indifferent to uncertainty (see also Blinder, 1997).⁹ This and other critiques¹⁰ led to the use of alternative objective functions, such as the Linex type, which is used in our model and is described in the next section.

3. The Linex Function

The Linex function, which will be used for the CB objective function, has the following form:¹¹

$$L = (e^{ax} - ax - 1) / a^2 \quad (1)$$

where e is the exponential function; x is the deviation from the inflation target; and a captures the degree of asymmetric preferences. In the case of a deviation from the target, its size as well as its direction is important, a result which the familiar quadratic function is unable to capture. Thus, when a is positive, there is a stronger aversion to a positive deviation ($x > 0$) than to a negative one. If $a = 1$, then in the case of a positive deviation,

⁷ With respect to unemployment, Ruge-Murcia (2004) found asymmetry in the US and France indicating a greater aversion to higher-than-natural rates of unemployment than to inflation, while in Canada, Japan, Italy and England the assumption of symmetric behavior could not be rejected.

⁸ CGG (1999) also address the weakness of the quadratic objective function (p. 1668): "One limitation of this approach, however, is that the models that are currently available do not seem to capture what many would argue is a major cost of inflation, the uncertainty that its variability generates for lifetime planning and for business planning ..."

⁹ See also Cukierman and Muscatelli (2008). For a more extensive review, see also Nagar (2007).

¹⁰ Among them are Brainard (1967), Theil (1966), Blinder (1997) and Goodhart (2001).

¹¹ For a broader description of this topic, see Varian (1974), Zellner (1986) and Cheristofferson & Diebold (1994). For monetary policy analysis, see Nobay & Peel (1998), Ruge-Murcia (2001, 2002) and Nagar (2007).

the loss for the policy makers will be much greater than in the case of a negative deviation of the same magnitude (which tends to be linear). When $a \rightarrow 0$ we obtain the quadratic function, which is a special case of the Linex function, in which case the loss is identical in both directions. The set of preferences is therefore described by the asymmetry parameter a which is built into the function.¹²

Another feature of the Linex function is its ability to capture the uncertainty surrounding the target variable. If x is given by $x = \bar{x} + \varepsilon$, where the expectation \bar{x} is conditional in this process and the distribution of the disturbance ε is conditionally normal with variance σ^2 , then, as shown by Christofferson & Diebold (1994), the expected loss is:

$$E(L) = (e^{a(\bar{x} + \frac{a}{2}\sigma_x^2)} - a\bar{x} - 1) / a^2. \quad (2)$$

Equation (2) implies that the expected value of x depends not only on the average \bar{x} (as in the case of a quadratic function, which assumes certainty equivalence), but also on $\bar{x} + \frac{a}{2}\sigma_x^2$.¹³ In other words: unlike the quadratic function, the Linex function takes into account uncertainty, which is priced both by the *degree* and the *direction* of risk aversion, as expressed by a , and the *amount* of risk σ^2 . When $a \rightarrow 0$, a quadratic function is obtained and the degree (and thus also the amount) of uncertainty becomes irrelevant.

4. The Model

4.1 The Economy

The basic economy follows a New Keynesian (NK) dynamic model with temporary nominal price rigidities. The model consists of two equations: the aggregate demand (AD or IS) equation and the aggregate supply (AS) equation, which is an expectations-augmented Phillips curve.¹⁴

¹² For an illustration of the Linex function, see Appendix 1.

¹³ See also Nobay & Peel (1998).

¹⁴ See, for example, CGG (1999), Woodford (2003) and Gali (2008).

4.1.1 The aggregate demand (AD) equation

The AD equation is given by:

$$x_t = E_t x_{t+1} - \varphi(i_t^l - E_t^l \pi_{t+1}) + g_t \quad (3)$$

where the output gap, x_t , is the difference between current output, y_t , and natural output, y^n (the output obtained if prices and wages are fully flexible), i.e. $x_t = y_t - y^n$; x_t is negatively affected by the real expected interest rate, which is the difference between the nominal monetary interest rate i_t^l and the expected inflation rate in the subsequent period, $E_t^l \pi_{t+1}$. Therefore, the real expected interest rate embodies the natural (long run) interest rate, r_t^n . (The symbol l indicates level in order to distinguish between levels and deviations from the announced inflation target.) We also assume that $\varphi > 0$. The shock g_t , which shifts the AD curve, can be induced by the government or the private sector and is serially correlated according to an AR (1) process, i.e. $g_t = \mu g_{t-1} + \varepsilon_t^g$ where $1 > \mu > 0$. ε_t^g is white noise and therefore is unforecastable on the basis of the information available to the CB at the beginning of period t .

4.1.2 The aggregate supply (AS) equation

The aggregate supply equation is given by:

$$\pi_t^l = \lambda x_t + \beta E_t^l \pi_{t+1} + v_t \quad (4)$$

Assuming $\lambda > 0$, $\beta \in (0,1]$, where β is a discount factor. This rather standard equation describes the inflationary process by relating the inflation rate to the output gap and expected inflation and has the flavor of a traditional expectation-augmented Phillips curve. However, the equation evolves from Calvo's price-staggering process, in which firms set nominal prices based on the expectation of future marginal cost. The shock v_t is a "cost push" shock which captures everything else except pressure from the demand side, which may have an unexpected impact on marginal cost and follows an AR(1) process, i.e. $v_t = \mu_v v_{t-1} + \varepsilon_t^v$ where $1 > \mu_v > 0$.¹⁵ Here again ε_t^v is white noise and is unforecastable on the basis of the information available to the CB at the beginning of period t .

¹⁵ For elaboration on the AS equation, see, for example, CGG (1999), Woodford (2003) and Gali (2008).

4.1.3 Terminology and notation

Before proceeding with the model it will be useful to introduce some terminology and notation. The notation for time is largely consistent with the standard NK model, such as that in CGG (1999).¹⁶ The CB affects the economy through its choice of the nominal interest rate which, given the expectations of inflation, affects the real expected interest rate in equation (3), which in turn affects the output gap and, following that, inflation in equation (4), where $E_t x_{t+1}$ and $E_t \pi_{t+1}$ are the private sector's expected values of these variables at the beginning of period t for the beginning of period $t+1$. It is assumed that the policy horizon is one year ahead, which will be denoted by time t . Although the CB can make decisions during the year, say at monthly intervals, its decisions are always forward-looking one year ahead. Therefore, the timing of the decision is always at the beginning of that one-year-ahead period and the decision is conditioned on all the information available at the time, i.e. at the *beginning* of period t . The information set also includes the announced inflation target for the year ahead, π_t^* , and the private sector's expectations of inflation and output, $E_t \pi_{t+1}$ and $E_t x_{t+1}$, respectively, which are also conditioned on the information available at the beginning of period t . The model will assume a discretionary policy regime such that the CB reoptimizes inflation and the output gap for the coming year at each decision point. The CB makes its decision prior to the realization of the white noise shocks, taking into account the available information set and makes use of its interest rate tool to achieve the optimized levels of the variables.

However, the optimized inflation level π_t^j for the coming year may be different than the inflation target π_t^* due to shocks that have already been realized and may take longer than

¹⁶Recall that the NK model is micro-founded. The AD equation is obtained by loglinearizing the consumption Euler equation resulting from the household's optimal saving decision, where c_t and $E_t c_{t+1}$ refer to current and next-period consumption, respectively, and $E_t \pi_{t+1}$ is expected inflation in the next period. The supply equation (4) is obtained by aggregating the individual firm's pricing decisions, which involves Calvo's staggered nominal price-setting process. In this feature, π_t and $E_t \pi_{t+1}$ are defined as $\pi_t = p_t - p_{t-1}$ and $E_t \pi_{t+1} = E_t p_{t+1} - p_t$, respectively (where p denotes price). However, the model implies that current inflation and consumption depend on *the future course* of these variables and hence the CB optimizes (under discretion) current inflation and the output gap (which is a variant of the consumption gap since there is no government in the model), subject to the constraints on behavior implied by equations (3) and (4), which include those expected variables.

one year to converge to zero according to the $AR(1)$ process (and therefore x_t may also differ from zero).

The model will be described hereafter in terms of deviations from the inflation target.¹⁷ This is done for convenience and to facilitate the empirical analysis and does not affect the results. By subtracting π_t^* from both side of the equation (4) (the Philips equation) we obtain: (i) the inflation deviation given by $\pi_t = \pi_t^l - \pi_t^*$ where the symbol l denotes level. (ii) the expected inflation deviation given by $E_t \pi_{t+1} = E_t^l \pi_{t+1} - \pi_t^*$ and therefore (iii) the nominal interest rate deviation given by $i_t = i_t^l - \pi_t^*$ in equation (3). Note also that in the steady state the nominal interest rate level is given by $i_t^l = \pi_t^* + r_t^n$, and when expressed as a deviation $i_t = r_t^n$ where r_t^n is the real natural (long run) interest rate. Note that $i_t \neq r_t^n$ in situations other than steady state.

4.2 The Policy Objective

The CB's problem is to choose an interest rate path that will guide the target variables – the inflation rate and the output gap – to their targets. In mathematical terms, it wishes to minimize the loss function, which has the following general formulation:

$$\frac{Min}{\{i_t\}} E_t \sum_{t=0}^{\infty} \beta^t L(\pi_t, x_t),$$

subject to the behavioral constraints in equations (3) and (4). This formulation, which is commonly found in the literature, contains two objectives, the inflation gap relative to the target and the output gap. The specific form of the loss function is Linex for the inflation target and quadratic for the output gap. Thus:¹⁸

$$L = \frac{1}{a^2} [(e^{a(\pi_t + k\pi_t^*)} - a(\pi_t + k\pi_t^*) - 1] + \frac{\alpha}{2} (x_t)^2, \quad (5)$$

¹⁷An analogous way of thinking about this is the case of an inflation target of zero: in such a case, equation (4) is actually determined in terms of deviations.

¹⁸The output gap enters here in quadratic form and does not exhibit Linex-type behavior. This is done because our focus is on inflation policy and because it complicates the model. However, this is often done in the literature – see Dolado et al. (2004), Ruge-Murcia (2001, 2002, 2003, and 2004) and CGG (1997) which tested for asymmetry with respect to only one policy variable. Surico (2007) used the Linex function for both target variables.

where $\alpha \geq 0$ reflects the weight attributed by policy makers to the output target.¹⁹ Note that in this expression the Linex terms differ from their standard form as shown in equation (1). The parameter k captures the extent to which the CB considers a *hidden* inflation target – which is unknown explicitly to the public and differs from the announced target, π_t^* . The total deviation of inflation from the *hidden target* is given by $\pi_t + k\pi_t^*$ and is composed of two parts: the deviation of inflation from the announced target, $\pi_t = \pi_t^l - \pi_t^*$; and the gap between the announced target and the hidden one, $k\pi_t^*$, which we will refer to as the "target gap". When $k=0$ there is no hidden target and the target gap is zero. However, when $k \neq 0$ the CB has adopted a hidden target. When $k > 0$, the hidden target is less than the announced one. For example, if the announced target is $\pi_t^* = 2\%$ while the hidden target is 1.5%, then $k = 0.25$ and the target gap is 0.5%. Note that in general k can also be negative and in such cases the hidden target exceeds the announced target. However, since our interest focuses on undershooting the announced inflation target, the relevant range is $k \in [0,1]$. The further k deviates from zero, the lower is the hidden target (in comparison to the announced target) and the larger is the target gap. When $k=1$, the hidden target is zero and the target gap is at its maximum level.

It should be emphasized that expression (5) contains two parameters that differentiate between asymmetric policy behavior, which is motivated by uncertainty along with aversion to inflation (IAP) and expressed by the parameter α , and hidden target behavior, which may have other motives, and is expressed by the parameter k . Our task is to minimize the CB's expected loss function and obtain econometric equations that will enable us to estimate these parameters.²⁰

¹⁹ When $\alpha = 1$, the weight attributed to both targets – inflation and output – is the same; when $\alpha = 0$ policy is directed at achieving only the inflation target. Thus, $1/\alpha$ is the relative weight attributed to the inflation target (see also Svensson, 2003).

²⁰ In light of comments offered by one of the referees, it is worth emphasizing that there is no need for assumptions regarding agents' " α and k ". The public's expectations of these parameters are embodied in the market's inflation expectations (to be explained later). Furthermore, there is no need for an assumption regarding the Central Bank's " α and k ". Therefore, the paper investigates whether these parameters do indeed exist, i.e. are different from zero, and what their magnitudes are. However, if the parameters do indeed exist, the CB knows what they are since it behaves rationally. Consequently, the econometrician faces uncertainty with regard to the true parameters.

4.3 Optimization

Optimizing (5) subject to the behavioral constraints in equations (4) yields the following Lagrangian:

$$L = \left\{ \frac{1}{a^2} [(e^{a(\pi_t + k\pi_t^*)} - a(\pi_t + k\pi_t^*) - 1] + \frac{\alpha}{2} (x_t)^2 + \gamma(\pi_t + k\pi_t^* - \lambda x_t - \beta E_t \pi_{t+1} - k\pi_t^* - v_t) \right\} \quad (6)$$

where γ is the Lagrange constraint and the term $k\pi_t^*$ appears on both sides of (4).²¹

We will consider the case of policy under discretion (i.e. in the absence of commitment to a rule), in which the CB cannot directly manipulate the private sector's expectations, which are therefore taken as given in solving the optimization problem. In addition, the course of future inflation and output is not affected by today's actions from the CB's point of view (even though, conditional on the CB's optimization, the private sector forms its expectations rationally). Hence, **in each period**, the CB chooses the target variables (x_t, π_t) and then the interest rate in an effort to optimize the objective function L (i.e. to minimize loss).²²

Differentiating with respect to inflation yields:²³

²¹ This solution is obtained when the CB maximizes its objective function subject to only the AS equation as a constraint, rather than both the AS and AD equations which are in principle both necessary. Following CGG (1999) pp. 1671-1672, this solution is more convenient and divides the problem into two stages: the one discussed in the text followed by the second stage to determine the value of i_t as implied by the demand curve, i.e. the interest rate that will support π_t and x_t . In principle, we could describe this problem as the CB choosing the triple $\{\pi_t, x_t, i_t\}$ in each period, i.e. the two target variables together with the interest rate instrument, in order to optimize the objective function subject to the AD and AS curves. This solution produces the same results from the CB's response function, although it is less convenient. Due to lack of space, the solution is not presented in the appendices, but is available from the author.

²² The case under discretion differs from that under commitment. Under commitment, the CB commits over the course of its future monetary policy and hence expectations of inflation are directly manipulated by the policy. Consequently, the optimization will be multi-period rather than over only one period. See, for example, CGG (1999) as well as Woodford (2003).

²³ Note that since the differentiation is by $(\pi_t + k\pi_t^*)$ rather than by π_t , as is the usual case, $k\pi_t^*$ had to be added to both sides of the supply equation (4) when entered as a constraint in (6). However, this element drops out in any case in the differentiation and the results are the same as when optimizing only with respect to π_t . This outcome is due to the fact that even when the total deviation of inflation from the hidden target is optimized, both ingredients of the hidden element, i.e. $k\pi_t^*$, are parameters or exogenous state variable, respectively, and hence are not subjected to the CB's optimization. Nonetheless, the optimization is formulized with respect to $(\pi_t + k\pi_t^*)$ for the sake of model consistency.

$$\frac{\partial(L)}{\partial(\pi_t + k\pi_t^*)} = \frac{1}{a^2} (e^{a(\pi_t + k\pi_t^*)} * a - a) + \gamma = 0$$

$$\frac{1}{a} (e^{a(\pi_t + k\pi_t^*)} - 1) = -\gamma \quad . \quad (6.1)$$

Differentiating with respect to the output gap yields:

$$\frac{\partial(L)}{\partial x_t} = \alpha x_t - \gamma \lambda = 0$$

$$\gamma = \frac{\alpha}{\lambda} x_t \quad . \quad (6.2)$$

Combining (6.1) with (6.2) yields:

$$\Rightarrow \frac{1}{a} (e^{a(\pi_t + k\pi_t^*)} - 1) = -\frac{\alpha}{\lambda} x_t$$

$$x_t = \frac{-\lambda}{\alpha a} (e^{a(\pi_t + k\pi_t^*)} - 1) \quad . \quad (6.3)$$

Substituting (6.3) into equation (4) (the supply equation) yields:

$$\pi_t = \frac{-\lambda^2}{\alpha a} (e^{a(\pi_t + k\pi_t^*)} - 1) + \beta E_t \pi_{t+1} + \nu_t \quad . \quad (6.4)$$

Assuming that inflation is a normally distributed process, the exponent term is characterized by a lognormal distribution, as in equation (2). By taking expectations and rearranging the terms in (6.4) we obtain:

$$E(\pi_t) - \beta E_t \pi_{t+1} = \frac{-\lambda^2}{\alpha a} (e^{a[E(\pi_t) + k\pi_t^* + \frac{a}{2}\sigma_\pi^2]} - 1)$$

$$1 - \frac{\alpha a}{\lambda^2} E(\pi_t - \beta E_t \pi_{t+1}) = e^{a[E(\pi_t) + k\pi_t^* + \frac{a}{2}\sigma_\pi^2]} \quad (6.4')$$

Taking the logs of both sides of (6.4') and rearranging yields:

$$\frac{1}{a} \ln[1 - \frac{\alpha a}{\lambda^2} E(\pi_t - \beta E_t \pi_{t+1})] = E(\pi_t) + k\pi_t^* + \frac{a}{2}\sigma_\pi^2 \quad . \quad (6.5)$$

For the purpose of solving this equation, we will use the following approximation:

$$\ln\left[1 - \frac{\alpha a}{\lambda^2} E(\pi_t - \beta E_t \pi_{t+1})\right] \cong -\frac{\alpha a}{\lambda^2} E(\pi_t - \beta E_t \pi_{t+1}).^{24} \quad (6.6)$$

Applying this to (6.5) yields:

$$-\frac{\alpha}{\lambda^2} E(\pi_t - \beta E_t \pi_{t+1}) = E(\pi_t) + k\pi_t^* + \frac{a}{2} \sigma_\pi^2. \quad (6.7)$$

Rearranging terms gives:

$$E(\pi_t) \left(1 + \frac{\alpha}{\lambda^2}\right) = -k\pi_t^* - \frac{a}{2} \sigma_\pi^2 + \frac{\alpha}{\lambda^2} \beta E_t \pi_{t+1}$$

$$E(\pi_t) = -\frac{k}{1 + \frac{\alpha}{\lambda^2}} \pi_t^* - \frac{a}{1 + \frac{\alpha}{\lambda^2}} \frac{\sigma_\pi^2}{2} + \frac{\alpha \beta}{\lambda^2 + \alpha} E_t \pi_{t+1}, \text{ or}$$

$$E(\pi_t) = -\frac{k}{\theta} \pi_t^* - \frac{a}{\theta} \frac{\sigma_\pi^2}{2} + \frac{(\theta-1)\beta}{\theta} E_t \pi_{t+1}, \text{ where } \theta = 1 + \frac{\alpha}{\lambda^2} > 1. \quad (6.8)$$

Equation (6.8) describes the average inflation deviation as a function of three components: (i) the inflation target gap, which depends on k , (ii) the extent of asymmetric behavior as captured by a and the magnitude of uncertainty (i.e. σ_π^2) and (iii) expected inflation. The first two components imply that Inflation will be lower for higher a and k . If both parameters are equal to zero, expected inflation is determined only by the last component, i.e. expected inflation. Another important implication of equation (6.8) is that both asymmetry and a hidden target can exist simultaneously. In other words, even when the CB adopts a hidden target for whatever reason, there is still the possibility of asymmetric policy (and vice versa) due to uncertainty.

Since all the variables in equation (6.8) are known it can be econometrically estimated:

$$\pi_t = c_0 - c_1 \pi_t^* - c_2 \frac{\sigma_\pi^2}{2} + c_3 E_t \pi_{t+1} + \varepsilon_t \quad (6.8')$$

²⁴ The approximation holds as long as we limit the inflation gap to less than say 20%. This is not the case for a disinflation process in which inflation declines from tens of percent to say 2%.

where: $c_1 = \frac{k}{\theta}$; $c_2 = \frac{a}{\theta}$; $c_3 = \frac{(\theta-1)}{\theta} \beta$.²⁵

4.4 The policy response function

Equation (6.8) only describes the inflation process in the absence of an interest rate response rule. Introducing the interest rate at this point is appropriate since: (i) as a policy variable it reflects CB behavior and optimization (see fn. 23) and (ii) we can benefit from an additional observed variable.

Starting from the output-gap equation (3) $x_t = E_t x_{t+1} - \varphi(i_t - E_t \pi_{t+1}) + g_t$ we isolate i_t to obtain:

$$i_t = \frac{1}{\varphi} (E_t x_{t+1} - x_t + \varphi E_t \pi_{t+1} + g_t). \quad (7)$$

From the optimum condition in equation (6.3) it emerges that:

$$E_t x_{t+1} = \frac{-\lambda}{\alpha a} (e^{a(E_t \pi_{t+1} + k\pi_{t+1}^* + \frac{a}{2}\sigma_{\pi,t+1}^2)} - 1), \quad (6.3')$$

where the inflation variance is expected for the period $t+1$. Substituting (6.3)' and (6.3) into (7) produces:

$$i_t = \frac{-\lambda}{\alpha a \varphi} (e^{a(E_t \pi_{t+1} + k\pi_{t+1}^* + \frac{a}{2}\sigma_{\pi,t+1}^2)} - 1) - \frac{-\lambda}{\alpha a \varphi} (e^{a(\pi_t + k\pi_t^*)} - 1) + E_t \pi_{t+1} + \frac{g_t}{\varphi}, \quad (7.1)$$

and after reorganizing we obtain:

$$i_t = \frac{\lambda}{\alpha a \varphi} [(e^{a(\pi_t + k\pi_t^*)} - (e^{a(E_t \pi_{t+1} + k\pi_{t+1}^* + \frac{a}{2}\sigma_{\pi,t+1}^2)})) + E_t \pi_{t+1} + \frac{g_t}{\varphi}]. \quad (7.1')$$

Using the approximation feature (for the proof see appendix 2):²⁶

²⁵ Note that in (6.8') the variance must be treated as a variable rather than as a constant since if it is treated as a constant then (6.8') yields the following formula:

$\Rightarrow (6.9) \pi_t = \delta_0 + \delta_1 \pi_t^* + \delta_3 E_t \pi_{t+1} + \zeta_t$, and the constant term δ_0 will include the term $c_2 = \frac{a}{\theta} \frac{\sigma_{\pi}^2}{2}$. Consequently, the parameter a will vanish within δ_0 .

²⁶ This is correct when the z's are small enough. In our case (and as in approximation (6.6) above), inflation is measured as a two-place decimal. Thus, for example, a 2% inflation target is expressed as 0.02 and the approximation has no significant deviation. Even when z_1 is 20% and z_2 is 10% the deviation is only one percent. Nevertheless, we should emphasize that this approximation is incorrect during the disinflation process when at its start the inflation rate is in the tens of percent.

$$e^{z_1} - e^{z_2} \cong e^{z_1 - z_2} - 1 \quad (7.2)$$

and rearranging yields:

$$i_t = \frac{\lambda}{\alpha a \varphi} \left(e^{a[(\pi_t - E_t \pi_{t+1}) + k(\pi_t^* - E_t \pi_{t+1}^*) - \frac{a}{2} \sigma_{\pi, t+1}^2]} \right) + E_t \pi_{t+1} + \frac{g_t}{\varphi}. \quad (7.3)$$

The last expression reflects the interest rate response to a change in expected inflation.²⁷ In addition, the interest rate response depends also on $\pi_t^* - E_t \pi_{t+1}^*$, which is the spread between the current year's official target and the expected official target for the subsequent year (which will be or has already been announced). In many economies, including Israel's, when the disinflation process ended the official target turned out to be a multi-period target. Therefore, the current target is actually the next-period target as well, i.e. $\pi_t^* = E_t \pi_{t+1}^*$, and therefore the term that includes the parameter k in equation (7.3) disappears. However, during the disinflation process, the official target gradually converges to the long-run target and therefore the term $\pi_t^* - E_t \pi_{t+1}^*$ in expression (7.3) is positive during that period (in general). In the case of Israel, for example, during the 1990's and up until 2002 the official target, in most cases, was announced for only one (calendar) year; only starting in 2003 was the long-run target of 1-3 percent adopted. Hence, there will be a few years in which $\pi_t^* \neq E_t \pi_{t+1}^*$ and thus the estimated parameter k may differ from zero.

By rearranging terms and taking logs from both sides of equation (7.3) we obtain:

$$\ln(i_t - E_t \pi_{t+1} - \frac{g_t}{\varphi}) = \ln\left(\frac{\alpha a \varphi}{\lambda}\right) + a(\pi_t - E_t \pi_{t+1}) + ak(\pi_t^* - E_t \pi_{t+1}^*) - \frac{a^2}{2} \sigma_{\pi, t+1}^2 \quad (7.4)$$

and finally for estimating purposes, we use the following econometric equation:

$$\ln(i_t - E_t \pi_{t+1}) = \ln\left(\frac{\alpha a \varphi}{\lambda}\right) + a(\pi_t - E_t \pi_{t+1}) + ak(\pi_t^* - E_t \pi_{t+1}^*) - \frac{a^2}{2} \sigma_{\pi, t+1}^2 + \varepsilon_t, \quad (7.5)$$

²⁷ For the linear case and in the NK model under discretion, it is a necessary condition for determinacy that the interest rate response function with respect to expected inflation be greater than one. See, for example, Woodford (2003) as well as CGG (1999). However, in the case of the Linex non-linear function used here it can be shown that it is always greater than one, even when the parameter a is negative. The proof appears in Appendix 3 which also shows that when $a > 0$, the response is higher than in the quadratic case and when $a \rightarrow 0$, which is the quadratic case, we obtain exactly the same result as in CGG (1999).

where the disturbances term on the left-hand side of equation (7.4) becomes part of the residual of equation (7.5). In contrast to equation (6.8), we can now explicitly estimate the parameters a and k .

Notice that equation (7.5) is not a "classic" response function since the term on the left-hand side is the real expected interest rate rather than the usual nominal interest rate which the CB determines (even though the real interest rate is an outcome of its policy). In this equation, we cannot separate the left-hand side variables because of the equation's (semi) logarithmic form. Note also that (7.5) does not include output as in the typical Taylor rule case²⁸ since the first-order condition for output is expressed in terms of inflation and the coefficients by way of equation (6.4).

4.5 Interest rate smoothing

The interest rate response function (equation 7.5) is derived from an optimization process. However, it is widely known that CBs generally smooth their response, i.e. they only partially adjust to the optimal interest rate derived from (7.5). CBs choose to act in this way for a number of reasons: (i) *uncertainty* – In practice, the current condition of the economy and the source, size and persistence of shocks may be uncertain; thus policy-makers prefer to adopt more moderate measures. (ii) *Political-economic factors* – As noted by Blinder (1998), raising the interest rate can be more difficult than cutting it due to political-economic circumstances. (iii) *Financial stability* – Large and unexpected changes may result in undesirable shocks to the financial markets and intermediation.²⁹

Smoothing of the interest rate takes the following form:

$$i_t^A = \rho(i_{t-1}^A) + (1 - \rho)i_t + \zeta_t \quad (7.6)$$

where i_{t-1}^A is the current actual interest rate (the decision for which took place in the previous period) which is weighted by the proportion $\rho \in [0,1]$, and i_t is the optimized interest rate response as in Eq. (7.4). To obtain an expression similar to (7.5), expected inflation (one period ahead) is subtracted from both sides of (7.6):

$$i_t^A - E_t \pi_{t+1} = \rho(i_{t-1}^A - E_t \pi_{t+1}) + (1 - \rho)(i_t - E_t \pi_{t+1}) + \zeta_t \cdot \quad (7.6)'$$

²⁸ See Taylor (1993), CGG (2000) and Sussman (2007) among others.

²⁹ See Cukierman (1992) among others.

In other words, the CB actually takes into account only the fraction $(1 - \rho)$ of the right-hand side of (7.5). Assuming the same semi-logarithmic form as in (7.5) and substituting (7.6)' into it yields the econometric equation to be estimated:

$$\begin{aligned} \ln(i_t^A - E_t \pi_{t+1}) &= (1 - \rho)d_0 + (1 - \rho)a(\pi_t - E_t \pi_{t+1}) + (1 - \rho)ak(\pi_t^* - E_t \pi_{t+1}^*) \\ &- (1 - \rho)\frac{a^2}{2}\sigma_{\pi,t+1}^2 + \rho(i_{t-1}^A - E_t \pi_{t+1}) + \varepsilon_t^A. \end{aligned} \quad (7.7)$$

where d_0 is the constant that includes the term $\ln(\frac{\alpha a \varphi}{\lambda})$ in (7.5). With respect to the variance of the inflation term in (7.7), we assume that the disturbances in equation (4) follow an $AR(1)$ process (i.e. $v_t = \mu_v v_{t-1} + \varepsilon_t^v$ where $1 > \mu_v > 0$) and therefore $v_{t+1} = \mu_v v_t + \varepsilon_{t+1}^v$ and conditional on v_{t-1} (which is assumed to be known) we obtain $v_{t+1} | v_{t-1} = \mu_v^2 v_{t-1} + \varepsilon_{t+1}^v$. Hence the conditional variance term in (7.7) is $(1 - \rho)a^2 \mu_v^2 \frac{\sigma_{\pi,t-1}^2}{2}$ and therefore (7.7) turns to be:

$$\begin{aligned} \ln(i_t^A - E_t \pi_{t+1}) &= (1 - \rho)d_0 + (1 - \rho)a(\pi_t - E_t \pi_{t+1}) + (1 - \rho)ak(\pi_t^* - E_t \pi_{t+1}^*) \\ &- (1 - \rho)a^2 \mu_v^2 \frac{\sigma_{\pi,t-1}^2}{2} + \rho(i_{t-1}^A - E_t \pi_{t+1}) + \varepsilon_t^A. \end{aligned} \quad (7.7')$$

Recall that the variance term is not important in itself, i.e. it is of no help in our main task of finding the parameters a and k . However, ignoring this term can lead to bias in estimating the main parameters due to specification error and therefore it may be important to include it.

This is the final equation of the model, which can be econometrically estimated and in which the parameters a, k (and now also ρ) can be explicitly estimated. Therefore, we can now proceed to the estimation of two equations, i.e. (6.8)' and (7.7)'. Recall that the first estimation equation is:

$$(6.8)' \quad \pi_t = c_0 - \frac{k}{\theta} \pi_t^* - \frac{a}{\theta} \frac{\sigma_\pi^2}{2} + \frac{(\theta - 1)\beta}{\theta} E_t \pi_{t+1} + \varepsilon_t. \quad (6.8')$$

For estimation purposes, it is important to emphasize that (7.7') can be interpreted as the forward-looking (ex-ante) view, i.e. each month the CB makes its decision (regarding the dependent variable) according to the variables on the right-hand side of the equation.

Equation (6.8)', on the other hand, can be interpreted as the ex-post view, i.e. each month the annual actual inflation rate is compared to the explanatory variables on the right-hand side as they were known one year previously when the decision was made.

5. Estimation and data

The estimation uses Israeli data for the period 1992:1-2007:06. Monetary policy during this period was dominated by the Bank of Israel's two Governors: Jacob Frankel from 1991-1999 and David Klein from 2000-2004.³⁰ In what follows, we first provide a short background and then present the data.

5.1 *The Israeli case*

The Bank of Israel first announced an Inflation target at the end of 1991³¹ for the 1992 calendar year (the target was 14-15 percent). However, due to the prevailing exchange rate regime, it was actually aimed at supporting the 9% slope of the newly-adopted diagonal (crawling peg) exchange rate band, which had replaced the previous horizontal band. Under this regime, the intention behind interest rate decisions was unclear: were they meant to influence the exchange rate or inflation?³² According to the official point of view, since the exchange rate regime is under the Government's mandate, monetary policy had to be restricted in order to support the exchange rate band as its first priority. The first inflation target was announced by the Government (only) in Sept. 1994 for the 1995 calendar year (see Table 1).

In light of the above, data from 1992-1993 will not be included. One could argue that 1994's data should not be used either. However, it should be noted that the use of the interest rate as the monetary instrument during 1994 was more directed at inflation than the exchange rate since the actual exchange rate was not bounded and was located in about the middle of the band. Another reason for including 1994 is the jump in the inflation rate that year (see Figure 1), which appeared to reinforce the Governor's intention of fighting inflation, as reflected in the first government announcement at the end of that year .

³⁰ Governor Stanley Fischer began his tenure in May 2005. His impact is only on the margin of this period, especially after taking into account the lagged impact of monetary policy.

³¹ In this respect, Israel was the third economy to announce an inflation target (after New Zealand and Canada). However, it was the CB's own independent announcement, rather than a joint announcement with the Government.

³²See Nagar (2002) and Sussman (2007). Barro and Gordon (1983) claim that such unclear response behavior, which is inconsistent with the self-declared monetary policy, is quite common.

Since 1994, the CB's desire to achieve the inflation target as opposed to maintaining the exchange rate (especially when it was bounded) was a source for much of the tension and debate between the CB and the Government (i.e. the Treasury).³³ In a few instances, the differences were resolved by reaching an agreement between them (hereafter: "deals"). As part of most of these deals, the CB lowered the interest rate while simultaneously widening the exchange rate band, a phenomenon that will be further discussed below.

Lowering actual inflation also depends on the target level set by the government. As can be seen in Figure 1, the target did not change dramatically during the period 1994-1998. This was also a source of tension between the CB and the Government since the CB wished to reduce inflation while the government was not yet prepared to "pay" the required price and to lower the target. However, it is reasonable to assume that it was more convenient for the politicians to fix the subsequent year's target at the current level of inflation than to lower it. For this reason, it may be a reasonable hypothesis that the CB had a hidden target which was lower than the announced one. Sussman (2007) claims that the CB had a hidden target of zero.

There are two additional parameters that are relevant to our estimation and assumptions: the horizon of the target and the timing of the announcement. As shown in Table 1, until 2000 the target level was announced for one calendar year and the announcement for the next (calendar) year was generally made at the end of the current year. Thus, as a result of the lag in the effect of monetary policy and the policy horizon of one year, there were numerous (monthly) interest rate decisions – especially during the second half of the calendar year – that were taken without knowing the official target for the subsequent year, although it was relevant for the coming 12 months. Against this background, there is a need for some assumptions and data adjustments, which will be discussed in the next section.

5.2 The data

5.2.1 *The estimation period* - The estimation is carried out using monthly data for the period 1994:1-2007:06, for a total of 162 observations. Two sub-periods were also used for comparison: 1994:1-1999:12 and 2000:01-2007:06. These sub-periods were chosen not only because they (roughly) coincide with the tenures of the two governors (Frankel and Klein, respectively), but also because the two periods differ so significantly. Thus, during the first

³³For more details, see Nagar (2002).

sub-period inflation converged from 10% to 2%, while during the second it was already near its long run level (Figure 1) and target levels were known for subsequent periods as well, rather than just for the current or next calendar year (see Table 1). Thus, generally speaking, the CB's job during the second period was to keep the inflation at its long run level, rather than lowering it as was its role during the 90's.

Table 1: Timing of the target announcement, the inflation targets and actual and expected inflation				
Timing of Announcement	Target Year	Inflation target (%)	Current inflation (%) ¹	Expected Inflation (%) ¹
12/1991	1992	14-15	18	15.1
11/1992 (beg.) ²	1993	10	8.1	8.6
07/1993 (end) ²	1994	8	10.6	8.0
09/1994 ³	1995	8-11	13.8	12.4
10/1995 (beg.) ²	1996	8-10	8.7	10.0
27/12/1996 ⁴	1997	7-10	10.6	8.9
8/8/1997 ⁵	1998	7-10	9.2	9.0
12/8/1998	1999	4	3.0	3.1
10/8/1999 ⁶	2000-1	3-4	6.3	3.7
16/8/2000	2001	2.5-3.5	1.0	1.6
	2002	2-3		
	from 2003 onward	1-3		

¹ As it was known at the time of the announcement. ² (beg.) and (end) denote the beginning and end of the month. ³ This is the first announcement that was a Government (rather than CB) decision. ⁴ The target also included achieving the average OECD rate of inflation in 2001. ⁵ The target also included achieving long run price stability through gradual convergence of the inflation rate. ⁶ The target was announced for two subsequent years (rather than one as previously).

5.2.2 *Measurement* - The annual Inflation rate is measured in terms of moving years. Its variance is calculated for a moving 12 months of annual inflation rates. One could argue that monetary policy should be judged according to the calendar year, rather than a moving year. However, the limited number of observations does not allow for this. Expected inflation for one year ahead is derived from the financial markets.³⁴

5.2.3 *The target horizon* - The inflation target is defined here as the middle of the target range. It is assumed that the horizon for monetary policy is, at any decision point, 12 months ahead. Table 1 shows the timing of the target's announcements for the subsequent year. It follows from the table that there were many monthly policy decisions made without knowing the target for the full policy horizon period. Take, for instance, the target of 7-10 percent for 1998 and the target of 4 percent for 1999 which was only announced in August 1998. Thus, in July 1998, the target for the next 12 months was not yet known. Therefore

³⁴ Since there are CPI-indexed government bonds in Israel, expectations of inflation can be derived from the difference in yields between indexed and non-indexed bonds of the same maturity.

the question arises of what target should be used in the estimation: 8.5 percent or 4 percent or an average of the two? We will consider two different cases below (denoted as specifications A and B).

5.2.4 *Dummy variables* – The first group of dummies captures the deals between the CB and the Government as described above. Following a deal, the timing as well as the size of the interest rate reductions deviated from the norm and were based on political-economic considerations rather than a "pure" economic rationale. The variable dum95 represents the May 1995 deal, which led to a one-percentage point (pp) interest rate cut while the exchange rate band was widened to 7% on either side of its mid-point. dum97 captures the June 1997 deal, in which the interest rate was cut by 1.2 pp while the exchange rate band was widened by another 14% (i.e., to a band of 28%). dum98 captures the August 1998 deal that led to a 1.5 pp interest rate cut while the slope of the lower band was lowered from 4% to 2%.³⁵ dum01 captures the December 2001 deal, in which the interest rate was cut by 2 pp in return for a promise by Prime Minister Sharon to reduce the budget deficit.

Another aspect of the deals is the length of the period during which they affected the CB's interest rate decision. Therefore, the second group of dummies captures the *possible delay* in interest rate response following a deal. As an example, the June 1997 deal led to a cut of 1.2 pp but it is not reasonable to assume that the monetary policy decision during the same month (or one month later, in July) was unaffected by the deal. This is because such an immediate increase after a sharp interest rate cut would undermine the Governor's credibility and his image of independence. Thus, the groups of dummies denoted as dum (j), $j=\{0,1,2,3,4\}$ control for a delay of 1-5 months following the month of the deal.

5.3 Estimation Method

There are two equations to estimate: (6.8)' and (7.7)'. The first was estimated using OLS and the second using three different approaches: OLS which will be referred as the base case; non-linear OLS (NLS) following comments on previous versions of the paper; and Instrumental Variables (IV) using GMM which will be discussed at a later stage.

The OLS estimation was carried out using the Newey-West procedure and with auto-correlation of up to order 2 (i.e. AR(1) and/or AR(2)) in order to overcome serial correlation and possible heteroskedasticity. The commonly used General to Specific Approach (GTSA)

³⁵ For more details, see Nagar (2002).

was also used, which starts with an unrestricted regression using all the variables and their cross products and gradually deletes the insignificant variables. The variables' names and their descriptions appear in Appendix 4.

6. OLS Estimation Results – the Base Case

6.1 The Results for Equation (6.8)'

Equation (6.8)' in monthly terms yields the following equation:

$$\pi_m = c_0 - \frac{k}{\theta} \pi_{m-12}^* - \frac{a}{\theta} \frac{\sigma_{\pi,m}^2}{2} + \frac{(\theta-1)\beta}{\theta} E_{m-12} \pi_m + \varepsilon_t, \quad (6.9)$$

where m denotes month and all the variables are in annual terms. This equation can be interpreted to mean that in each month the success of monetary policy is judged ex-post in terms of inflation deviations. Note that the dependent variable is expressed in terms of the deviation of the actual annual inflation rate during the last 12 months, i.e. π_m^l , and the official target level for month m , assuming that this was the target level in $m-12$ for month m , i.e. $\pi_m = \pi_m^l - \pi_m^*$. This will be referred to as specification A. In specification B, $\pi_m = \pi_m^l - \pi_{m-11}^*$, where π_m^l is as explained above and π_{m-11}^* is the target in $m-12+1$, implying that the announced target when the monetary policy decision was made 12 months ago remains valid for 12 months. The variance of inflation was calculated for annual (12-month) moving inflation rates.

Table 2 shows the estimation results for equation (6.9) under specification A. The first two coefficients are both negative, indicating that *the hidden target parameter k and the asymmetry parameter a are both positive*. These results are consistent with the model and, as expected, with the Israeli narrative as well. However, while they are both significant for the period as a whole and for the 1st sub-period, during the 2nd sub-period the asymmetry parameter is not significant. In other words, the results for the 1st sub-period provide evidence for both IAP and a hidden target, thus suggesting a different motive for each. The existence of a hidden target during the 1st sub-period is consistent with Sussman (2007); however, he reached this conclusion implicitly while in our analysis this is done through an explicit specification. (He also claimed that the hidden target was zero – a claim which we will consider later.)

			1	2	3
Explanation	Variable	Coefficient	Total Period ²	1 st sub-period ²	2 nd sub-period ²
Constant	c		0.012(0.9)	0.052 (4.6)	-0.003 (-0.3)
2001 deal dummy	Dum01		0.015 (4.2)		0.016 (5.7)
The inflation target ³	π_t^*	$-\frac{k}{\theta}$	-0.53 (-8.3)	-0.5 (-8.7)	-0.71 (-2.7)
Variance of inflation	$\sigma_\pi^2 / 2$	$-\frac{a}{\theta}$	-0.56 (-2.2)	-1.33 (-3.4)	-0.21 (-0.7)
Expected inflation ⁴	$E_{-12}\pi_t$	$\frac{(\theta - 1)\beta}{\theta}$	0.37 (-3.5)	0.42 (2.9)	0.37 (2.1)
Change in the exchange rate	Log(ex(-2)/ex(-12))		0.092 (4.1)	0.13 (4.1)	0.07 (2.36)
	AR(1)		1.5 (18.9)	1.58 (14.7)	1.36 (14.6)
	AR(2)		-0.54 (-6.9)	-0.67 (-6.2)	-0.4 (-4.0)
	R ² adj		0.95	0.95	0.95
	DW		1.98	2.11	2.03
	LM (p Val.)		0.86	0.78	0.32
	Observations		151	61	90

¹ The results are obtained by applying the Newey-West procedure, with AR(1) and AR(2). The *t*-values appear in parentheses.

² Estimation period: 1994:1-2007:06. 1st sub-period: 1994:01-1999:12; 2nd sub-period: 2000:01-2007:06.

³ Multiplied by the term (log(ex(-2)/ex(-12))). ⁴ Average for lags from 10 to 12 months.

With regard to the 2nd second sub-period, in which only the hidden target parameter was found to be significant, one could ask whether this is a reasonable result, in view of the fact that the target was already at its long-run level of 1-3 percent during most of the period. One possible answer – aside from the fact that during 2000-2 the target was still above its long-run level (Table 1) – is that the hidden target was in the lower part of the 1-3 percent range, rather than in the mid-range around 2 percent.

The coefficient of expected inflation is between zero and one, as expected (recall that $\theta = 1 + \frac{\alpha}{\lambda^2} > 1$, and therefore $0 < \frac{\theta - 1}{\theta} \beta < 1$). However, it should be noted that this result was achieved by using a moving 10-12 month average of expected inflation; applying a 12-month moving average, as suggested by the theory (equation (6.9)), produces a negative coefficient, which is not a reasonable result. Interestingly, by calibrating to the conventional parameters of the NK model following Galí (2008)³⁶ we obtain approximately $\theta = 1.6$ and a coefficient of 0.37 for expected inflation, which is similar to the results in Table 2. Recall also that mathematically we can explicitly extract the parameters *k* and *a* (by moving the

³⁶ See Galí (2008) Ch. 3 page 52 and Appendix 5 for details.

parameter θ to the left-hand side of equation (6.9)). However, in this case, the dependent variable becomes $\pi\theta$ instead of π and as a result the right-hand side parameters k and a (and β) will be larger than what is shown in Table 2. For example, we obtain the result $k > 1$ which implies that the hidden inflation target was below zero - an unreasonable result. Therefore, we do not isolate these parameters and in Table 2 they appear with θ in the denominator; hence, they should be interpreted as the "impact of k and a ".

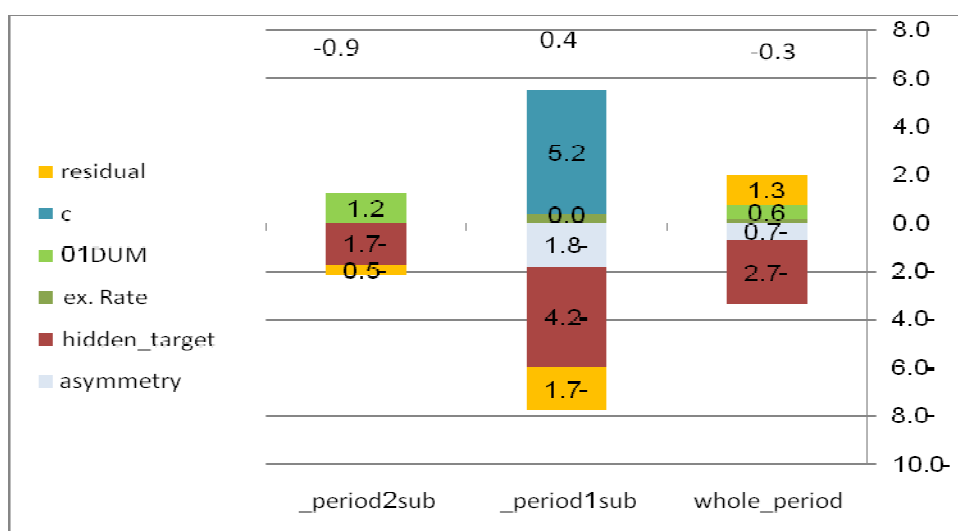
Table 3: The estimated parameters of equation (6.9) for specification A¹									
	Total period			1 st sub-period			2 nd sub-period		
A. Estimated coefficients	Low	High	Avg	Low	High	Avg	Low	High	Avg
$\frac{k}{\theta}$	0.47	0.67	0.57	0.5	0.61	0.55	0.5	0.71	0.59
$\frac{a}{\theta}$	0.56	0.61	0.58	0.68	1.33	1.41	0.2*	0.32*	0.24*
$\frac{(\theta - 1)\beta}{\theta}$	0.32	0.37	0.35	0.36	0.46	0.41	0.36	0.51	0.42
θ (derived)	1.54	1.67	1.58	1.60	1.91	1.74	1.36	2.14	1.73
B. For Reference:									
Actual 12-month inflation	4.3			8.3			1.5		
The inflation target	4.6			7.9			2.4		
¹ Changes in the NIS/\$US exchange rate. The low and high values are obtained for various exchange rate lags as explained in the text. The parameter θ is derived by calibrating beta to 0.96.									

The specification of the regression presented in Table 2 is obtained by multiplying the inflation target by changes in the NIS/\$US exchange rate, i.e. $\pi^* * \log(ex(-2)/ex(-12))$. It emerges that the parameters are sensitive to the specification of the numerator's lag. Table 3 presents the lowest, highest and average parameters as a result of varying the lag of the exchange rate between zero and 5 months, i.e. from $ex(0)/ex(-12)$ to $ex(-5)/ex(-12)$. On average, the hidden target parameter receives a value of 0.57 for the whole period and 0.55 for the 1st sub-period. In other words, while the announced target was 7.9 percent for the 1st sub-period the hidden target was 3.6 percent or 55% less. This tends to disprove Sussman's (2007) claim of a zero hidden target during the 1st sub-period. Note also that the value for θ is near the calibrated value mentioned above.

Figure 2 illustrates the contribution of the hidden target policy to reducing inflation under the specification as in Table 2 above (i.e. $\log(ex(-2)/ex(-12))$): -2.7 percent points for the whole period, -4.2 percent points for the 1st sub-period and -1.7 percent points for the 2nd sub-period. The asymmetric policy's contribution is -0.7 percent points for the whole period,

-1.8 percentage points for the 1st sub-period and insignificant for the 2nd sub-period. (The total deviation of inflation from the target is shown in Figure 2 as the part of the bars above zero; see also Table 3 part B.) The exchange rate changes contribute only slightly to the deviation in inflation (0.2 percentage points for the whole period and 0.6 percentage points for the 1st sub-period). Interestingly, expectations of inflation do not contribute to the deviation of inflation, while the constant term contributes 5.2 percentage points in the 1st sub-period. This may indicate the intensity of price stickiness during the disinflation process and the slow pace of the public's learning process, which may justify the hidden target policy (to be discussed in Section 7). Figure 2 also shows the contribution of the 2001 deal which added 1.2 percentage points to inflation during the 2nd sub-period. Recall that the contributions do not sum up to the deviation of actual inflation from the target (the part of the bars above the zero line), particularly for the whole period and the 1st sub-period. This is due to the $AR(1)$ and $AR(2)$ coefficients, which sum up to be positive (Table 2 above).

Figure 2: The variables' contribution to inflation



6.1.2 Robustness

1. It is important to note that the results were also robust to changes in the estimation periods i.e. gradually shortening the whole period to 1996:12-2004:12 and the 1st sub-period to 1996:12-2002:12. However, it is not possible to shorten the 2nd sub-period beyond 2002:01 since the variance declines to a very low level as a result of the long-run inflation target of 1-3 percent from 2003 onward.

Table 4: The estimated parameters of eq. (6.9) for π_{m-11}^* under Specification B¹									
	Total period			1 st Sub-period			2 nd Sub-period		
A. Estimated Coefficients	Low	High	Avg	Low	High	Avg	Low	High	Avg
k/θ	0.67	0.87	0.78	0.78	0.85	0.81	0.79	0.91	0.83
a/θ	0.56	0.64	0.59	1.25	1.64	1.41	0.22*	0.33*	0.26*
$(\theta - 1)\beta/\theta$	0.34	0.55	0.43	0.36	0.51	0.44	0.29	0.58	0.46
θ (derived)	1.56	2.06	1.82	1.61	2.15	1.85	1.43	2.5	1.95
B. For Reference									
Actual 12-month Inflation	4.3			8.3			1.5		
Inflation target	5.1			8.6			2.6		
¹ Changes in the NIS/\$US exchange rate. The high and low values are derived from the various exchange-rate lags as explained in the text. The parameter θ is derived by calibrating beta to 0.96.									

2. Equation (6.9) measures the success of monetary policy by comparing the actual annual inflation rate against the ex-post official target. The target variable is defined as π_m^* according to the specification in Table 2, as if policy makers knew the 12-month-ahead target at all points in time, an assumption which is only valid for most of the 2nd sub-period. Specification B adopts a different assumption (an ex-ante view) by using π_{m-11}^* instead, i.e. by using an 11-month lag, as noted above. This specification implies that this was the 12-month-ahead target level faced by policy makers that would be valid from the next month onward (i.e. $m-12+1$, one year ahead), an assumption that is mainly relevant for the 1st sub-period during which the one-year-ahead target was generally unknown (see Table 1). The results for specification B are shown in Table 4 which presents the values for k and a (as in Table 3) derived from the estimated regression coefficients for 0 to 5 lags of the exchange rate changes.

While the estimated asymmetry parameter is generally similar to that in Table 3, the parameter k is about 20% higher. This can be explained as follows: Recall that the average target is also higher than under specification A, with the difference reaching 0.5 percent for the period as a whole. In a process of disinflation, the target is diminishing over time; hence, the 12-month-ago target is higher than the true announced target for month m , i.e. $\pi_{m-11}^* - \pi_m^* \geq 0$. Consequently, the dependent variable (i.e. the deviation of inflation from the official target) is lower than in specification A above, while in contrast the target explanatory variable is higher and therefore leads to a larger coefficient.

6.2 Estimation Results for Equation (7.7)

Recall that the equation to be estimated is as follows:

$$\begin{aligned} \ln(i_t^A - E_t \pi_{t+1}) &= (1 - \rho)d_0 + (1 - \rho)a(\pi_t - E_t \pi_{t+1}) + (1 - \rho)ak(\pi_t^* - E_t \pi_{t+1}^*) \\ &+ \rho(i_{t-1}^A - E_t \pi_{t+1}) - (1 - \rho)a^2 \mu_v^2 \frac{\sigma_{\pi,t-1}^2}{2} + \varepsilon_t^A. \end{aligned} \quad (7.7')$$

Expressing the equation in monthly terms, we obtain:

$$\begin{aligned} \ln(i_{m+1}^A - E_{m-1} \pi_{m+12}) &= (1 - \rho)d_0 + (1 - \rho)a(\pi_{m-1} - E_{m-1} \pi_{m+12}) + \\ &(1 - \rho)ak(\pi_{m+12}^* - E_m \pi_{m+13}^*) + \rho(i_m^A - E_{m-1} \pi_{m+12}) - (1 - \rho)a^2 \mu_v^2 \frac{\sigma_{\pi,m-1}^2}{2} + \varepsilon_m^A \end{aligned} \quad (7.8)$$

where all the variables are in annual terms and the indexes denote the relevant month as will be explained below. As noted above, this equation differs from the conventional response function since the interest rate is defined in real rather than nominal terms on both sides and because it is semi-logarithmic. The inflation target appears here in two forms: π_{m+12}^* which is the annual target that is available for 12 months ahead; and $E_m \pi_{m+13}^*$ which is the next period's annual expected inflation target and which is available from 13 months ahead onward. However, under the assumption that the policy horizon is 12 months ahead, the question remains of how to specify π_{m+12}^* (and $E_m \pi_{m+13}^*$) due to the fact that for many years, especially during the 1990's, the official target was in fact unknown for $m+12$ (see Table 1).

Note that (7.8) can be interpreted as forward-looking and therefore, the variables are conditional on the information set available at the time of the decision. The Israeli Central Bureau of Statistics (CBS) publishes the measured inflation rate for a particular month on the 15th of the subsequent month and the Bank of Israel's meetings to set the interest rate for the next month are held after that date. In other words, the information available when the decision is made in month m is updated only to the previous month.³⁷ Consequently, the last actual figure for the annual inflation rate available at the time of the decision in month m is π_{m-1} and the expected annual inflation rate available at the time is $E_{m-1} \pi_{m+12}$.

³⁷ To be more precise, there is a flow of information for the current month from the financial markets but, in general, it does not affect the current decision.

The CB's interest rate decision each month applies from the *next* month ($m+1$) onward. Thus, the actual interest rate for each month m is dependent on information with a two-month lag, i.e. from $m-2$, and therefore, the time lag of the dependent variable in equation (7.8) is as follows: $i_{m+1} - E_{m-1}\pi_{m+12}$. On the other hand, the inflation target is known at the time of the decision and hence there is no need for any modification; nonetheless, we will use two specifications as will be explained below. Recall that the variance term is not important in and of itself since it is of no help in determining the parameters a and k . However, ignoring this term may lead to bias in the main parameters due to specification error and therefore it may be important to include it.

6.2.1 The Estimation Results

Table 5 below illustrates the estimation results for the main parameters of equation (7.8) i.e. a , k and the interest rate smoothing parameter ρ . In this case, we can explicitly determine the size of these parameters. However, this is not all that straightforward and requires some algebraic manipulation. This is because the equation is in semi-logarithmic form and therefore needs to be fitted. Also, the parameters a and k are in this case derived from the regression coefficients. The regression and the calculations are presented in Appendix 6. Note that the results for the response function (7.8) are in terms of real rather than nominal expected interest rates.

The results in Table 5 are presented for two specifications, which differ in the third term of equation (7.8) i.e. the difference between the inflation target at the time of the decision in month m for the month $m+12$ and the inflation target for $m+13$ onward. While the latter is the same for both specifications, Table 5 presents two cases for the former. Thus, for example, in August 1998 when the target for 1998 was 8.5 percent and the target announced for 1999 was 4 percent (see Table 1); the question arises as to which target monetary policy related to in September 1998 – 8.5 percent, 4 percent or a weighted average of the two. Specification A assumes 4 percent while specification B assumes 8.5 percent. Therefore, the hidden target parameter is lower in specification A, as shown in Table 5. These specifications correspond to those for equation (6.9) in Tables 3 and 4 above, respectively, which have an ex-post perspective as opposed to the ex-ante view here. However, recall that from January 2003 onward the long-run target range of 1-3 percent remained unchanged and therefore there is no difference between the specifications for

that period. Consequently, there is also a lack of variation³⁸ during the 2nd period (2000.1-2007.6), which is the reason why the hidden target is statistically not significant. Hence, it remains inconclusive as to whether a hidden target existed during the 2nd sub-period.

		Specification A ¹			Specification B ¹		
		1	2	3	4	5	6
	Parameters	Total period ²	1 st Sub-period ²	2 nd Sub-period ²	Total period ²	1 st Sub-period ²	2 nd Sub-period ²
Hidden target	K	0.39	0.55	-1.45**	0.54	0.67	-0.03**
Asymmetry	A	0.52	0.4	0.56	0.56	0.48	0.57
Interest rate smoothing	ρ	0.21	0.19	0.57	0.22	0.17	0.57
Response coefficient	$(1 - \rho)a$	0.41	0.33	0.24	0.44	0.4	0.24
	μ_v	(-)0.35**	(-)0.76**	1.11	(-)0.36**	(-)0.59**	1.24

¹ For the hidden target parameter, the specifications differ in the definition of the target for $m+12$ at the time of the decision. For example, in August 1998 the target for 1998 was 8.5 percent and in that month a target of 4 percent was announced for 1999 (see Table 1). Thus, according to specification A the target is already 4 percent from August 1998 onward while according to specification B the official target remains at 8.5 percent for 1998.

² Estimation period: 1994:1-2007:06. 1st sub-period: 1994:01-1999:12 and 2nd sub-period: 2000:01-2007:06.

** Denotes a lack of significance. The (-) sign for the μ_v parameter denotes a negative sign for the *whole* coefficient as should emerge from the last term of equation (7.8).

The fact that the parameters have positive signs is consistent with our initial expectations from the model and with the Israeli experience, which in itself is an impressive result. Consider first specification A in which the *hidden target* was found to be 0.39 for the whole period and 0.55 for the 1st sub-period. These results are somewhat lower than those in Table 3 (in which the results related to the *impact* of these parameters, rather their *explicit* size as is the case here). The *asymmetry* parameters were found to be 0.52 for the whole period and 0.4 for the 1st sub-period. The parameters are much lower than in Table 3 (where the parameter was 1.4) while for the whole period they are similar. The results for the 1st sub-period again provide evidence (as in Table 3 above) for both IAP and a hidden target, thus suggesting different motives for each. However, during the 2nd sub-period, the hidden target is not significant due to a lack of variation in the explanatory variable as noted above while the asymmetry parameter was found to be 0.57. These results are the reverse of those in Table 3 where the hidden target parameter was significant but the asymmetry parameter was not. Thus, the results in Table 3 and 5 for the 2nd sub-period are inconclusive as to

³⁸ The standard deviation of this variable is 2.98 for the whole period and 2.45 for the 1st sub period, in comparison to 0.37 for the 2nd sub-period.

whether asymmetry or a hidden target was the adopted policy, thus perhaps suggesting that one or the other was used to implement IAP policy.

The main difference between specification B and specification A is in the higher value of parameter k (0.54 for the whole period and 0.67 for the 1st sub-period). In comparison to the corresponding specification for equation (6.8)' in Table 4, the values are again lower in this case.

Another important result is related to the interest rate smoothing parameter ρ .³⁹ Thus, during the 2nd sub-period it was almost three times larger than in the 1st sub-period (0.57 according to both specifications in the 2nd sub-period as compared to 0.21 in the 1st sub-period). In other words, during the 1st sub-period, the CB's responses took less account of its past responses and hence they were more aggressive in comparison to the 2nd sub-period. This is consistent with a situation in which both the hidden target *and* asymmetry characterized the 1st sub-period, as compared to either the hidden target *or* asymmetry in the 2nd sub-period (Tables 3 to 5). Recall also that the 2nd sub-period was in general characterized by a declining interest rate, thus suggesting that the higher smoothing coefficient is also reflecting a highly conservative approach to inflation.

Note also that the coefficient of the interest rate response to an increase in the deviation of inflation from its expectations is 0.41 for the whole period, which implies about 1.4 in nominal terms. This result (i.e. a value of greater than 1) is a necessary condition for determinacy in the case of New Keynesian models under discretion (see Woodford, 2003) and also in the case of the Linex function (see the proof in Appendix 3).

The values of the μ_v parameter in Table 5 should reflect our assumption that the disturbances in equation (4) follow an $AR(1)$ process and therefore we expect $1 > \mu_v > 0$. This parameter is extracted from the coefficient of the last term of equation (7.8) which has a negative sign (note that the negative signs in parentheses in Table 5 indicate whether the estimated coefficient's sign is indeed negative). In line with our expectations, the results show that for the whole period and for the 1st sub-period the parameter is less than one and has a negative sign, although the coefficient is not significant. For the 2nd sub-period, on the

³⁹ Equation (7.8) is formulated in real terms and therefore ρ cannot be compared to the smoothing parameter in nominal terms. Argov and Elkayam (2007) estimated an NK model for Israel for the period 1992:1-2005:4 and found the smoothing parameter in Israel to be 0.8 in nominal terms.

other hand, it is significant, though it is positive and greater than one. We conclude that the parameter was not successfully extracted from the model.

6.2.2. Robustness

Besides the two specifications in Table 5, which roughly exhibit similar results, other robustness tests were also carried out. They showed that the results are generally robust to changes in, among other things, the estimation period. In addition, all the regressions were carried out using the Newey-West procedure in order to overcome possible heteroskedasticity and serial correlation.

Table A-3 in Appendix 6 presents the full regression results for specification A in Table 5. It shows the case in which dummy variables for deals (i.e. dum95 and dum01) are added as constants and dummy variables for the CB's response delay (dum2) are added to the third variable (see also Appendix 4). The main contribution of the constant dummy variables (when they were needed) was to satisfy the *LM* probability test for serial correlation. The main regression parameters were also robust to changes in these dummies for the relevant periods, i.e. dum97 or dum98 for the whole period and the 1st sub-period and dum01 for the whole period. The delay dummy variable mainly contributed to the significance of the parameters. The *main* regression parameters were also found to be robust to other delay dummies, i.e. dum, dum1, dum3 and dum4 when the serial correlation condition was not violated.

6.3 NLS regression of equation (7.8)

One could argue that equation (7.8) is nonlinear in the parameters and therefore the fact that the coefficient as a whole is significant does not prove the derived parameters to be significant as well. Table 6 shows the Eviews results for Non-Linear Regression (NLS), again for both specifications.⁴⁰ The results show that the parameter values are again similar to those in Table 5. The parameters *k* and *a* are again significant, although in general only at the 5-10% levels in comparison to the 1% level in Table 5. It is worth emphasizing that the *hidden target* parameter is once again not significant for the 2nd sub-period according to both specifications while the asymmetry parameter is. In addition, the response coefficient is similar to that in Table 5.

⁴⁰ See Appendix 7 for more detailed results of the NLS regression.

Table 6: The NLS Regression Results for Equation (7.8) – Total period and sub-periods ¹							
		Specification A ^{2,3}			Specification B ^{2,3}		
		1	2	3	4	5	6
	Parameters	Total period ²	1 st sub-period ²	2 nd sub-period ²	Total period ²	1 st sub-period ²	2 nd sub-period ²
Hidden target	k	0.48*	0.5	2.5**	0.54*	0.62*	0.64**
Asymmetry	a	0.52	0.47*	0.47	0.52	0.42*	0.42*
Interest rate smoothing	ρ	0.19	0.21	0.52	0.22	0.23	0.38
Response coefficient	$(1-\rho)a$	0.42	0.37	0.23	0.41	0.32	0.26

¹ Estimation period: 1994:1-2007:06. 1st sub-period: 1994:01-1999:12. 2nd sub-period: 2000:01-2007:06.
² For the hidden target parameter, the specifications differ in the definition of the target for $m+12$ at the time of the decision. For example, in August 1998 the target for 1998 was 8.5 percent and in that month a target of 4 percent was announced for 1999 (see Table 1). Thus, according to specification A the target was 4 percent already from August 1998, while according to specification B the official target remained at 8.5 percent.
³ Parameters are significant up to the 5% level unless denoted otherwise: * for the 10% level of significance and ** for not significant.

6.4 Estimating equation (7.8) with instrumental variables (IV) using the GMM approach

A referee commenting on a previous version of the paper claimed that equation (7.8) suffers from an endogeneity problem since the dependent variable and the second term on the right-hand side are simultaneous and therefore IV estimation is called for. For convenience, we present the equation again:

$$\ln(i_{m+1}^A - E_{m-1}\pi_{m+12}) = (1-\rho)d_0 + (1-\rho)a(\pi_{m-1} - E_{m-1}\pi_{m+12}) + (1-\rho)ak(\pi_{m+12}^* - E_m\pi_{m+13}^*) + \rho(i_m^A - E_{m-1}\pi_{m+12}) - (1-\rho)a^2\mu_v^2 \frac{\sigma_{\pi,m-1}^2}{2} + \varepsilon_m^A \quad (7.8)$$

where the month is denoted by m in annual terms. On the left-hand side, i_{m+1}^A is the interest rate decision in month m to be implemented from the next month onward (hence $m+1$), based on the information available up to month $m-1$. The variable $E_{m-1}\pi_{m+12}$ is the expectation of inflation, which is already known at the time of the decision in month m . On the right-hand side of the equation, the first term is a constant. The second is the difference between the actual annual rate of inflation, based on the latest available information (for month $m-1$) and the expected rate of inflation for the next year, i.e. 12 months onward. Recall that the expectations are derived from the financial markets and hence are treated as exogenous. The third term is the difference between the inflation target for the current year and that for the subsequent year and is exogenous since it is the result of a government

decision (rather than that of the CB). The fourth term is the lagged dependent variable – the previous month’s interest rate decision where expected inflation is updated to that month. The fifth term defines the variability of inflation and is also exogenous. The last term is the residual.

The claim of endogeneity relates to the second term on the right-hand side. The justification for using OLS is that this term is predetermined. In addition, the expectations of inflation are determined in the financial market and therefore are exogenous to the policy decision. A further justification is theoretical, whereby, under discretion, expected inflation is exogenous to the policy decision (and optimization is carried out for just one period ahead). However, in this case, it can be claimed that lagging the right-hand side variable is not an appropriate solution in a forward-looking optimization problem and that the variable is not really exogenous under rational expectations. This is because an expectation of the upcoming interest rate decision is already embodied in the expectations of inflation. In other words, expected inflation can depend on the past, current and also expected future course of the interest rate and hence may not be orthogonal to the residual. Therefore, we face a simultaneity problem even with lagged variables, which calls for IV estimation. Mavroeidis Sophocles (2005) supports this claim. He analyzes Gali and Gertler (1999) (hereafter: GG) which used GMM techniques to estimate the New Keynesian Phillips Curve (NKPC) and found that using only lagged variables in a forward-looking rational expectation model leads to bias.

6.4.1 Some background from the literature

The literature on this topic, including GG (1999), does not use expectations of inflation derived from the financial markets as is done here. Rather, actual inflation with an error term is used as the expectation of inflation, thus creating an endogeneity problem by construction. Note that in our case we use inflation expectations derived from the financial markets rather than actual inflation as in GG. (It is worth noting the difference between expected and actual inflation in Figure 1.) Nevertheless, it can be claimed that in our case the endogeneity problem still exists since under the assumption of rational expectations actual and expected inflation will move together.

Clarida and Gertler (1997, equation (8), pp. 398) estimate a Taylor-rule type of interest rate response function, i.e. with the expected inflation gap and the output gap on the right-hand side of the equation, for the Bundesbank. Their explanation for the use of IV is that

cumulative expected explanatory variables will in general depend on the current interest rate. They use three lagged values of the dependent and explanatory variables as IV's to eliminate serial correlation, together with the following exogenous variables: real commodity prices, the money supply, the real exchange rate and the Fed rate. They also claim that if there is no serial correlation in the error term, then the lagged independent variables are legitimate instruments.

Dolado et al. (2000) estimate similar Taylor rule functions, with a smoothing term, for the Fed and three European central banks - the Bundesbank, the Banque de France and the Bank of Spain. For the expected explanatory variables, they use the variation of the lagged actual variables, together with the following IVs: the real exchange rate, foreign interest rates and the money supply. They used the GMM technique for estimation.

Argov and Elkayam (2009) use the GMM technique for estimating the response function in the case of Israel. They use the following IVs: the constant; the inflation target; the current level and two lags of the Fed rate and the percentage change in the consumption of import goods; two lags of the dependent variable, the output gap, the real long-term yield on CPI-linked Treasury Bonds (TB) as a proxy for the natural interest rate, the real exchange rate gap and the devaluation in the nominal exchange rate; and four lags of inflation (excluding housing and fruit and vegetables). Note also that the authors use two specifications for expected inflation: actual ex-post inflation and expectations from the financial markets (as in this paper). They found that the latter provided better results.

6.4.2 Using instrumental variables with the GMM technique

An instrumental variable must satisfy two requirements: it must be correlated with the included endogenous variable and orthogonal to the error term.⁴¹ Equation (7.8) includes one endogenous variable (the second term on the right-hand side) and four exogenous variables, which we will denote as matrix X1 and X2, respectively. In addition, we define matrix Z1 to include the predetermined fourth and fifth lags of the dependent variable and matrix Z2 to include excluded exogenous variables. Hence, the IV matrix Z is defined as $Z=[X2, Z1, Z2]$ and includes the following variables:

⁴¹ It is interesting to note that none of these studies explains how their IVs satisfy the requirement of correlation.

a. The included exogenous variables, X2, and the fourth and fifth (monthly) lags of the dependent variable, Z1. (Note that the main task of the lagged dependent variable is to eliminate the serial correlation that was found.)

b. The real yield on CPI-linked TBs with 8 years to redemption (lagged once), which is a proxy for the natural interest rate and hence is exogenous to X1. This variable is correlated with X1 since it denotes a long-run point of the real yield curve, where the dependent variable is the expected real short term interest rate which denotes a point on the short run part of this curve. This slope is an indication of the extent of monetary expansion and therefore affects the expectations of inflation (i.e. X1). Other things being equal, a shift of the long-term yield affects this slope and hence the extent of monetary expansion.

c. The real NIS/\$US exchange rate (with 1-6 lags) which is exogenous since it is determined by, among other things, foreign inflation (and foreign exchange rate movements against the dollar), which leads to imported inflation and thus is correlated with X1.

d. The Fed rate with 1-6 lags. This variable is obviously exogenous and is correlated with X1 since the interest rate gap may affect the nominal exchange rate and therefore inflation as well.

e. Annual inflation in commodity prices with various lags, which are clearly exogenous. This variable is correlated with X1 since it leads to imported inflation. The lags were found to differ among the various regressions and samples as follows: 6 lags for the total sample; 20 to 30 lags for the 1st sub-period sample (i.e. 1994:1-1999:12); and one lag for the 2nd sub-period sample (i.e. 2000:1-2007:12) according to specification A and 7 lags according to specification B. The difference in number of lags between the 1st and 2nd sub-periods may reflect the different degrees of openness of the Israel economy.

6.4.3 Testing the correlation condition statistically

The most convincing explanation for correlation is not necessarily statistical but rather economic, as explained above. Nevertheless, the statistical correlation condition can be tested in a regression as follows:⁴² In the first stage, we regress the endogenous variable X1 on the full set of instruments Z; we then regress X1 on the excluded exogenous variable Z1 and Z2. The relevant test statistic in this case is the explanatory power of the excluded

⁴² As is also recommended by Bound et al. (1995). Baum, Schaffer and Stillman (2002) provide a review of instrumental variables and the differences between the use of 2SLS and GMM techniques.

instruments and the test is an F-test on the difference in the sum of squared residuals between the two regressions:

$$(ESS_R - ESS_U) / ESS_U \sim F(j - m, n - j)$$

where j and m are the number of variables in Z and $Z1+Z2$, respectively and n is the number of observations. ESS_U denotes the sum of squared residuals when we regress $X1$ on the full set of instruments Z and ESS_R denotes the sum of the squared residuals in the regression of $X1$ on the excluded instruments, i.e. $Z1$ and $Z2$ together. Under the null hypothesis, there is no difference between the explanatory power of the regressions, i.e. $ESS_R=ESS_U$.

As an example, Appendix 8 shows the results of these regressions for the whole period. Taking $n=150$, $j=21$ and hence $n-j=129$, $Z1=2$, $Z2=14$ and hence $m=16$ and $j-m=21-16=5$, we obtain:

$$\frac{(ESS_R - ESS_U) / 5}{ESS_U / 129} = \frac{(0.035396 - 0.018482) / 5}{0.018482 / 129} = 23.61 > F_c^{0.05} = 2.21$$

Thus, the null is rejected and therefore $Z1+Z2$ do have explanatory power. Table 7 shows the statistical correlation test for the whole period and for the 1st and 2nd sub-periods. Recall that n differs between the samples, though there is no difference in j and m .

	1st Sub-period¹	2nd Sub-period¹	Total period¹
ESS _R	0.010984	0.017863	0.0035396
ESS _U	0.004436	0.007913	0.018482
N	72	150	78
Computed F-stat.	15.06	14.33	23.61

The orthogonality condition will be tested using the J-test, which also tests for the existence of overidentification restrictions. In the case of GMM, if, and only if, overidentification restrictions exist, i.e. there is a surfeit of instruments, then we can test whether the instruments are uncorrelated with the error process. The J-stat is asymptotically distributed, $J(\hat{\beta}_{EGMM})^A \sim \chi^2_{L-J}$, where L is the total number of variables (endogenous and exogenous), i.e. $L=[X1, Z]$, and J is the total number of coefficients ($\hat{\beta}$) to be estimated in equation (7.8). The *p-value* (see Table 8 below, in parentheses) is the *J-statistic's* probability under the null that the instruments are orthogonal to the error process. All the estimations were done

under a Heteroskedasticity and Autocorrelation Consistent (HAC) procedure including Newey-West Bandwidth selection.

6.4.4 The results of the GMM regressions

Table 8 presents the results of the GMM regression using the IVs mentioned above. These results again provide evidence for both IAP and a hidden target, as we found in the OLS and the NLS regressions. However, in general, the hidden target, asymmetry and response parameters are smaller than or equal to the OLS results presented in Table 5.

The estimated hidden target parameters for the whole period are very similar to those of the OLS regression. The only difference relative to the OLS regression results is for the 1st sub-period, in which the parameter was found to be 0.33 in both specifications, which is close to half the size of the OLS estimate. In other words, during the 1st sub-period (i.e. during

		Specification A ¹			Specification B ¹		
		1	2	3	4	5	6
	Parameter	Total period ²	1 st Sub-period ²	2 nd Sub-period ²	Total period ²	1 st Sub-period ²	2 nd Sub-period ²
Hidden target	k	0.38	0.33	-2.72**	0.54	0.33	5.91**
Asymmetry	a	0.27	0.40	1.00	0.27	0.41	0.41
Interest rate smoothing	ρ	0.16	0.12	0.79	0.18	0.21	0.72
Response coefficient	$(1-\rho)a$	0.23	0.35	0.21	0.22	0.32	0.12
	μ_v	1.29**	irrelevant	irrelevant	1.1**	irrelevant	irrelevant
Regressions statistics							
J-stat.		0.12 (0.21) ³	0.22 (0.94) ³	0.20 (0.34) ³	0.10 (0.39) ³	0.24 (0.91) ³	0.12 (0.83) ³
Observations after adjustment		150	54	78	150	54	78
Adj. R ²		0.86	0.58	0.93	0.87	0.57	0.93
DW		2.12	1.66	1.67	2.19	1.87	1.65
<p>¹. For the hidden target parameter, the specifications differ in the definition of the target for $m+12$ at the time of the decision. For example, in August 1998 the target for 1998 was 8.5 percent and in that month a target of 4 percent was announced for 1999 (see Table 1). Thus, according to specification A the target was 4 percent already from August 1998, while according to specification B the official target remained at 8.5 percent.</p> <p>² Estimation period: 1994:1-2007:06. 1st sub-period: 1994:01-1999:12. 2nd sub-period: 2000:01-2007:06.</p> <p>³ The probability (p-value) under the null that the instruments are orthogonal to the error process, conditional on the existence of overidentification, appears in parentheses. This test statistic is asymptotically chi-square distributed with L-J degrees of freedom.</p> <p>** denotes not significant. "Irrelevant" means that the estimated coefficient of the fifth term of equation (7.8) is positive while we expect a negative sign. Hence, the μ_v parameter cannot be extracted.</p>							

the 90's) the CB had a hidden inflation target of 5.4 percent on average, in comparison to an average announced target of 8 percent (recall that the OLS results implied a hidden target of 4 percent). In other words, when using the GMM approach, the difference between the announced and hidden targets during the 1st sub-period is smaller than when OLS is used.

The estimated asymmetry parameter also differs such that for the *whole sample* it declined to half of the OLS estimate. However, for the 2nd sub-period under specification A, the asymmetry parameter increased to 1, which is almost double the OLS estimate.

Also interesting is the estimate of the smoothing parameter, which was found to be 0.75 in the 2nd sub-period, as compared to only 0.57 in the OLS results.

It is important to note that since the largest differences in comparison to the OLS regressions are found for the sub-periods, which have smaller samples, the result may be attributable to the poor small-sample property of GMM. Indeed, the sub-periods have around half the number of observations of the whole period.

We were unsuccessful in extracting the μ_v parameter, which appears in the fifth term of equation (7.8), as was the case for the other estimation techniques. However, that parameter is not critical to our purposes and it is not important to estimate this coefficient per se. The parameter should reflect the AR(1) process of the disturbances of the Phillips curve (equation 4) and therefore we expect that $1 > \mu_v > 0$. Furthermore, according to equation (7.8) it should have a negative sign, while each element of the coefficient, as well as the variable, is positive. However, the estimation results show a positive sign for the fifth term of equation (7.8) for both sub-periods, where we would expect a negative sign; for the whole period, the results indeed show a negative sign but the estimate is not significant.

6.5 Summary of the estimation results

At this stage, it is useful to summarize the regression results for equations (6.8) and (7.8), as presented in Tables 3, 4, 5, 6 and 8. Thus, Table 9 presents the results for the main parameters, i.e. the hidden target parameter k and the asymmetry parameter a , for both specifications and for each equation. For equation (7.8), it can be concluded that the parameter is in the vicinity of 0.5, implying that the hidden target was 50% lower than the official one, which is in addition to the asymmetric policy that was conducted. The average for both equations is slightly higher; however, it should be emphasized that in equation (6.9) the parameters are k/θ and a/θ rather than simply a and k . Translating the coefficient of k into numbers means that, on average, the hidden target was 4 percent during the 1st sub-

period in comparison to the announced target of 8 percent. Considering only the GMM results ($k=0.33$) implies a hidden target of 5.6 percent.

Specification		Total period		Sub-period 1		Sub-period 2	
Equation	Tables	k	a	k	A	k	A
(6.9) ² OLS	3	0.57	0.58	0.55	1.41	0.59	
(6.9) ² OLS	4	0.78	0.59	0.81	1.41	0.83	
(7.8) OLS	5-A	0.39	0.52	0.55	0.4		0.56
(7.8) OLS	5-B	0.54	0.56	0.48	0.37		0.57
(7.8) NLS	6-A	0.48	0.52	0.5	0.47		0.47
(7.8) NLS	6-B	0.54	0.52	0.62	0.42		0.42
(7.8) GMM	8-A	0.38	0.27	0.33	0.4		1.0
(7.8) GMM	8-B	0.54	0.27	0.33	0.41		0.41
Average for only (7.8)		0.48	0.44	0.47	0.41		0.57
Overall average		0.53	0.48	0.52	0.66	0.71	0.57

¹Cells are empty if the estimate is not significant. ²Recall that for equation (6.9) the parameters are k/θ and a/θ for the averages of the various parameters (see tables 3 and 4).

For the 2nd sub-period, there is no clear-cut evidence in favor of k or a at first glance. However, recall that the specification of equation (7.8) limits the ability to estimate the hidden target parameter for this period and therefore only a was found to be significant. This is in contrast to the specification of equation (6.9) in which only k was significant even though both were unconstrained, and therefore it can be claimed that a hidden target policy rather than an asymmetric one was adopted in the 2nd period. In conclusion, one or the other technique seems to have been used for conducting IAP policy during the 2nd sub-period. The existence of both a hidden target and asymmetric policy in the 1st sub-period suggests that the hidden target policy had a different motive than that of IAP.

7. Discussion

Given the evidence of the existence of a hidden target (alongside AIP) two questions emerge:

(1) How can a hidden target policy, especially one that continues for several years, be reconciled with rational expectations, or in other words how can the target remain hidden from the public and not enter into its calculations?

A possible answer is the CB's desire to manipulate the public's expectations, which does not contradict rational expectations. In other words, the hidden target is not really hidden from the public – even if it is not announced – and in fact the public perceives it through the CB's actions.

However, if there is no contradiction between rational expectations and the "hidden" target, then a second question emerges:

(2) Recall that under discretion the expectations of inflation are exogenous to the CB and therefore are given in the optimization process. In that case, how can the CB manipulate expectations under discretion when it takes them as given?

Several answers are possible:

(2.1) The inflation process is not a "one-shot game" but is rather a "repeated game". The CB indeed takes the public's expectations of inflation as given in its one-period-ahead optimization. The public then implicitly perceives the CB's optimization and – if the CB has credibility – under rational expectations it adapts its expectations accordingly. In the next period, the same game is repeated, but now the CB takes as given the adapted expectations from the first round and the process is repeated. In other words, in a repeated game *the CB does in fact manipulate the public's expectations* even under discretion. However, it appears that a necessary condition for the CB's ability to manipulate expectations is its credibility among the public and it takes time to build up such credibility since it involves a learning process in which the public observes the CB's behavior and responses and is only gradually convinced.

Why does the building up of credibility require a long learning process? *First*, In light of the history of inflation and political instability, such as in the case of Israel, the public first attempts to determine the CB's ability to maintain the announced target, not to mention the hidden (and lower) target. However, as can be seen in Figure 1, until 1997 the inflation target was frequently overshoot even with respect to the upper bound of the target. Only when the announced target is maintained or the CB undershoots it is there a possibility of a hidden (and lower) target. *Second*, due to the asymmetry in information between the CB (which has adopted a hidden target policy and an asymmetrical response to inflation) and the public, the public learns the CB's behavior only implicitly, which is accomplished over time. *Third*, recall that most economic variables are characterized by uncertainty. Therefore, determining whether the CB's responses are due to uncertainty or to the possibility of a hidden target is not an easy task. Thus, it takes time to make such a distinction, which is accomplished by comparing the present response to similar ones in the past. Interestingly, the stylized facts suggested by Figure 1 may also reflect a learning process and the CB's process of building credibility. Thus, while during the 1990s expectations of inflation (the red

line) moved together with actual inflation, during the 2000's expectations of inflation moved within the inflation target range while actual inflation fluctuated at much higher levels.

(2.2) It may also be that a hidden target was maintained in order to convince the government to lower the next-period announced target. In other words, the CB wished to reach the long-run inflation target at a faster pace than the government. It is the conventional wisdom that politicians operate according to short-run horizons and in general are not willing to pay the cost of lowering inflation. Therefore, they determine the next period's announced target (during the disinflation process) to be similar to the current actual rate of inflation. This outcome is also shown in Figure 1, such that until 1998 the annual targets did not change dramatically and followed the actual inflation rate; only for 1999 was the announced target lowered dramatically, again following a decline in the actual inflation rate. In such a case, one possible way of convincing the politicians to lower the next-period target is by undershooting the current one. However, such a claim cannot stand by itself since the process has to be carried out via the public's expectations and thus we return to possibility (2.1) above.

(2.3) Another possibility is that the CB does not respond (at least not adequately) to a recognized negative shock to inflation, i.e. it lets inflation return gradually to its previous higher level through its $AR(1)$ process.

The long learning process may also explain why the inflation constant in regression (6.8) was so high for the 1st sub-period.

In summary, since "policy under commitment" is not a practical option, a *lower hidden target* under discretion may be a practical way to manipulate expectations. The apparatus of the learning process is not the focus of this paper and is left for future research.⁴³ The implications of a hidden target's motives are also an open question. While IAP motives are understandable and apparently efficient, the motives for a hidden target involve a lack of policy transparency and perhaps misleading the public and may be inefficient. On the other hand, since an enduring hidden target does not contradict rational expectations, it may in any case be efficient. Another outcome is that the CB takes non-authorized actions under a hidden target policy.

⁴³ See, for example, Cukierman and Vestin (2008), draft.

8. Summary and Conclusions

This paper investigates the question of whether the persistent undershooting of the inflation target during the disinflation process in Israel was due to Inflation Avoidance Preferences (IAP) or to a hidden inflation target that was adopted by the CB. To the best of my knowledge, this distinction has not yet been examined in the literature. The Central Bank (CB)'s behavior under IAP is motivated by the uncertainty regarding inflation and the prevailing economic conditions, together with an aversion to inflation; it however *aims to achieve the target* which results in an asymmetric policy with respect to inflation (Cukierman 2000, 2002; and Cukierman and Muscatelli, 2008). A hidden target policy, on the other hand, may be aiming to undershoot the announced target and is perhaps motivated by other reasons, such as the manipulation of the expectations of inflation, even under discretion. The paper is also motivated by the claim made by Sussman (2007) that during the disinflation process in Israel in the 1990s the CB had a hidden inflation target of zero. Another question examined is whether both policies – asymmetry and a hidden target – are different techniques motivated by the same goal, i.e. IAP policy to achieve the announced target, or whether they embody different motives aimed at achieving different goals.

The model developed here is based on a New Keynesian economy, in the case of discretion and a non-linear Linex CB objective function. After developing the model, it was empirically tested for Israel for the period 1994-2007 using monthly data. This period was also divided into two sub-periods: the first to capture the 90s - a period under the tenure of Bank of Israel Governor Jacob Frankel - which was characterized by a disinflation process and the second starting from 2000 which mainly coincides with the tenure of Governor David Klein (which ended in 2004).

The empirical estimations were performed using three different approaches: OLS, Non-Linear OLS (NLS) and instrumental variables (IV) with the GMM approach. The main results are as follows: (a) During the main period of the disinflation process (i.e. the 90s) the CB adopted a hidden target that was roughly 4 percent, on average, in comparison to an average announced target of 8 percent. (b) During the whole period and the 1st sub-period, the CB conducted both a hidden target policy and an asymmetric policy, which suggests that they were directed at achieving different goals. (c) During the 2nd sub-period, on the other hand, it cannot be determined whether a hidden target or an IAP policy was conducted, thus suggesting that one or the other was used to implement the goal of IAP. (d) Another

important accomplishment of this paper is the estimation of the interest rate response parameter with respect to inflation, which was found to be about 1.3 and the interest rate smoothing parameter in real terms which was estimated to be about 0.2.

The finding of both a hidden target and an asymmetric policy during the 90's suggests that the hidden target had motives other than IAP, such as perhaps the manipulation of the public's expectations of inflation. When CB policy involves a repeated game and a prolonged learning process on the part of the public, a *hidden target* that is lower than the announced one may be a practical way of manipulating expectations, even under discretion.

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Appendices

Appendix 1: Illustration of the Linex function

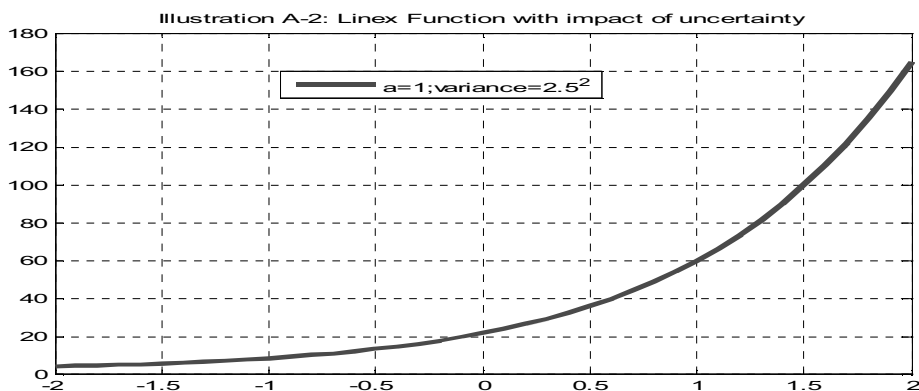
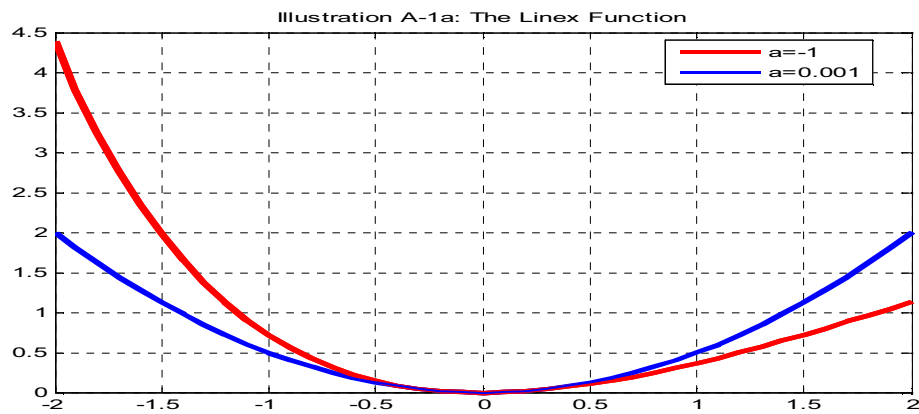
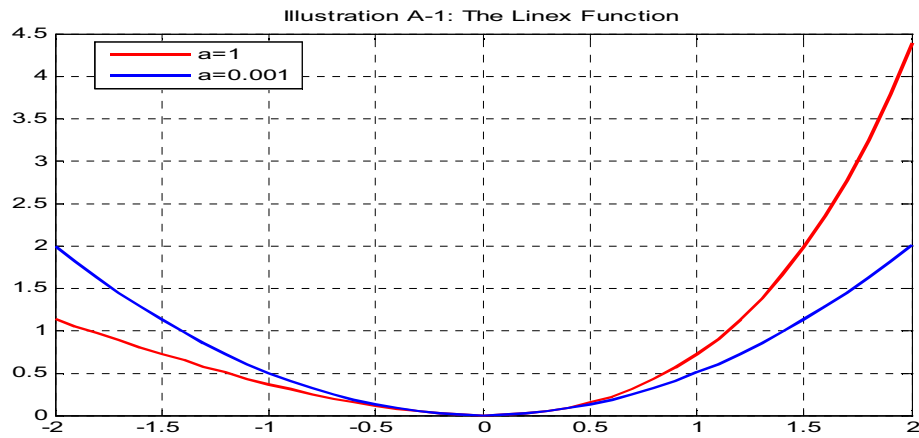


Illustration A-1 presents the Linex function with aversion to inflation (for $a=1$). The loss (measured on the y-axis) from a deviation above the target (measured on the x-axis) is considerably higher than for a deviation of the same magnitude below the target. For comparison, the quadratic case (in which a tends to zero), which has symmetric losses for positive and negative deviations, is also shown. Illustration A-1a presents the opposite case (for $a=-1$) of greater aversion to a negative deviation than a positive one. Illustration A-2 shows the impact of uncertainty, such that even when the expected deviation is zero, there is a positive loss.

Appendix 2: Proof of the approximation $e^{z_1} - e^{z_2} + 1 \cong e^{z_1 - z_2}$ for sufficiently small z's

1. Expanding the Taylor series of the function e^{z_1} of order 3 around z_2 yields the following expression:

(A2) $e^{z_1} = e^{z_2} + e^{z_2}(z_1 - z_2) + \frac{1}{2!}e^{z_2}(z_1 - z_2)^2 + \frac{1}{3!}e^{z_2}(z_1 - z_2)^3$. The reason for an order of only 3 is that higher orders add only negligible values that can be ignored. Rearranging (A2) yields the following expression:

$$(A2.1) \quad e^{z_1} - e^{z_2} = e^{z_2}(z_1 - z_2) + \frac{1}{2!}e^{z_2}(z_1 - z_2)^2 + \frac{1}{3!}e^{z_2}(z_1 - z_2)^3$$

2. We now develop the Taylor expansion series of the function $e^{z_1 - z_2}$ around zero (i.e. $(z_1 - z_2)(0)=0$).

$$(A2.2) \quad e^{z_1 - z_2} = 1 + (z_1 - z_2) + \frac{1}{2!}(z_1 - z_2)^2 + \frac{1}{3!}(z_1 - z_2)^3, \text{ or}$$

$$(A2.3) \quad e^{z_1 - z_2} - 1 = (z_1 - z_2) + \frac{1}{2!}(z_1 - z_2)^2 + \frac{1}{3!}(z_1 - z_2)^3$$

3. Subtracting (A2.3) from (A2.1) yields the following expression:

$$(A2.4) \quad e^{z_1} - e^{z_2} - (e^{z_1 - z_2} - 1) = (e^{z_2} - 1)(z_1 - z_2) + \frac{1}{2!}(e^{z_2} - 1)(z_1 - z_2)^2 + \frac{1}{3!}(e^{z_2} - 1)(z_1 - z_2)^3$$

The terms on the right hand-side of equation (A2.4) are very small. Note also that they decrease in value as the order increases and therefore this series converges to zero. By assuming that $z_1 \geq z_2$ and taking $\lim_{z_1 \rightarrow 0}$ we obtain that both sides of the equation are

zero. Hence, $e^{z_1} - e^{z_2} + 1 \cong e^{z_1 - z_2}$.

Q.E.D.

Table A-1 provides some examples for the right-hand side of equation (A2.4). In the first example, where z_1 is 20% and z_2 is 1%, the error is only 0.2%.

Table A-1: An example of (A2.4) for sufficiently small z's				
z_1	z_2	$e^{z_1} - e^{z_2} + 1$	$e^{z_1 - z_2}$	The difference
0.2	0.01	1.21135	1.20925	0.00210
0.2	0.05	1.17013	1.16183	0.00830
0.2	0.1	1.11623	1.10517	0.01106
0.1	0.01	1.09512	1.09417	0.00095
0.1	0.05	1.05390	1.05127	0.00263

Appendix 3: Proof that the response function (7.3) is always greater than one with respect to inflation and that when the asymmetry parameter a is greater than zero the response function in the (non-linear) Linex case is greater than in the quadratic case (as, for example, in CGG, 1999).

Woodford (2003) shows that in the quadratic case, a necessary condition for determinacy in the NK model is that the response function with respect to inflation expectations will be greater than one. Here it is shown that also in the Linex case, which is non-linear, the same necessary condition is obtained for determinacy in the NK model. Also, it will be shown that if $a > 0$, it must be that the response function with respect to expected inflation in the Linex case is greater than in the quadratic case.

A3.1 Proof - We begin with the response function (7.3):

$$i_t = \frac{\lambda}{\alpha\alpha\varphi} (e^{a(\pi_t - E_t\pi_{t+1} + k(\pi_t^* - E_t\pi_{t+1}^*))}) + E_t\pi_{t+1} + \frac{g_t}{\varphi} \quad (7.3)$$

Differentiating with respect to expected inflation yields:

$$\frac{\partial i_t}{\partial E_t\pi_{t+1}} = 1 + \frac{\lambda}{\alpha\alpha\varphi} e^B * (a \frac{\partial \pi_t}{\partial E_t\pi_{t+1}} - a) = 1 + \frac{\lambda}{\alpha\varphi} e^B (\frac{\partial \pi_t}{\partial E_t\pi_{t+1}} - 1), \quad (A7.3.1)$$

where B denotes the expression above the e in equation (7.3). Now, if $\frac{\partial \pi_t}{\partial E_t\pi_{t+1}} > 1$, then

(A7.3.1) is also greater than 1 for every a . It will be shown that $\frac{\partial \pi_t}{\partial E_t\pi_{t+1}} = \frac{1}{\mu_\nu} > 1$. Note that

$0 < \mu_\nu < 1$ is the coefficient that defines the $AR(1)$ process of the disturbances in the supply equation (4), i.e. $\nu_t = \mu_\nu \nu_{t-1} + \varepsilon_t^\nu$.

We present again equation (6.4) which is the outcome of the F.O.C. conditions under discretion:

$$\pi_t = \frac{-\lambda^2}{\alpha\alpha} (e^{a(\pi_t + k\pi_t^*)} - 1) + \beta E_t\pi_{t+1} + \nu_t. \quad (6.4)$$

Equation (6.4) defines the inflation process as a function of expected inflation, which is exogenous (under discretion) to the policy optimization. However, under rational expectations, this process will also determine the public's expectations. Therefore, substituting $E_t\pi_{t+1} = \pi_t$ into Eq. (6.4) yields:

$$\pi_t = \frac{-\lambda^2}{\alpha\alpha} (e^{a(\pi_t + k\pi_t^*)} - 1) + \beta\pi_t + \nu_t. \quad (A7.3.2)$$

$$1 - \frac{\alpha\alpha}{\lambda^2} (\pi_t(1 - \beta) - \nu_t) = (e^{a(\pi_t + k\pi_t^*)} - 1). \quad (A7.3.2)'$$

Taking logs of both sides yields:

$$\frac{1}{a} \log \left\{ 1 - \frac{\alpha a}{\lambda^2} (\pi_t (1 - \beta) - v_t) \right\} = \pi_t + k\pi^* . \quad (\text{A7.3.3})$$

By using the approximation:

$$\log \left\{ 1 - \frac{\alpha a}{\lambda^2} (\pi_t (1 - \beta) - v_t) \right\} = - \frac{\alpha a}{\lambda^2} (\pi_t (1 - \beta) - v_t) ,$$

and substituting and rearranging terms we obtain:

$$\pi_t = \frac{\alpha}{\alpha(1 - \beta) + \lambda^2} v_t - \frac{\lambda^2}{\alpha(1 - \beta) + \lambda^2} k\pi^* . \quad (\text{A7.3.4})$$

Now, inflation in the next period will be:

$$E_t \pi_{t+1} = \frac{\alpha}{\alpha(1 - \beta) + \lambda^2} v_{t+1} - \frac{\lambda^2}{\alpha(1 - \beta) + \lambda^2} k\pi_{t+1}^* . \quad (\text{A7.3.5})$$

However, since $v_{t+1} = \mu_v v_t + \varepsilon_{t+1}^v$ we obtain:

$$E_t \pi_{t+1} = \frac{\alpha}{\alpha(1 - \beta) + \lambda^2} \mu_v v_t - \frac{\lambda^2}{\alpha(1 - \beta) + \lambda^2} k\pi_{t+1}^* \quad (\text{A7.3.6})$$

Isolating v_t from (A7.3.4) produces:

$$v_t = \frac{\alpha(1 - \beta) + \lambda^2}{\alpha} \pi_t + \frac{\lambda^2}{\alpha(1 - \beta) + \lambda^2} k\pi^*$$

Substituting into (A7.3.6) gives:

$$E_t \pi_{t+1} = \mu_v \pi_t + \frac{\lambda^2}{\alpha(1 - \beta) + \lambda^2} (k\pi_t^* - k\pi_{t+1}^*) \quad (\text{A7.3.7})$$

By isolating inflation we obtain:

$$\pi_t = \frac{1}{\mu_v} \left[E_t \pi_{t+1} - \frac{\lambda^2}{\alpha(1 - \beta) + \lambda^2} k(\pi_t^* - \pi_{t+1}^*) \right] \quad (\text{A7.3.8})$$

Finally, differentiating (A7.3.8) with respect to expected inflation yields:

$$\frac{\partial \pi_t}{\partial E_t \pi_{t+1}} = \frac{1}{\mu_v} > 1 .$$

Q.E.D.

A3.2 Comparison of results to the quadratic case as in CGG (1999)

CGG (1999) arrive at the following result for the quadratic CB behavior function (equation (3.6), page 1672):

$$i_t = \gamma_\pi E_t \pi_{t+1} + \frac{g_t}{\phi} \quad (\text{CGG, 3.6})$$

where

$$\gamma_\pi = 1 + \frac{(1-\rho)\lambda}{\rho\phi\alpha}$$

and where $\rho_{CGG} = \mu_{v,L}$ (i.e. CGG's ρ is our μ_v). In comparison to the case of the Linex function (denoted by L) in (A7.3.1), we obtain:

$$\gamma_\pi^L = 1 + \frac{(1-\mu_v)\lambda}{\mu_v\phi\alpha} e^{a(\pi_t - E_t \pi_{t+1} + k(\pi_t^* - E_t \pi_{t+1}^*))}$$

Recall that when a approaches zero, the quadratic case is obtained:

$$\lim_{a \rightarrow 0} \frac{\gamma_\pi^L}{\gamma_\pi} = 1 + \frac{(1-\mu_v)\lambda}{\mu_v\phi\alpha},$$

and we arrive at exactly the CGG result, i.e. $\gamma_\pi = \gamma_\pi^L$. In other words, in the Linex case, and when $a > 0$, the exponent term is greater than one and hence it must be that $\gamma_\pi < \gamma_\pi^L$ (also, when $a < 0$, it must be that $\gamma_\pi > \gamma_\pi^L$).

Q.E.D.

Appendix 4

Table A-2: The variables

The variable ¹	Explanation
agach8	The real yield on CPI-indexed Treasury Bonds with 8 years to maturity (as a proxy for the real natural interest rate).
ex	The NIS/\$US exchange rate.
Dum95	Dummy for the May 1995 deal (agreement between the CB and the Government).
Dum97	Dummy for the July 1997 deal.
dum97	Dummy for the August 1998 deal.
dum01	Dummy for the December 2001 deal.
Dum0	Dummy for a one-month response delay by the CB (as the result of a deal).
Dum1	Dummy for a 2-month response delay by the CB (as the result of a deal)
Dum2	Dummy for a 3-month response delay by the CB(as the result of a deal).

Dum3	Dummy for a 4-month response delay by the CB (as the result of a deal).
Dum4	Dummy for a 5-month response delay by the CB(as the result of a deal).
Sinfexpx	Deviations of expected inflation from the target.
Sinf	The deviation of the annual rate of inflation (last 12 months) from the target which was known 12 month ago.
Sribx	The gap between the CB interest rate and the inflation target.
Targmx	The Inflation target which is known for the current year.
Targm13x	The Inflation target for the next calendar year (13 months onward).
Varinfa	The variance of inflation – measured annually for the last 12 months.
¹ All the variables are expressed in terms of decimals i.e. 2% is expressed as 0.02.	

Appendix 5: Calibrating the third coefficient of equation (6.9) using the conventional NK parameters

The third coefficient of equation (6.8)' is $\frac{(\theta-1)\beta}{\theta}$, where $\theta = 1 + \frac{\alpha}{\lambda^2} > 1$. We are interested in the size of this coefficient or in other words, $\frac{\alpha}{\lambda^2}$, using the conventional parameters for an NK model, as in, for example, Gali (2008), Ch. 3, p. 52.

$\alpha = \frac{\lambda}{\varepsilon}$ is the weight given by the CB to the output gap in its response function, where $\varepsilon=6$ denotes the elasticity of substitution between goods (a-la Dixit-Stieglitz utility function), $\lambda = \lambda_G(\sigma + \frac{\varphi + \alpha_G}{1-\alpha})$, $\lambda_G = \frac{(1-\theta_G)(1-\beta\theta_G)}{\theta_G} \Theta$ and $\Theta = \frac{1-\alpha_G}{1-\alpha_G-\alpha_G\varepsilon}$ where the symbol G denotes the parameters in Gali (2008) (which differ from the parameters used here). We set $\beta = 0.96$ while the other parameters are as in Gali (2008): $\sigma = 1$ which is the substitution coefficient of the consumer utility function, $\alpha_G = 0.33$ which is the production function parameter, $\theta_G = 0.667$ which is the Calvo parameter and $\varphi_G = 3$ which is the labor substitution parameter in the consumer utility function. Computing these parameters gives $\Theta = 0.25$, $\lambda_G = 0.045$, $\lambda = 0.27$, $\frac{\alpha}{\lambda^2} = 0.617$ and $\frac{(\theta-1)\beta}{\theta} = 0.366$. Perhaps surprisingly, we obtained similar magnitudes in our estimation (see Table 3).

Appendix 6: The estimation results for equation (7.8)

Table A-3 presents the regression results for equation (7.8). The main parameters are extracted from these coefficients as explained below and the results are presented as specification A in Table 5.

Recall equation (7.8):

$$\ln(i_{m+1}^A - E_{m-1}\pi_{m+2}) = (1-\rho)d_0 + (1-\rho)a(\pi_{m-1} - E_{m-1}\pi_{m+2}) + (1-\rho)ak(\pi_{m+2}^* - E_m\pi_{m+3}^*) + \rho(i_m^A - E_{m-1}\pi_{m+2}) - (1-\rho)a^2\mu_v^2 \frac{\sigma_{\pi,m-1}^2}{2} + \varepsilon_m^A \quad (7.8)$$

1. Extracting the hidden target parameter for the first sub-period, 1994.1-1999.12, is done as follows: $k = \frac{(1-\rho)ak}{(1-\rho)a} = \frac{3.38}{6.16} = 0.55$.

Table A-3: The Regression Results for Equation (7.8) – Total period and sub-periods (dependent variable: $\ln(i_t^A - E_t\pi_{t+1})$)							
Variable	Parameters	Total period ¹		1 st Sub-period ¹		2 nd Sub-period ¹	
		Original	Translated ₂	Original	Translated ₂	Original	Translated ₂
1. The regression coefficients³							
Constant	$(1-\rho)d_0$	-3.3		-3.5		-3.69	
Dum95				0.33			
Dum01		-0.21				-0.32	
(sinf(-1)-sinfexp(-1))	$(1-\rho)a$	8.77	0.41	6.16	0.37	5.73	0.2
Targmx(-1)-targm13x(-1)	$(1-\rho)ak$	3.43	0.16	3.38	0.23	-8.33*	-0.35*
(Sribx-sinfexp(-1))*(1+dum2)	ρ	4.39	0.21	3.51	0.14	13.53	0.55
Varinfa(-1)*(1+dum2)/2	$(1-\rho)a^2\mu^2$	-0.58*		-1.45*		3.92**	
AR(1)		0.9		0.57		0.78	
adj. R ²		0.88		0.64		0.94	
DW		2.08		2.14		1.81	
LM_prob. test for serial correlation		0.66		0.22		0.54	
Observations after adjustment		150		72		78	
2. The extracted parameters⁴							
Hidden target	k		0.39		0.55		-1.45*
Asymmetry	a		0.52		0.4		0.56
	μ		0.36*		0.76*		1.1
Average of the dependent variable			0.047		0.0561		0.042
¹ Estimation period: 1994.01-2007.06; ^{1st} sub-period: 1994.1-1999.12; ^{2nd} sub-period: 2000.01-2007.06. ² Translated from the logarithmic function. ³ The level of significance is 1% unless denoted ** for 10% or * for not significant. ⁴ See below.							

2. For the semi-logarithmic form of the equation, such as in (7.8), the marginal effect

$$\frac{d(y)}{d(x)} \text{ is: } \beta = \frac{d(\ln y)}{d(x)} = \frac{1}{y} * \frac{d(y)}{d(x)} \Rightarrow \beta y = \frac{d(y)}{d(x)}.$$

Therefore each of the "original" regression coefficients β_i has to be multiplied by the average value of the dependent variable (which also appears in Table A-3). The outcome of this calculation appears in the "translated" column in Table A-3. The regression coefficients themselves appear in the "original" column.

3. Regarding the response coefficient to inflation $(1 - \rho)a$, it should be emphasized that it is in *real* terms, rather than *nominal* terms, which is the convention. This means that in nominal terms it is greater than one, which is the necessary condition for determinacy in an NK model (see Appendix 3 above).

Appendix 7: An example of Non-Linear Regression (NLS) of equation (7.8)

The main results of the NLS regression are presented in Table 6 in the text. The following is an example of the NLS regressions, which was run for the whole sample period and under specification A using the Eviews software.

Note that in comparison to the OLS regression presented in Table 5 in the text, the real yield on 8-year CPI-linked Treasury Bonds was added in the form of a 6-month average.

The results are presented in the following table:

Table A-4: The NLS regression results for equation (7.8) ¹					
Parameters	NLS Coefficients	The variable	Regression Coefficients	Coefficient p-values	The translated coefficients ²
D_0	CF90(5)		1.29	0.002	
K	CF77(1)		0.54	0.074	0.48
A	CF77(2)		-2.36	0.024	0.52
ρ	CF77(3)		4.66	0.0001	0.19
$a^2 \mu_v^2$	CF77(4)		-0.59	0.48	
	C(11)	Agach8	28.5	0.0001	
	C(9)	AR(1)	0.8	0.0000	
adj. R ² =0.89; DW=2.012 ³					
¹ Sample: 1994:1-2007:6, 150 observations after adjustment. The variable list appears in Appendix 4. ² Translated from the logarithmic function. ³ In the NLS regression, the Eviews software does not plot the values of the LM serial correlation statistics. Serial correlation was tested for using the AC and Q-statistic correlograms of residuals.					

And the NLS regression is as follows:

$$\text{LOG}(\text{SRIBX}(1)\text{-SINFEXPX}(-1)) = (1\text{-CF77}(3))\text{*CF90}(5) + (1\text{-CF77}(3))\text{*CF77}(2)\text{*}(\text{SINF}(-1)\text{-SINFEXPX}(-1)) + (1\text{-CF77}(3))\text{*CF77}(2)\text{*CF77}(1)\text{*}(\text{TARGM13X}\text{-TARGMX}(12)) + \text{CF77}(3)\text{*}(\text{SRIBX}\text{-SINFEXPX}(-1))\text{*}(1\text{+DUM4}) + (1\text{-CF77}(3))\text{*CF77}(4)\text{*VARINFA}(-1) \text{*}(1\text{+DUM})/200 + \text{C}(11)\text{*}@MOVAV(\text{AGACH8}(-1),6)\text{+}[\text{AR}(1)=\text{C}(9)]$$

Appendix 8: Statistical testing of the correlation between the exogenous instrumental variables matrix Z2 combined with the predetermined variables matrix Z1 and the endogenous variable matrix X1.

The following example refers to the whole sample period. The same process was carried out for the 1st and 2nd sub-periods (results not shown here).

(a) *The unrestricted equation:* Regressing X1 on Z=[X2, Z1, Z2] yields a sum of squared residuals (ESS_U) equal to 0.018482 as follows:

Dependent Variable: SIN(-1)-SINFEXP(-1), Method: Least Squares,
Sample (adjusted): 1994M01-2006M06, Included observations: 150 after adjustments

Prob.	t-Statistic	Std. Error	Coefficient	Variable
0.2782	1.089039	0.023949	0.026082	C
0.0070	2.739092	0.006188	0.016950	DUM1
0.0001	-3.976195	0.097239	-0.386643	TARGMX-TARGMX(12)
0.0000	4.361893	0.099022	0.431923	(SRIBX-SINFEXP(-1))*(1+DUM2)
0.0000	-6.675414	0.095065	-0.634600	VARINFA(-1)*(1+DUM1)/200
0.1012	1.651003	0.205597	0.339442	AGACH8(-1)
0.7418	-0.330169	0.006101	-0.002014	RIB_FED(-1)
0.6115	0.509226	0.008860	0.004512	RIB_FED(-2)
0.7297	0.346273	0.008568	0.002967	RIB_FED(-3)
0.6499	-0.454900	0.008645	-0.003933	RIB_FED(-4)
0.7287	-0.347621	0.008922	-0.003101	RIB_FED(-5)
0.8177	0.231002	0.006293	0.001454	RIB_FED(-6)
0.4223	0.804986	0.001904	0.001533	EXR1(-1)
0.8814	-0.149546	0.003607	-0.000539	EXR1(-2)
0.6837	-0.408372	0.003385	-0.001382	EXR1(-3)
0.7559	0.311588	0.003345	0.001042	EXR1(-4)
0.5048	0.668900	0.003658	0.002447	EXR1(-5)
0.0814	-1.756541	0.001927	-0.003385	EXR1(-6)
0.4399	-0.774794	0.098514	-0.076328	(SRIBX(-4)-SINFEXP(-5))*(1+DUM2)
0.0020	-3.152068	0.098818	-0.311482	(SRIBX(-5)-SINFEXP(-6))*(1+DUM2)
0.0000	-7.713450	0.009107	-0.070243	INF_COMO(-6)
0.003496	Mean dependent variable		0.637185	R-squared
0.018490	SD of dependent variable		0.580935	Adjusted R-squared
-5.883693	Akaike info criterion		0.011970	S.E. of regression
-5.462204	Schwarz criterion		0.018482	Sum of squared residuals
11.32766	F-statistic		462.2769	Log likelihood
0.000000	Prob(F-statistic)		0.442062	Durbin-Watson statistic

where the variables are defined as follows: The constant Dum1 is a dummy variable for a two-month delay in CB interest rate response due to a deal between the CB and the government, as explained in the text. The next three variables are the third, fourth and fifth terms of equation (7.8). AGACH8 is the yield on CPI-linked Treasury Bonds with eight years to maturity. RIB_FED is the Fed interest rate. EXR1 is the real NIS/\$US exchange rate. This is followed by two lagged dependent variables and finally the rate of inflation in commodity prices.

(b) The restricted equation: regressing X1 on Z1 and Z2 yields ESS_R of 0.035396 as follows:

Dependent Variable: SINF(-1)-SINFEXPX(-1). Method: Least Squares

Sample (adjusted): 1994M01-2007M04. Included observations: 160 after adjustments

t-Statistic	Std. Error	Coefficient	Variable
1.644815	0.200447	0.329698	AGACH8(-1)
0.436072	0.007798	0.003401	RIB_FED(-1)
-0.204316	0.011485	-0.002347	RIB_FED(-2)
0.144878	0.011072	0.001604	RIB_FED(-3)
0.142164	0.011160	0.001587	RIB_FED(-4)
-0.134539	0.011505	-0.001548	RIB_FED(-5)
-0.253354	0.007788	-0.001973	RIB_FED(-6)
2.155207	0.002292	0.004940	EXR1(-1)
-1.139758	0.004554	-0.005190	EXR1(-2)
-0.670747	0.004395	-0.002948	EXR1(-3)
1.227224	0.004248	0.005213	EXR1(-4)
0.262204	0.004738	0.001242	EXR1(-5)
-1.308478	0.002471	-0.003233	EXR1(-6)
0.352421	0.121672	0.042880	(SRIBX(-4)-SINFEXPX(-5))*(1+DUM2)
-2.386822	0.123476	-0.294716	(SRIBX(-5)-SINFEXPX(-6))*(1+DUM2)
-7.003048	0.009389	-0.065754	INF_COMO(-6)
Mean dependent variable		0.341302	R-squared
SD of dependent variable		0.272688	Adjusted R-squared
Akaike info criterion		0.015678	SE of regression
Schwarz criterion		0.035396	Sum of squared residuals
Durbin-Watson statistic		446.2752	Log likelihood

The test is an F-test with degrees of freedom as follows:

$$(ESS_R - ESS_U) / ESS_U \sim F(j - m, n - j),$$

where $n=150$, $j=21$ and hence $n-j=129$; $Z1=2$, $Z2=14$, $m=2+14=16$ and $j-m=21-16=5$.

Under the null of no difference between the explanatory power of the regressions (i.e. $ESS_R=ESS_U$), we obtain:

$$\frac{(ESS_R - ESS_U) / 5}{ESS_U / 129} = \frac{(0.035396 - 0.018482) / 5}{0.021940 / 129} = 23.61 > F_c^{0.05} = 2.21$$

Thus, the null is rejected and therefore $Z1+Z2$ have explanatory power.