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Monetary Studies

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December 2005 2005.04

Discussion Papers מאמרים לדיון

Bank of Israel
Monetary Department

בנק ישראל
המחלקה המוניטרית

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Catalogue no. 3111505004/4

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WICKSELL'S CLASSICAL DICHOTOMY: IS THE NATURAL RATE OF INTEREST INDEPENDENT OF THE MONEY RATE OF INTEREST?

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and

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Proponents of Taylor Rules assume that the natural rate of interest is independent of the rate of interest set by the central bank. We use data for Israel to test this hypothesis. We proxy the natural rate of interest by the forward yield to maturity on indexed-linked treasury bonds. If the null hypothesis is false it is difficult to suggest persuasive instruments that would identify the causal effect of the money rate on the natural rate of interest. Our identification strategy is therefore built around natural experimentation and event analysis. Large and seemingly exogenous shocks to monetary policy have no measurable effect on the natural rate of interest according to nonparametric and parametric tests. Therefore Wicksell's Classical Dichotomy is empirically valid.

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The views expressed in this paper are those of the authors only, and do not necessarily represent those of the Bank of Israel.

1. Introduction

1.1 The Classical Dichotomy and Neo Wicksellian Monetary Policy

According to the Classical Dichotomy (Patinkin 1965) real variables, such as GDP and unemployment, should be independent in the long run of nominal variables, such as the money stock or the exchange rate. Although this independence is hotly disputed in the short run, there is a surprising degree of consensus about the empirical validity of the Classical Dichotomy in the long-run. Indeed, many New Keynesian economists, such as Blanchard and Qua (1989), resort to the Classical Dichotomy to apply long run restrictions in order to identify SVAR models of macroeconomic activity. In many instances the Classical Dichotomy is accepted as a matter of faith. However, the prediction that the "natural" or equilibrium rate of unemployment should be independent in the long run of nominal variables has been widely tested empirically.

In this paper we turn our attention to the predictions of the Classical Dichotomy regarding the relationship between what Wicksell (1898) termed the "money" and "natural" rates of interest[3]. In Wicksell's "cumulative process" deviations between the money and natural rates of interest affect inflation and economic activity in the short run, but in the long run the two rates of interest move back into line. In this process it is the money rate that adjusts to the natural rate, not the other way round. Indeed the natural rate is hypothesized to be independent of the money rate. As in the Classical Dichotomy the natural rate of interest is ground out in general equilibrium by real economic forces, and is therefore assumed to be independent of nominal phenomena including the money rate of interest.

This Classical Dichotomy has become more important recently due to the resurgence of interest in neo-Wicksellian monetary policy (Woodford 2003), or NWMP for short. NWMP assumes that prices are sticky, and perhaps wages too. It also assumes that central banks use the rate of interest rather than the money supply as the operating instrument for monetary policy. NWMP further assumes that monetary policy is conducted through a Taylor Rule in which the money rate of

[3] Friedman (1968) borrowed Wicksell's terminology to invent the "natural" rate of unemployment, which subsequently outshone the original concept.

interest, which is set by the central bank, responds to actual and expected deviations of inflation and output from their target values. A crucial feature of the Taylor Rule is the role of the natural rate of interest. The Taylor Rule assumes that the central bank anchors the money rate of interest to the natural rate of interest[4]. This means that changes in the natural rate of interest are eventually reflected in the rate of interest set by the central bank. Finally, NWMP takes Wicksell's Classical Dichotomy for granted by assuming that the natural rate of interest is independent of monetary policy, inflation and other nominal phenomena.

It is crucially important therefore for NWMP, which is widely practiced by central banks, that the natural rate of interest be independent of the money rate. If this were not so, the real economy would lack a Classical anchor, just as would be the case if the natural rate of unemployment was not neutral with respect to monetary policy. In this case the economy would be affected by hysteresis and shocks to monetary policy would have permanent real implications via its influence on the natural rate of interest. Also, if the natural rate of interest depended upon the money rate of interest, econometric estimates of Taylor Rules in which empirical proxies for the natural rate are assumed to be exogenous, would be misspecified[5]. In this context too it is important to establish that the natural rate of interest is independent of the money rate. In short, the foundations of NWMP would be seriously undermined if the natural rate of interest was determined by the money rate of interest.

1.2 Background and Methodology

In this paper we investigate empirically whether the natural rate of interest is independent of the money rate of interest. We represent the former by the forward yield to maturity on treasury bonds in Israel that are indexed to the consumer price index. We represent the latter by the Bank of Israel’s (BOI) rate of interest, which is not indexed. We justify our proxy for the natural rate of interest later.

Since the Taylor principle predicts that the money rate depends on the natural rate, and rejection of the null hypothesis predicts that the natural rate depends upon the money rate, there is an obvious identification problem to be resolved in testing the

[4] See, for example, Woodford (2003) pages 286-90.
[5] See Clarida, Gali and Gertler (1999) for examples.

null hypothesis. In the terminology of the econometric analysis of treatment effects (Wooldridge 2002, chap. 18), identification requires instruments that affect the treatment (the central bank's rate of interest) that do not directly affect the outcome (the natural rate of interest). Since in macroeconomics everything may depend upon everything else, it is difficult to find credible instruments to disentangle the causal relationship between the money and natural rates of interest. For almost every conceivable instrumental variable hypothesized to affect the central bank's rate of interest, it is possible to argue that the same variable may also affect the outcome of interest, in which case the causal effect of the money rate on the natural rate is not identified.

It cannot be ruled out that variables such as inflation, growth and unemployment, which typically feature in empirical Taylor Rules, affect the natural rate of interest. If Wicksell's Classical Dichotomy is indeed false, and the natural rate of interest is affected by the money rate, it may also be influenced by inflation and other variables that, according to the Taylor principle, affect the money rate of interest set by the central bank.

The quest for credible instruments to identify the causal effect of the central bank's interest rate on the natural rate lies at the heart of the matter in hand. In a similar context Estrella and Mishkin (1997) and Evans and Marshall (1998) do not use instruments at all. Instead they "identify" the effect of short rates on long rates by simply assuming that there is no immediate reverse causality. These and similar authors interpret the partial correlation between short-term and long-term rates of interest as a causal effect of the former on the latter. They rule out the possibility that there might be a causal effect running in the opposite direction from long rates to short rates.

Ideally, identification requires genuine or natural experimentation with monetary policy to evaluate its effect on the outcomes of interest. Indeed, this is the approach that we apply here. The same approach was also adopted by Romer and Romer (1989), who drew their inspiration from Friedman and Schwartz (1963). Friedman and Schwartz looked for shocks to monetary policy, which "like the crucial experiments of the physical scientists, the results are so consistent and sharp as to leave little doubt about their interpretation." Romer and Romer studied the protocols of the FOMC to identify such quasi experiments carried out by the Federal Reserve System.

In a similar spirit we identify several events where BOI changed its rate of interest in an extreme and arguably unexpected way. We treat these events as quasi experiments from which we may learn about the causal effect of monetary policy on the outcomes of interest. In this paper the outcome of interest is our proxy for the natural rate of interest. BOI does not have the equivalent of FOMC. However, BOI publishes various reports, which may serve a similar narrative function to the FOMC's protocols.

2. The Natural Rate of Interest

2.1 Defining the Natural Rate of Interest

According to Wicksell (1936, p102) the natural rate if interest "is necessarily the same as the rate of interest which would be determined by supply and demand if no use were made of money and all lending were effected in the form of real capital goods." The natural rate of interest ".. depends upon the efficiency of production, on the available amount of fixed and liquid capital, on the supply of labour and land, in short on all the thousand and one things which determine the current economic position of a community.." (p 106). In section A of chapter 9 Wicksell states that his theory of the natural rate of interest is essentially the same as Jevons' and Böhm – Bawerk's. In modern parlance this means that the natural rate of interest is the counterfactual marginal productivity of capital (MPK) that would materialize in a moneyless economy.

Woodford (2003, p248) too defines the natural rate of interest in counterfactual terms. It is,".. the equilibrium real rate of return in the case of fully flexible prices." Wicksell's definition differs from Woodford's because the rate of interest in an economy with money and perfectly flexible prices will generally be different to the rate of interest in an economy without money[6]. Since both concepts are

[6] See, e.g. Johnson (1967), Pesek and Saving (1967) and Sidrausky (1967).

counterfactual, measuring the natural rate of interest is not straightforward. Wicksell's definition requires hypothetical data for a moneyless economy and Woodford's definition requires hypothetical data for an economy with perfect price flexibility. Neither Wicksell nor Woodford (2003, p288) have suggested how in practice the natural rate of interest might be measured. Woodford's definition requires the estimation of a model and simulating the rate of interest under the assumption of price flexibility. This too seems problematic. We need to seek more direct and simpler measures of the natural rate of interest.

2.2 The Marginal Productivity of Capital

One measure of the natural rate of interest is the marginal productivity of capital. National income accounting data may be used to calculate the average return to capital, defined as profits divided by the stock of physical capital. We present such data for Israel[7] on Figure 1 (see Appendix 2), which shows that the return to capital has varied quite substantially. If the aggregate production function happened to be Cobb-Douglas ($Q = AK^{\alpha}L^{1-\alpha}$) the marginal product of capital (MPK) is equal to α times the average productivity of capital (APK = Q/K), so that MPK = αAPK = αQ/K. Since α denotes the profit share, we may calculate MPK from factor share data and from data on the productivity of capital[8]. Alternatively, MPK may be calculated as in Figure 1 directly from data for profits, and the capital stock. In any case, to make this measure conform to Woodford's definition it would be necessary to have counterfactual data in Figure 1, i.e. the data that would have been obtained had prices been flexible.

A common practice in this regard[9] is to calculate such counterfactual data by applying a filter such as the Hodrick-Prescott filter to variable Y and to attribute the detrended value of Y to price stickiness[10]. We think that this practice is wrong because Y is made up of at least three components rather than two. The first

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[7] Using net capital stock data excluding roads.
[8] In the CES case matters are less simple because $MPK = \alpha APK^{1/\sigma}TFP^{1-1/\sigma}$ where σ denotes the elasticity of substitution.
[9] E.g. Roberts (1997).
[10] Woodford (2003, p609) eschews the HP filter on practical rather than conceptual grounds, preferring instead the multivariate Kalman filter since it exploits more information than the HP filter.

component is a nonstationary variable trend (θ_t), the second is a stationary component induced by real business cycles (c_t), and the third is a stationary component induced by price stickiness (x_t). Therefore $Y_t = \theta_t + c_t + x_t$ and the natural rate of Y is $Y_n = \theta + c$. The HP filter identifies the first component and the sum of the second two components. It fails to identify x and therefore Y_n. Alternatively, it identifies Y_n if c is assumed to be zero. Therefore the widespread practice of filtering does not produce plausible measures of the natural rates[11].

2.3 Indexed Bonds

The natural rate of interest is a real variable. It is tempting therefore to look to the market for indexed bonds, which embody real rates of interest. Indexed treasury bonds were first issued in the United States in 1997, and in the United Kingdom in 1982, where they have played a marginal role in their respective capital markets. The same applies in Canada, Sweden and France. However, in Israel they have performed a major role since their introduction in 1955. According to neoclassical term structure theory the yield to maturity (y_{mt}) on an indexed bond maturing in period t + m is:

$$(1+y_{mt})^m = (1+\pi_{mt})\prod_{i=1}^{m}[1+E_t(r_{t+i})] \qquad (1)$$

where π_m denotes a term premium. Equation (1) states that YTMs tend to exceed the underlying spot rate expectations, which is why yield curves tend to slope upwards. The m – ahead forward rate (f_{t+m}) is derived by using market data on the YTMs on bonds maturing m and m-1 periods ahead:

$$f_{t+m} = \frac{(1+y_{mt})^m}{(1+y_{(m-1)t})^{m-1}} - 1 \qquad (2)$$

and the rate of interest expected m periods ahead is equal to:

$$E_t r_{t+m} = \frac{(1+f_{t+m})(1+\pi_{(m-1)t})}{1+\pi_{mt}} - 1 \qquad (3)$$

Since term premia normally vary directly with m, equation (3) says that forward rates tend to be greater than the expected spot rates to which they refer. Suppose the effects

[11] Niess and Nelson (2002) even argue that the filtered output gap is negatively correlated with theory-based measures of the gap.

of price stickiness dissipate after m* periods. The solution to equation (3) would equal the current expectation of the natural rate of interest m periods ahead provided m > m*. If m < m* the expected real rate of interest would be influenced by price stickiness, in which case it could not be considered as a natural rate of interest.

The forward yield to maturity m* periods ahead on indexed bonds with maturity M – m* is equal to:

$$z_t = \frac{(1+y_{Mt})^M}{(1+y_{m^*t})^{m^*}} - 1 = \frac{1+\pi_{Mt}}{1+\pi_{m^*t}} \prod_{i=m^*+1}^{M} [1+E_t(r_{t+i})] - 1 = E_t(y_{(M-m^*)t+m^*}) \qquad (4)$$

Equation (4) states that z_t is the current expected value m* periods ahead of the yield to maturity on indexed bonds with maturity M – m*. For example, if M = 10 years and m* = 3 years, z is the current expectation of the yield to maturity on a 7 year indexed bond in 3 years time. Since the effects of price stickiness dissipate after m* years this forward rate is clean of the effects of price stickiness and conforms to Woodford's counterfactual definition. Equation (4) also shows that this forward yield to maturity reflects the natural rates of interest expected to prevail between 4 and 10 years ahead. Since term premia tend to vary directly with m, the forward YTM tends to overstate the natural rates of interest to which they refer. If prices were perfectly flexible, i.e. m* = 0, then z is the current yield to maturity on "natural" bonds maturing M years ahead.

If the term premium ratio is stable, equation (4) shows that changes in z are perfectly correlated with changes in expected natural rates of interest. Although absolute term premia might vary over time, the ratio between them is likely to be more stable for two reasons. First, real term premia are likely to be more stable than nominal term premia. Secondly, real term premia shocks are likely to be positively correlated, so that π_M and π_{m^*} change in the same direction.

In summary, we use market data on the term structure of indexed bonds to calculate the forward yield to maturity, which we use to proxy the expected natural rates of interest. We cannot directly proxy the current natural rate unless we assume that prices are flexible (m* = 0). Nevertheless, we hope that finding a plausible proxy for the expected natural rate is a step forward. In principle we may infer the entire term structure of natural interest rates. However, we prefer to use the forward yield to maturity because this smoothes measurement error in the individual forward rates, which stems from the auxiliary neoclassical hypothesis used to generate the data. Since m* is unknown we experiment with different values. Since the results are insensitive to minor changes in m* we report results for m* = 3 years.

In Figure 2 (see Appendix 2) we plot illustrative yield curves for indexed treasury bonds in Israel. In Figure 3 we plot the forward interest rates that are implied by the data in Figure 2. These forward interest rates are real rates of interest because the term structures in Figure 2 refer to real rates of interest. The data in Figure 3 have been calculated under the assumption that the term premia are zero. Since these unknown term premia tend to vary directly with the term to maturity, equation (2) implies that the data in Figure 3 are over-estimates of the expected future spot rates of interest.

In Figure 4 (see Appendix 2) we plot the 3-year forward yield to maturity on 7-year indexed bonds implied by equation (4) derived from the yields to maturity on 3-year and 10-year indexed treasury bonds. This forward rate rose from about 2.5% in 1992, peaked at 6% in 2002 and was about 4% in 2004. Note that these implied natural rates of interest are much less volatile than their counterparts from Figure 1. Here too, we have ignored the term premia. Since the term premium on a 10-year bond is normally higher than on a 3-year bond, equation (3) implies that the forward rates in Figure 4 are over-estimates of the expected YTM

If the term premia vary over time the forward rates will contain measurement error that is time dependent. However, this measurement error is mitigated in our case because, as mentioned, the term premia are real rather than nominal.

3. Testing for Neutrality

3.1 Identification

According to the null hypothesis β = 0 in the following linear model for the natural rate of interest:

$$r_{nt} = \alpha + \beta i_t + \theta Z_t + u_t \qquad (5)$$

where Z denotes a vector of exogenous variables hypothesized to determine the natural rate of interest, and i denotes the money rate of interest. The money rate of interest is hypothesized to be determined by a Taylor Rule:

$$i_t = (1-\lambda)r_{nt} + \lambda i_{t-1} + \phi X_t + e_t \qquad (6)$$

where X contains the variables to which monetary policy is hypothesized to react. Also, the random components may be correlated, i.e.:

$$e_t = \mu u_t + \varepsilon_t \qquad (7)$$

We assume that ε is iid. If the null hypothesis is correct and μ = 0, equation (6) is recursive to equation (5) implying one-way causation from the natural rate to the money rate. If, however, μ ≠ 0 then β is not identified. If the null hypothesis is incorrect equations (5) and (6) are simultaneous in which case the identification of β requires instrumental variables that affect i_t but which do not directly affect r_{nt}. Clearly i_{t-1} cannot serve as an instrument because Z_t will include i_{t-1} if the money rate has a lagged causal effect on the natural rate. Nor will components of X_t contain identifying information if we cannot rule out that that the same components are contained in Z_t. For example, the output gap and excess inflation are components of X_t, but they arguably may also be components of Z_t, especially if Wicksell's Classical Dichotomy is empirically invalid.

We eschew the widespread practice[12] of appealing to weak exogeneity as a source of identification. For example, if the lagged natural rate is specified in equation (6) instead of its current counterpart, β would be identified provided equation (5) did not include the lagged natural rate. Identification through weak exogeneity is risky because it requires dynamic restrictions, which are quite arbitrary. Economic theory usually has little to say about the dynamic specification of models. Therefore the appeal to weak exogeneity depends upon happen-chance, which in our opinion does not serve as a convincing methodological basis for hypothesis testing.

In a natural or quasi experiment the treatment varies in a way that is entirely independent of the outcome. In the present context this means that the central bank alters its rate of interest for reasons that have nothing to do with the natural rate of interest. More formally it means that shocks to ε_t occur independently of u_t and Z_t.

[12] Especially in the context of numerous applications of GMM.

Since Z_t potentially includes X_t, this means that the central bank changes its rate of interest for reasons that are in some sense unusual or even haphazard. For example, the central bank might act out of panic and change the money rate in an abrupt and sharp fashion. Or it might act as a result of political pressure. What is important is that whatever triggers the natural experiment has nothing to do with current and lagged values of the natural rate and Z, and therefore X.

Note that a natural experiment is different from a real experiment in which shocks are initiated in a coordinated, premeditated way and even self-conscious way. Real experiments may induce Hawthorne effects, which corrupt the experiment because the treated do not behave as they normally would (Jones 1992). By contrast natural experiments occur without individuals being properly aware that they are in fact part of an experiment. As a result they behave unselfconsciously and naturally. Just imagine what would happen if the Chairman of the Fed announced that he is cutting interest rates by a whole percentage point to help econometricians identify the effects of monetary policy. People would want to know how long does he intend to run this experiment? Does he intend to reverse the experiment in due course? Capital markets would get muddled.

As Friedman and Schwartz and the Romers before us, we try to identify "large and independent monetary disturbances", which represent the εs, or at least a subset of them. In principle the disturbances do not have to be large, but as we shall see, it is their very largeness that points to their independence, because large changes to interest rates are typically unexpected. If ε is small it not only generates less statistical resolution, it is also more difficult to be persuaded that it is indeed independent.

3.2 Event Analysis

Having identified the εs we use a non-parametric procedure based on event analysis (e.g. Campbell, Lo and MacKinley 1997, cap 6) to investigate the effect of the shocks on the proxy for the natural rate of interest. We take each "event" and track our proxy for the natural rate before and after the event. According to the null hypothesis the behavior of the natural rate should be independent of the event both before and after its occurrence. If the null hypothesis is rejected we expect to see significant changes in the natural rate in the aftermath of the event. Since there is no reason why the timing and the response of the natural rate should be identical across events we use nonparametric tests to investigate qualitative rejections of the null hypothesis.

We distinguish between different types of falsifying evidence in response to positive events ($\varepsilon > 0$):

1. The natural rate rises permanently and instantaneously to a new level after the event.
2. As in #1 but the response is gradual.
3. As in #1 but the response is transitory.
4. The natural rate adjusted prior to the event.
5. A combination of #1 and #4.

Note that since by definition ε is orthogonal to Z in equation (5), the event analysis identifies the dynamic effect of the money rate on the natural rate. It is not necessary to specify other variables that determine the natural rate as would be required for structural estimation. Suppose for example that the first type of rejection applies, this would identify β, the instantaneous causal effect of the money rate on the natural rate. If the second type applied, the dynamic causal effect of the money rate on the natural rate would be identified. Therefore the baseline in the event analysis does not have to take into account what the outcome variable would have been in the absence of the treatment. The estimation of treatment effects in this way does not require knowledge of structural parameters such as θ, ϕ, λ and μ[13].

Let $g_n = \Delta_d Y_n$ denote the normalized[14] response of the outcome variable in the n'th quasi experiment where d denotes time since the shock. If the data are daily and d = 1 the response of the outcome variable is measured by the normalized change in the outcome variable during the first day after the shock. The larger is d the longer is the time frame over which the change in the outcome variable is measured. It is of course possible that there is no short-term response, i.e. when d is small, but there is a long-term response, i.e. when d is large, or vice-versa. This implicitly assumes that in the absence of

[13] In clinical trials one does not require a complete structural model of the patients. It is merely necessary to compare the responses of the treated and the controls. Treatment effects are therefore reduced form parameters.

[14] We normalize by the size of the change in the BOI's rate if interest and its direction.

the shock $E(\Delta_d Y) = 0$. According to the null hypothesis $g_n = 0$ since shocks to the money rate should have no effect on the natural rate. We apply Wilcoxon's signed-rank test (W), which assumes that the quasi experiments are independent, by ranking the g's for different time frames d. W is normally distributed even when the number of experiments[15] is quite small. If W > 0 exceeds its critical value we may reject the null hypothesis that g = 0 over a given time frame. Alternatively, if W < 0 exceeds its critical value we may reject the null on the grounds that the effect of the money rate on the natural rate is significantly perverse.

3.3 Time Series Models

In addition to non-parametric event analysis we also use more standard econometric techniques for identifying the effect of quasi-experimental shocks to the money rate on the natural rate. We denote the expected real money rate of interest (r) as the money rate (i) minus expected inflation (π^*): $r = i - \pi^*$. In the long run Wicksell's model implies (up to a constant) that $r = r_n$. We use the following vector error correction model (VECM) to identify the causal nexus between the natural and money rates of interest. For simplicity we assume that the VECM is first-order:

$$\Delta r_{nt} = \pi_1 + \sum_{i=1}^{p} \pi_{2i} \Delta r_{nt-i} + \sum_{i=0}^{s} \pi_{3i} \varepsilon_{t-i} + \pi_4 r_{t-1} + \pi_5 Z_t - \pi_6 r_{nt-1} + u_t \qquad (8)$$

$$\Delta i_t = \kappa_1 + \sum_{i=1}^{q} \kappa_{2i} \Delta i_{t-i} + \sum_{i=0}^{h} \kappa_3 \Delta r_{nt-i} + \kappa_4 (r_{nt-1} - r_{t-1}) + \kappa_5 X_t + v_t \qquad (9)$$

As in equation (1), Z in equation (8) is a vector of real variables that determine the natural rate of interest in the long run, which, under the null hypothesis, is equal to $(\pi_1 + \pi_5 Z)/\pi_6$. The null hypothesis is rejected in the short-run if $\pi_{30} \neq 0$, it is rejected in the medium run if $\pi_{3i} \neq 0$ for i = 1, 2,..s, and it is rejected in the long-run if $\pi_4 \neq 0$, i.e. there is error correction from the money rate of interest to the natural rate of interest. Normally, we expect these coefficients to be positive. As in equation (2), X in equation (9) is a vector of "Taylor Rule" variables, which tend to zero over time as targets are achieved. Wicksell's Classical Dichotomy predicts that $r = \kappa_1/\kappa_4 + r_n$ in the long run, so that there is error correction from the natural rate to the money rate of interest, but not the other way around.

[15] Owen (1962) provides exact critical values for W when the sample size is small.

4. Results

4.1 The Events

We have chosen 1994 – 2004 as the observation period since the structure of monetary policy was homogeneous during this period. The government operated inflation targets, the exchange rate was flexible[16], and BOI announced (about 10 days in advance) its rate of interest for the next month. For most of this period Jacob Frenkel was Governor of the Bank of Israel. David Klein was Governor during 2000 – 2004[17]. As may be seen in Table 1 (see Appendix 3) the rate of inflation was reduced from the teens to zero, the rate of unemployment tended to grow, and the economy grew at an average annual rate of 4%. It was during this period that the economy absorbed mass immigration from the former Soviet Union, which added about 20% to the population during the 1990s[18]. In Figure 5 (see Appendix 2) we plot the BOI's interest rate, which serves as the money rate of interest.

During the period 1994 – 2004 we have identified 7 events that constitute "large and independent monetary disturbances". Some of these events were doubles (events 5 and 7) in that BOI changed interest rates more than once. Details of the event analyses for our 7 experiments are presented in the Appendix 1, where we show the response of our natural rate proxy before and after the event using an event window of 2 months. Note that we use daily data to increase resolution. In each event window we are looking for the effect of the shock on changes in the outcome variable. For example, in the first event, which took place at the end of August 1994, BOI raised its interest rate by 1.5%. However, there was no discernable change in the forward yield to maturity on indexed bonds either before or after the shock. There was a very small increase on August 21 but this was not statistically significant. It is unreasonable to claim that the bond market anticipated the shock.

Some of the events were triggered by shocks overseas. For example, Event 5 followed the Ruble Crisis, which broke out on August 17, 1998 when the Russian government defaulted on its ruble bonds. At first the crisis was regarded as a parochial

[16] The exchange rate floated throughout the entire period, at first within a band, but the band was progressively widened. Until 1998 the float was managed, but subsequently there has been no exchange rate intervention. In June 2005 the exchange rate bands were formally abolished.

[17] Stanley Fischer became Governor in May 2005.

[18] For a review of economic developments in Israel during this period see Ben Bassat (2001).

matter until it became clear 6 weeks later that Long Term Capital Management was threatening to fail as a result. Contagion was feared, panic struck and BOI raised interest rates twice and even broke precedent by raising interest rates in the middle of the month. There is an obvious problem of identification here. The Ruble Crisis caused BOI to raise its interest rate, and it caused bond yields to rise. The event window shows that the bond market in Israel remained steady until mid September. By contrast domestic bond markets in other emerging markets, such as Brazil, South Korea and South Africa weakened substantially. It is ironical that by the time BOI took action bond markets in these countries had more or less recovered. Therefore Event 5 was simply panic reaction, which has obvious identifying power.

Other events were triggered by political shocks. For example, Event 6 followed extraordinary political pressure on Governor Klein, who quite uncharacteristically cut interest rates massively. Having realized his error this lead to Event 7 when interest rates were raised by a record amount of 3.5%. Figure 6 (see Appendix 2) provides a bird's eye view of the events.

4.2 Nonparametric Tests

Visual examination (see Appendix 1) of each of the events does not suggest that the 3-year ahead forward yield to maturity on 7-year indexed bonds responds to interest rate policy. In Table 2 (see Appendix 3) we classify the results for our 7 experiments.

The Wilcoxon test statistic is initially positive (when d = 1 day) but it falls well below its critical value. When a wider window is used W turns out to be negative, but never approaches statistical significance. While the event windows do not suggest that monetary policy affects our proxy for the expected natural rate of interest, they suggest that monetary policy may be affected by the natural rate of interest. It is noticeable that positive events (when BOI raised its rate of interest) followed increases in the natural rate, and negative events followed decreases. Indeed, this impression is confirmed by our estimates of the VECM.

4.3 Taylor Rule

In Table (3) (see Appendix 3) we report estimates of equation (9), which has been estimated using the general-to-specific methodology (Hendry 1995). The X- variables to which BOI is hypothesized to react are similar to those reported by Sussman (2004) and Melnick (2005). They include the output gap, the BOI's coincident indicator of economic activity, inflation, expected inflation, target inflation, and the output gap. The signs of these variables are as expected. Table 3 shows that BOI reacts particularly to changes in expected inflation, so that the Taylor Rule is forward-looking. However, it is also backward-looking since lagged inflation matters too. Note also that changes in the output gap rather than its level, and changes in the rate of growth in the BOI's coincident indicator induce reactions by BOI.

An important novelty is that we introduce our proxy for the natural rate of interest (z) into the model. Table 3 shows that BOI reacts to lagged changes in the natural rate of interest and that there is error correction from the natural rate to the (real) money rate. Therefore, in the long-run the natural rate drives the money rate, on a one-to-one basis (up to a constant). There is both short-term and long-term error correction from the natural rate to the money rate. Within 6 months BOI raises its rate of interest by half a percentage point when the natural rate increases by one percentage point. Within a year it has completely adjusted its rate of interest to the natural rate.

4.4 Parametric Test of Wicksell's Classical Dichotomy

We estimated equation (8) using a variety of alternatives for the Z variables. These included expected yields to maturity on 10-year bonds issued by the US Treasury, the rate of growth of per capita income in Israel, and the ratio of government debt to GDP. In none of these specifications did the π_3 and π_4 parameter estimates turn out to be even remotely statistical significant. Therefore, both in the short-run and in the long-run there is no evidence that shocks to the money rate of interest affect the natural rate of interest. The only statistically significant coefficients are the autoregressive parameters (π_2) at lags 1 and 2. Table 4 (see Appendix 3) presents a typical result. None of the coefficients on the ε's is remotely statistically significant, in which case the π_3's are zero. The same applies to the coefficients on the lagged changes in the money rate of interest. Finally, there is no error correction since the coefficient of r – NRI does not approach statistical significance in which case π_4 is zero.

At one level this none-result is disappointing, because we have been unable to determine the variables that drive the natural rate of interest. On the other hand, it is encouraging because it shows that we cannot reject Wicksell's Classical Dichotomy, and that this result is robust with respect to alternative specifications of the Z variables.

In Table 4 m* = 3 years, which assumes that it takes 3 years for the effect of price stickiness to dissipate. We could find no causal effect of the BOI's interest rate on forward YTMs on indexed bonds when m* > 3, suggesting that price stickiness does not take longer than 3 years to dissipate. However, the same was not true when m* was reduced. For example, setting m* = 0, we estimated the following restricted model for YTM on 10 year index bonds:

$$\Delta YTM_t = \underset{(-0.1599)}{-0.0023} + \underset{(6.1217)}{0.5094}\Delta YTM_{t-1} - \underset{(-3.3061)}{0.2726}\Delta YTM_{t-2} + \underset{(3.3976)}{0.0829}\varepsilon_t$$

$$R^2 \text{ (adjusted)} = 0.2831 \quad DW = 1.9276 \quad SE = 0.1624$$

The autoregressive structure is the same as in Table 4. What is different is the coefficient on ε_t, which is statistically significant, suggesting that there is an instantaneous causal effect of the money rate of interest set by BOI on the long-term indexed bond market. This result is to be expected if price are not perfectly flexible, and so does not reject Wicksell's Classical Dichotomy. However, when m* = 1 this effect weakens and disappears altogether when m* = 3 years as in Table 4. This suggests that price stickiness dissipates after about 2 years.

5. Conclusion

To test Wicksell's Classical Dichotomy we use the forward yield to maturity on indexed bonds to proxy expected "natural" yields to maturity. In the absence of convincing exclusion restrictions on potential instrumental variables, we use natural experimentation and event analysis to identify the effect of monetary policy on the natural rate of interest. We select 7 events in which the Bank of Israel changed its interest rate in a quasi-experimental manner. We use nonparametric and parametric tests to investigate the causal effect of the BOI's interest rate policy on the expected natural rate of interest. These tests turned out to be negative, confirming the empirical validity of Wicksell's Classical Dichotomy.

Our results show that whereas there is no causal effect of the money rate of interest on the natural rate of interest, there is a causal effect of the natural rate on the money rate. This result confirms Taylor Rule theory, which predicts that the natural rate of interest anchors the money rate of interest. It takes about a year for BOI to adjust the money rate of interest to developments in the natural rate. It also means that the natural rate of interest serves as a strongly exogenous regressor in Taylor Rule regressions. Therefore to estimate Taylor Rules (for Israel) it is not necessary to find instrumental variables for the natural rate of interest.

The empirical confirmation of Wicksell's Classical Dichotomy implies that monetary policy is not hysteretical; it does not affect the level of output and other real variables in the long run.

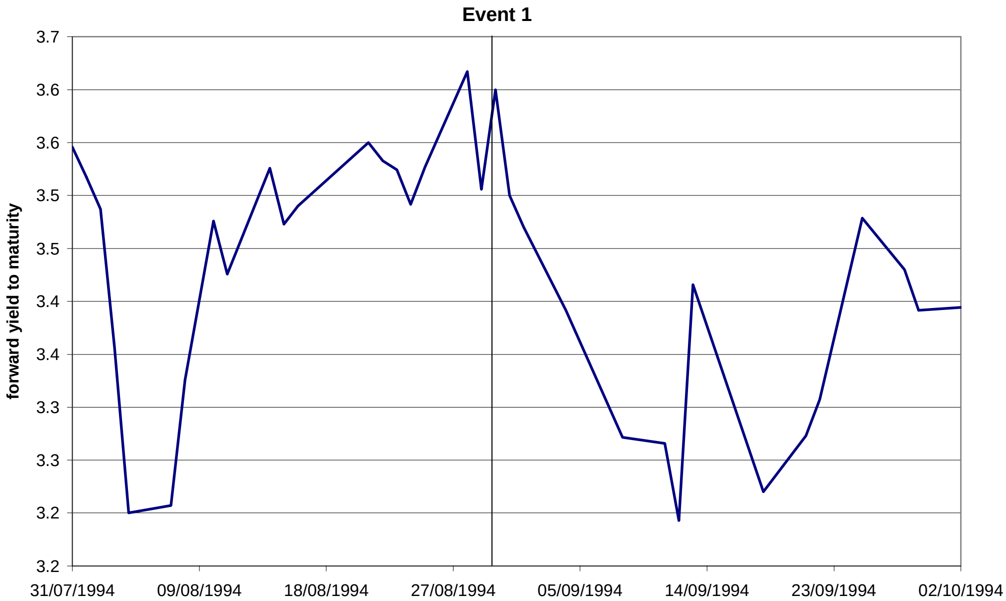
Appendix 1: The Events[19]

Events 1 and 2

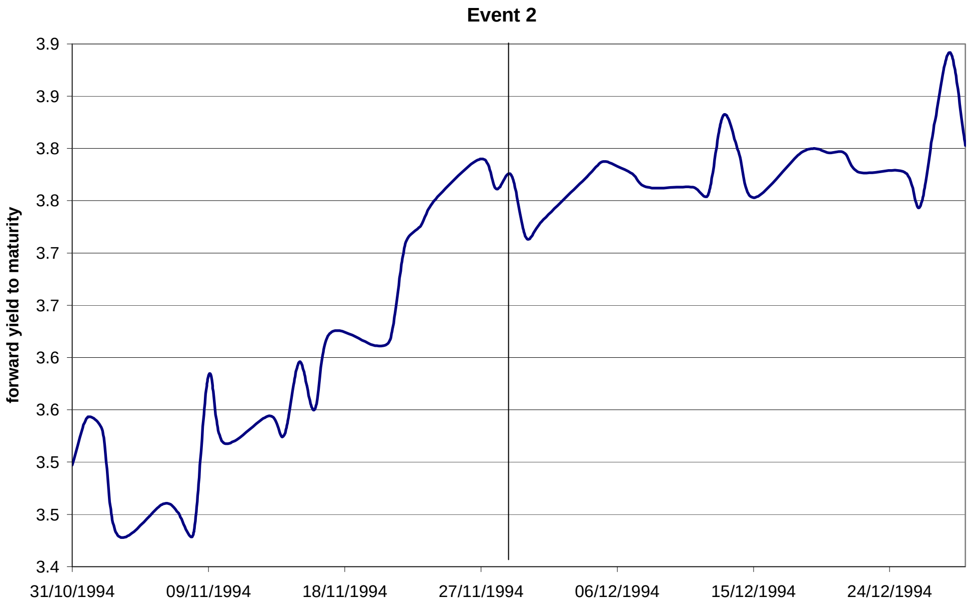
On 30.08.1994 the Bank of Israel announced a change in interest rates by 1.5% to take effect from date 01.09.1994.
On 29.11.1994 the Bank of Israel announced a change in interest rates by 1.5% to take effect from date 01.12.1994.

"Against the background of rising prices during this period, which was relatively high at 14%, and concern about further acceleration in the future, together with expanding aggregates and other indicators of demand expansion, BOI raised its rate of interest at the beginning of September by 1.5 percentage points, and by the same amount in October and December." (Bank of Israel Report 1994, page 302)

Comment: The background to the hike in interest rates was quite conventional, but the scale came as a complete surprise. These events signaled the inauguration of the BOI's new policy of interest rate activism.



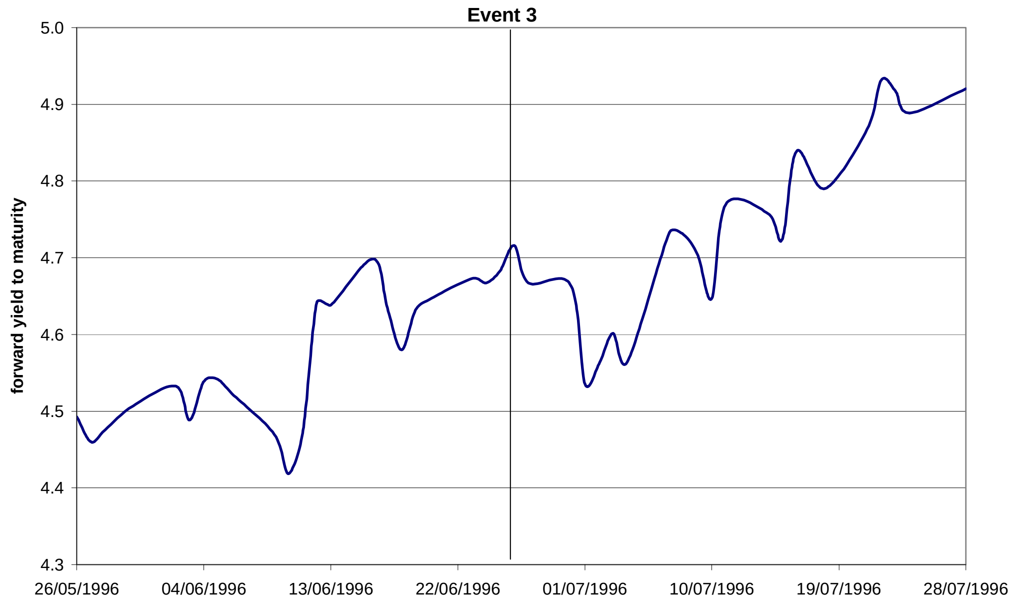
[19] We are grateful to Yifat Lerner who helped prepare this appendix.



Event 3
On 27.06.1996 the Bank of Israel announced a change in interest rates by 1.5% to take effect from date 31.06.1996.

"During the first third of the year, and in April and May in particular, prices accelerated by substantially more than the inflation target. Also, expected inflation substantially exceeded the inflation target. In response to this BOI raised its rate of interest." (Report 1996, page 165)

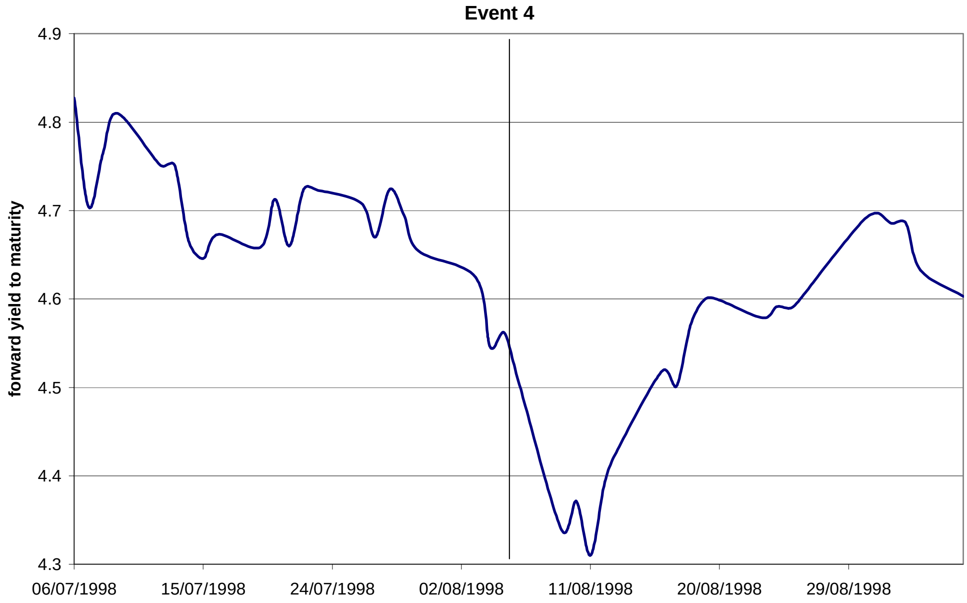
Comment: The background to the hike in interest rates was quite conventional, but the scale came as a complete surprise.



Event 4
On 6.08.1998 the Bank of Israel announced a change in interest rates by 1.5% to take effect from date 9.08.1998.

"Against the background of the sharp and unexpected fall in inflation BOI gradually lowered interest rates during the first 7 months of the year." (Report 1998, p 191)

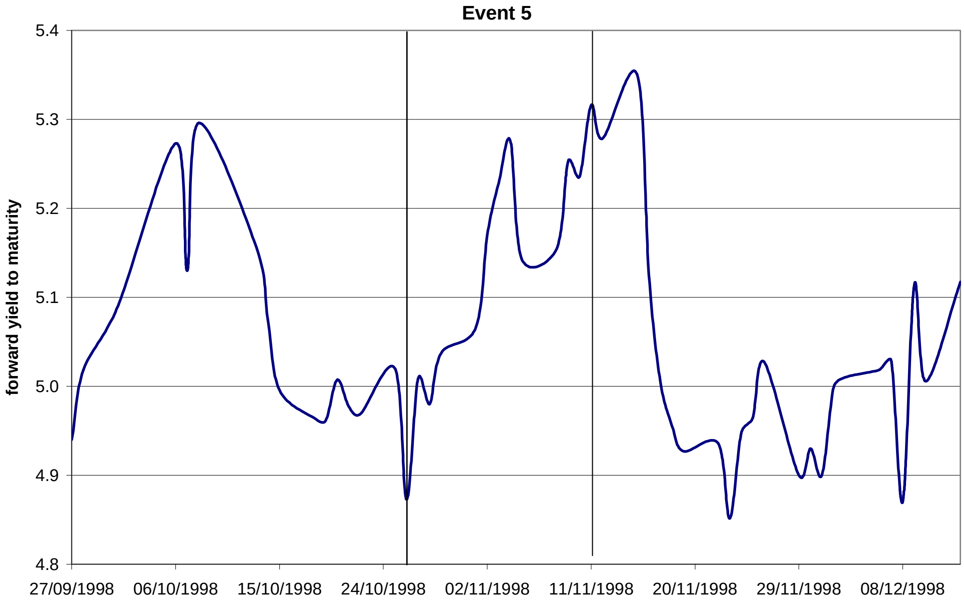
Comment: Surprisingly, nothing is mentioned of the large cut in interest rates announced on August 8. The cut coincided with the announcement of a lower inflation target and a widening of the exchange rate band.



Event 5
On 26.10.1998 the Bank of Israel announced a change in interest rates by 2% to take effect from 29.10.1998.
On 12.11.1998 the Bank of Israel announced a change in interest rates by 2% to take effect from15.11.1998.

"Following the devaluation in early October, which at 15% was unprecedented in recent years, and which was entirely caused by market forces, prices began to rise, expected inflation soared, and it was feared that inflation would accelerate. To prevent this BOI raised interest rates on October 26 and November 12 by 2% each time." (Report 1998, page 195)

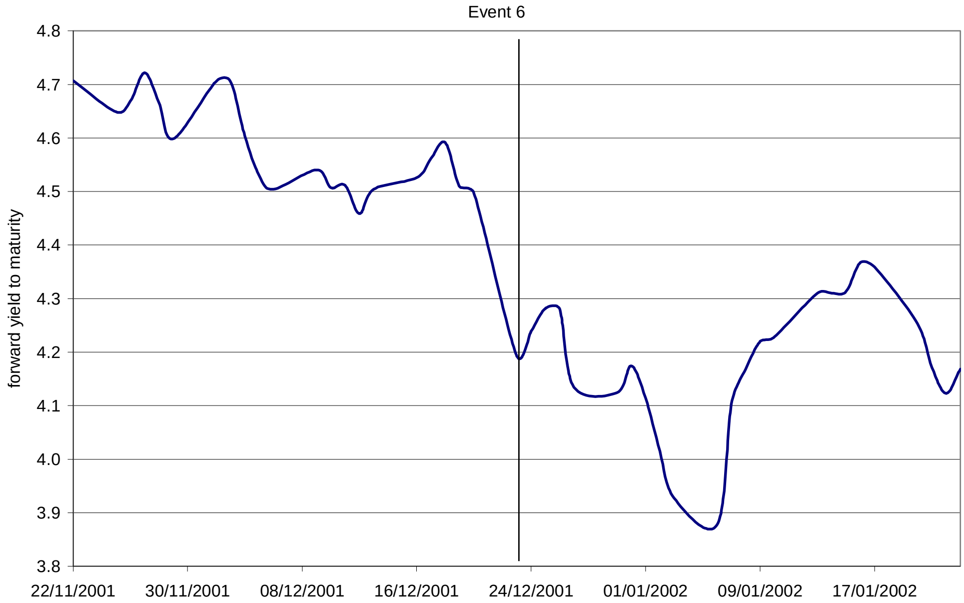
Comment: The ruble crisis broke out on August 17. Domestic bond markets in emerging markets such as South Africa and Brazil suffered, but not in Israel. By the time of the outbreak of the LTCM crisis at the end of September bond markets in South Africa and Brazil had recovered. There was no logical reason why the LTCM crisis should affect Israel (or elsewhere). Most probably BOI misinterpreted the shekel's weakness in October and panicked. It even broke precedent by changing interest rates in the middle of the month.



Event 6
On 23.12.2001 the Bank of Israel announced a change in interest rates by 2% to take effect from 25.12.2001.

"During the last quarter of 2001 expected inflation was less than the lower bound of the inflation target, and it was apparent that the recession was deepening. These developments justified a cut in interest rates. On the other hand, the fiscal deficit substantially exceeded its target… Against this background the Government decided on a coordinated move in which fiscal discipline would be restored and BOI would cut interest rates by 2%." (Report 2001, page 4)

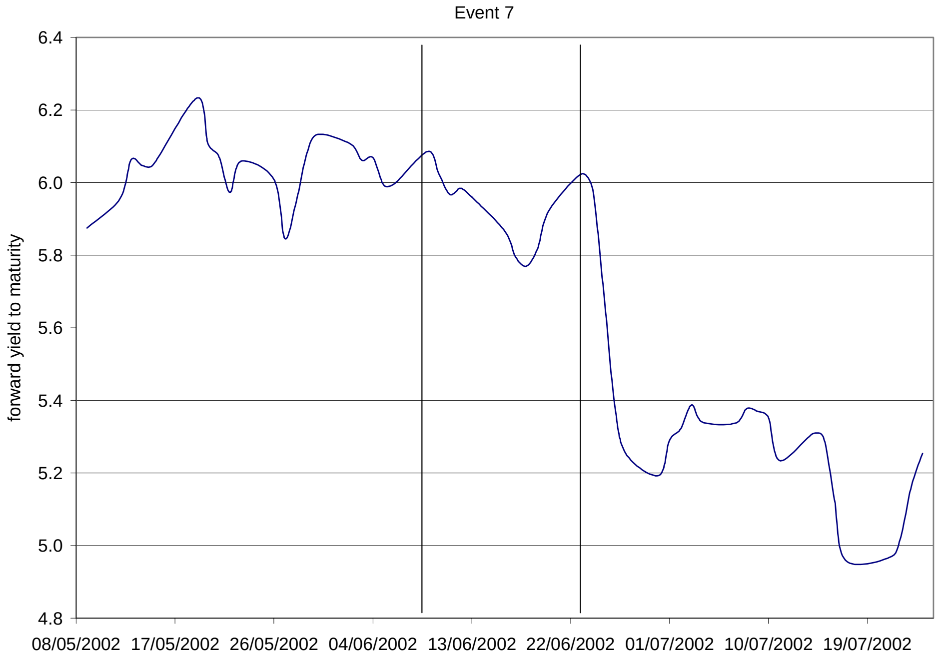
Comment: This cut, announced on December 23, was most out of character. The otherwise extremely cautious Governor Klein had drastically cut interest rates in return for a promise of fiscal discipline by a notoriously incautious finance minister (Silvan Shalom).



Event 7
On 9.06.2002 the Bank of Israel announced a change in interest rates by 1.5% to take effect from11.06.2002.
On 24.06.2002 the Bank of Israel announced a change in interest rates by 2% to take effect from 27.06.2002.

"Between April and the end of June all the relevant indicators of price and financial stability deteriorated persistently. In particular, the exchange rate and expected inflation continued to increase. BOI raises interest rates by 0.2% in May, but to no effect, and in June BOI raised interest rates twice by a total of 2.5%." (Report 2002, page 3)

Comment: Once again BOI broke precedent by changing interest rates in the middle of the month. This event unwound Event 6. Fiscal discipline was not restored until the finance minister was replaced by Benjamin Netanyahu.


Event 7
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
forward yield to maturity
08/05/2002
17/05/2002
26/05/2002
04/06/2002
13/06/2002
22/06/2002
01/07/2002
10/07/2002
19/07/2002

Appendix 2 :The Figures

Figure 1 – The Return to Capital in the Business Sector

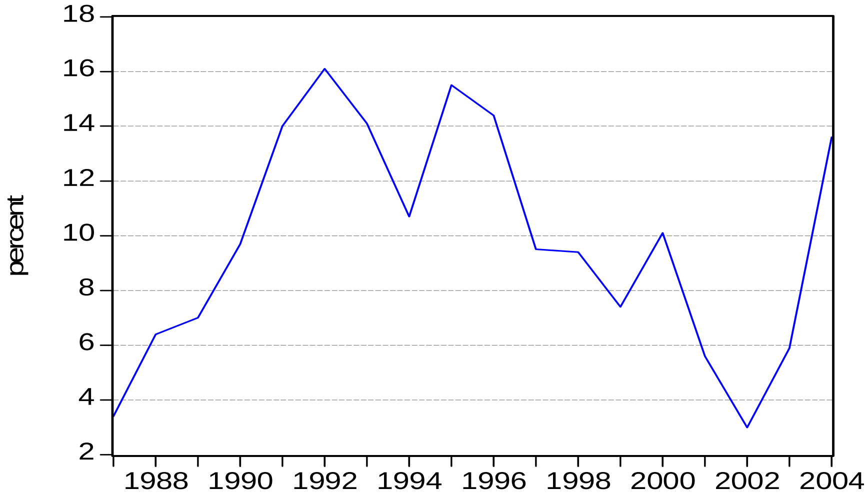


Figure 2 – Yield Curves for Indexed Treasury Bonds

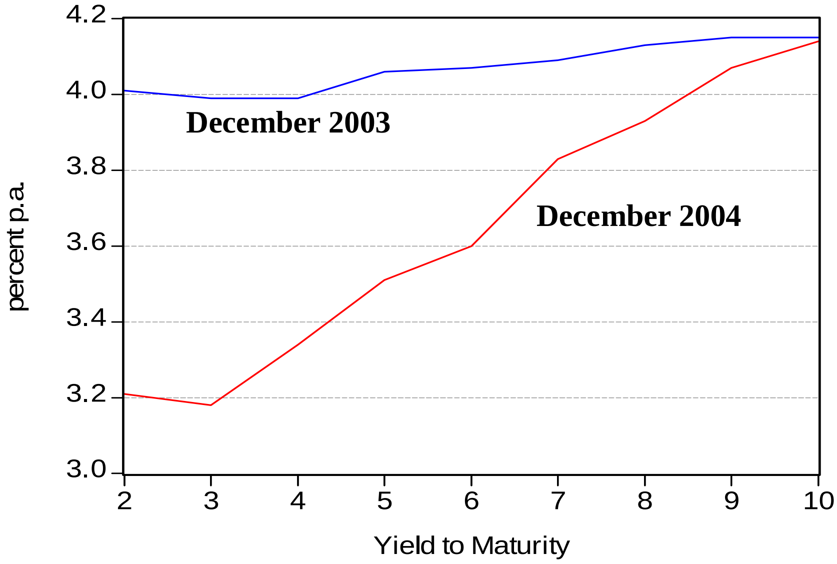


Figure 3-Forward Interest Rates on Indexed Treasury Bonds (annual)

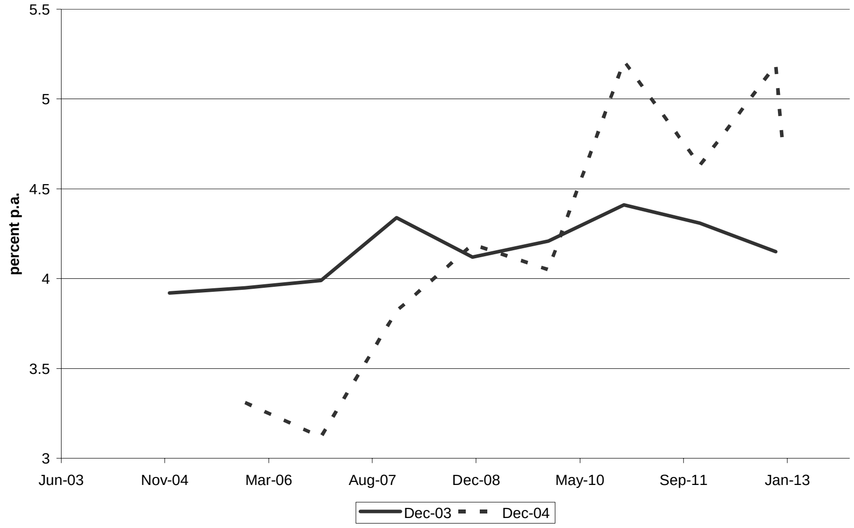


Figure 4- 3-Year Forward Yield to Maturity on 7 Year Indexed Treasury Bonds

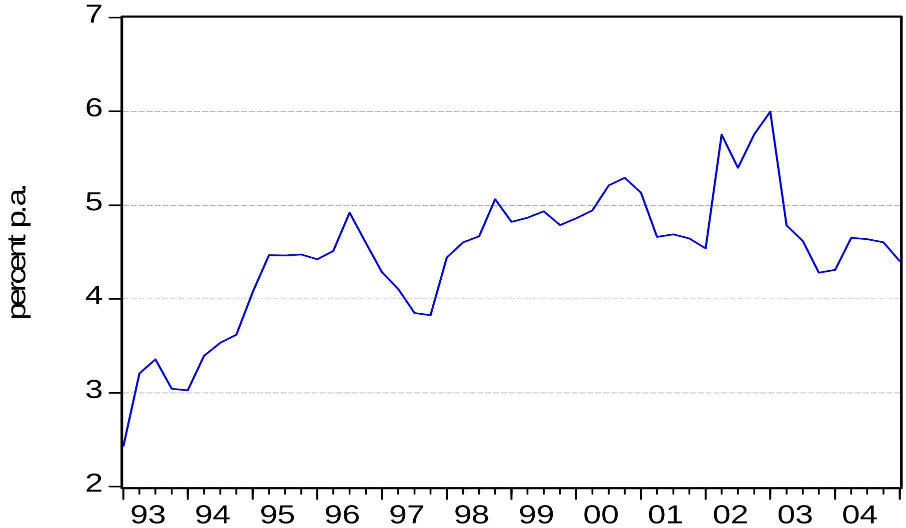


Figure 5 – The Rate of Interest Set by the Bank of Israel

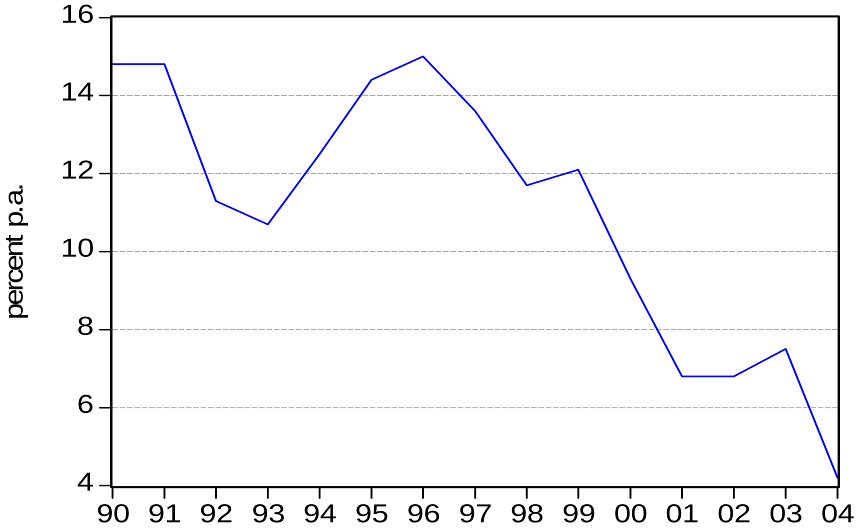
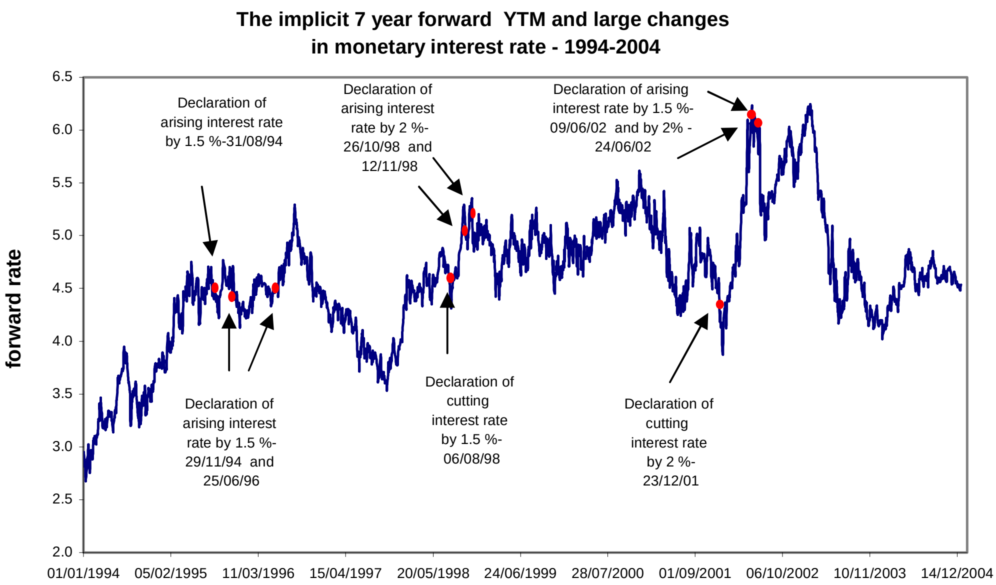


Figure 6- Bird's Eye View of Monetary Events



Appendix 3 : The Tables

Table 1- Background Data of Israel, 1990-2004

Inflation Rate (percent p.a.)	Growth rate of GDP (percent p.a.)	Unemployment Rate (rate percent)	Year
17.6	6.6	9.6	1990
18.0	6.1	10.6	1991
9.4	7.2	11.2	1992
11.2	3.8	10	1993
14.5	7.0	7.8	1994
8.1	6.6	6.8	1995
10.6	5.2	6.6	1996
7.0	3.5	7.6	1997
8.6	3.7	8.6	1998
1.3	2.5	9.0	1999
0.0	8.0	8.8	2000
1.4	-0.9	9.3	2001
6.5	-0.7	10.3	2002
-1.9	1.3	10.7	2003
1.2	4.3	10.4	2004

Table 2- Event Classification

Event	Temporary Effect (1 week)	Permanent Effect (1 month)
1	-0.1	-0.2
2	NONE	NONE
3	NONE	0.2
4	0.2	-0.1
5	First Announcement NONE Second Announcement -0.4	First Announcement NONE Second Announcement -0.2
6	NONE	NONE
7	First Announcement NONE Second Announcement -0.7	First Announcement -0.7 Second Announcement -0.6
Wilcoxon Statistic	d: 1 3 5 10 20 30 W: 1.13 -0.89 -0.77 -0.89 -0.89 -1.6	

Table 3 -Taylor Rule Model
(dependent variable: Δi_t)

	Coefficient	p-value
Intercept	-0.6139	0.0569
Δi_{t-1}	0.1513	0.0320
Δi_{t-4}	0.1169	0.0319
Δz_{t-4}	0.4170	0.0207
$(r-z)_{t-1}$	-0.1559	0.0212
$\Delta \pi^e_{t-1}$	0.2873	<0.0001
$\Delta \pi^e_{t-3}$	0.1623	0.0027
π_{t-1}	0.0142	0.0130
π_{t-2}	0.0190	0.0025
$\Delta \pi_{t-3}$	0.0134	0.0078
$\pi^*_{t-1} - \pi^*_{t-4}$	-0.1578	0.0030
$\Delta^2 C_t$	0.0492	0.0125
$\Delta^2 C_{t-2}$	0.0321	0.1051
$GAP_{t-2} - GAP_{t-4}$	0.0549	0.0093
R^2 adjusted	0.69553	
Standard error	0.3747	
LM(12)	12.49	0.4069

OLS May 1994 – December 2004. π = annual inflation, π^e = expected inflation (derived from capital market data), π^* = target inflation, C = log coincident indicator, GAP = output gap (derived from HP-filter).

Table 4 -Testing Wicksell's Classical Dichotomy
(Dependent variable is ΔNRI)

Variable	Coefficient	P-value
Intercept	0.0732	0.8258
ΔNRI_{t-1}	0.3899	0.0001
ΔNRI_{t-2}	-0.2566	0.0080
$(r-NRI)_{t-1}$	-0.0022	0.8520
ε_t	-0.0333	0.3248
ε_{t-1}	-0.0466	0.4335
ε_{t-2}	-0.0281	0.6499
ε_{t-3}	-0.0203	0.7491
ε_{t-4}	-0.0367	0.5260
Δi_{t-1}	0.0273	0.6607
Δi_{t-2}	0.0589	0.4115
Δi_{t-3}	-0.0266	0.7080
Δi_{t-4}	0.0459	0.4237
R^2 adjusted	0.0882	
LM	14.421	0.2746

OLS May 1994 – December 2004. Controls for 4 lags on debt/GDP. LM tests for upto 12^{th} order serial correlation.

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