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The Effect of Fiscal and Monetary Policies and the Global Economy on Real Yields of Israel Government Bonds

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השפעתן של המדיניות הפיסקלית והמוניטרית בישראל, ושל הכלכלה הגלובלית,
על התשואות הריאליות של האג"ח הממשלתיות בישראל: בחינה מחודשת לאחר עשור

עדי ברנדר וסיגל ריבון

תקציר

המחקר בוחן כיצד המדיניות הפיסקלית והמוניטרית בישראל, וכן הפעילות הכלכלית והסביבה העולמית, השפיעו על התשואות הריאליות על האג"ח הממשלתיות בישראל בין 2001 לספטמבר 2013. אנו מוצאים כי למדיניות הפיסקלית, כפי שהיא מתבטאת ביחס החוב הציבורי לתוצר הפוטנציאלי, יש השפעה על התשואות, וכי ההשפעה על האופקים הארוכים גדולה יותר. למדיניות המוניטרית השפעה ניכרת על התשואות הקצרות, אך גם השפעה מובהקת – אם כי קטנה – על התשואות הארוכות. לסביבה הפיננסית העולמית, כפי שהיא משתקפת בתשואות הארוכות בארה"ב, השפעה חיובית ומובהקת על התשואות הריאליות המקומיות בכל האופקים. טכניקת האמידה שבחרנו מאפשרת השפעות לא-לינאריות של המשתנים, והיא מלמדת כי ההשפעות של החוב הממשלתי והתשואות בארה"ב התעצמו במהלך תקופת המדגם. כאשר מנתחים את התרומות להתפתחות התשואות בעשור האחרון, מוצאים כי הירידה בריבית המוניטרית מסבירה חלק ניכר מהירידה שחלה באמצע העשור בתשואות הקצרות והבינוניות, ואילו הירידה בחוב הממשלתי מסבירה חלק גדול מהירידה בתשואות הארוכות. הסביבה הכלכלית הגלובלית תרמה משמעותית לשינויים שחלו בתשואות בכל התקופות ובכל האופקים. הממצאים דומים איכותית לאלו שהעלו לפני כעשור Ber, Brender and Ribon (2004), אך משקפים גידול בהשפעת הכלכלה העולמית והחוב הציבורי על התשואות בישראל וירידה בחשיבותו של הגירעון כמייצג של המדיניות הפיסקלית.

The Effect of Fiscal and Monetary Policies and the Global Economy on Real Yields of Israel Government Bonds

Adi Brender and Sigal Ribon

Abstract

This study examines the effect of fiscal and monetary policies, as well as domestic and global economic activity, on real yields of Israel government bonds between 2001 and 2013. We find an effect of fiscal policy on yields that is larger in longer maturities and discover that the fiscal policy variable that affects yields is the expected debt/GDP ratio rather than the deficit. Monetary policy is found to have a dominant effect on the determination of short-maturity yields but also a statistically significant, although small, effect on forward long ones. The global financial environment, represented by the real yields on US Treasury bonds, affects domestic yields to all maturities. Our nonlinear estimation indicates that the effects of the public debt and the global financial environment intensified during the sample period. Decomposing the change in yields over the sample period, we find that monetary policy played a dominant role in the decline of short- and medium-term yields in the middle of the previous decade, while the decline in the public debt ratio explains much of the decline in the long-term yields. It was also found that the global financial environment significantly affected yield changes to all maturities throughout the sample period. Our findings qualitatively match those of Ber, Brender, and Ribon (2004) but reflect an enhancement of the effects of the public debt and the global environment on Israeli yields and a shift of the representation of fiscal policy from the deficit to the debt ratio.

1. Introduction and Brief Literature Review

In the past decade, real yields on Israel CPI-indexed government bonds have been falling for long maturities and, to an even greater extent, for shorter ones. The background factors in this development are a declining public debt/GDP ratio, the contraction and re-widening of the (cyclically adjusted) government deficit, and a stable inflation environment, coupled with steep lowering of the Bank of Israel interest rate (hereinafter: IBOI) and the real rate derived from it. These factors accompanied two business cycles—the first upon the recession that began in late 2000 and the second, worse abroad but milder domestically, that began with the US financial crisis in 2008.

This paper analyzes and quantifies the factors that affected the development of real yields to various maturities—short and longer.

Many studies analyze the factors that affect yields and changes in yields,[1] particularly the role of fiscal policy. Although these studies usually find that fiscal policy affects yields, they present no unequivocal conclusion as to the strength of the effect, for reasons including the use of different indicators for fiscal policy, different research methods and different periods. Gale and Orszag (2002), in a paper that reviews some sixty studies, note that only half of the studies found a clear effect of the deficit on yields; the others were inconclusive. Many of the studies probe the factors that affect yields by using a panel of developed or emerging markets; others tackle the question in reference to a single country, usually the United States.

The customary indicators of fiscal policy are the deficit and the debt. Many studies, however, find that the most meaningful magnitude that affects yields is not an actual development but a forecast or expectations of the deficit or the debt. Engen and Hubbard (2005) find that the debt and deficit predictions of US federal offices affect yields significantly whereas the actual data do not affect them at all. Laubach (2009) also finds a significant effect of forecasts on nominal yields—approximately 0.25 percentage point for a 1 percent of GDP increase in the expected deficit and 0.03–0.04 for a 1 percent change in the expected debt/GDP ratio.

Among the studies that examine the matter using a panel of countries, Gruber and Kamin (2012) is noteworthy for finding, for the years 1987–2007 (preceding the financial crisis), that the deficit and the debt had significant effects on nominal yields, of 0.11–0.18 and 0.02, respectively. For real yields the coefficients obtained were significant but slightly smaller, and the authors' probe of forward yields did not find significant results. Poghosyan (2012), investigating the factors that affect government bond yields in twenty-two developed markets by applying cointegration methods to a panel, finds a 0.02 effect of the debt/GDP ratio on long-maturity nominal yields.

The 2008 financial crisis emphasized the importance of global effects on domestic yields and the possibility that one policy might have different effects in different economic and financial environments. With the recent financial crisis in the background, a welter of studies asks whether the extent of the effect of fiscal variables on yields depends on

[1] It is often conventional to examine the factors that affect *nominal* yields because, with few exceptions, government bonds are nominal and not indexed to the CPI. In Israel, the braod use of CPI indexed bonds facilitates the direct examination of real yields.

additional factors such as the global situation, sovereign risk or the level of the debt. Ardagna, Caselli, and Lane (2004), although investigating the pre-crisis period, use a sixteen-country panel to find that the effect of the debt on yields is non-linear but squared and is positive and significant only when the debt exceeds a certain level. They also find that higher financial development lowers long-term interest rates and that the interaction of a financial development indicator with fiscal variables weakens their effect. Jaramillo and Weber (2012), using a nonlinear specification to examine effects on emerging-market sovereign yields, find that the effect of domestic factors on yields depends on the degree of global risk aversion. That is, when the global environment is perceived as riskier (when the VIX index exceeds a certain value), an increase in the debt/GDP ratio has a large effect—around 0.06 and significant—as against 0.02 in calmer times. Baldacci and Kumar (2010), using a panel of thirty-one countries, show that the effect of the deficit and the debt depends on the structural fundamentals of the economy and effects originating in global financial markets. Alper and Forni (2011) find spillovers from public debt in large developed markets to bond yields in other countries, emerging markets in particular. Using a nonlinear (squared) effect, they show that a 1 percent increase in the public debt/GDP ratio raises emerging-market yields by 0.025–0.04 and developed-market yields by 0.01–0.07; furthermore, an increase in debt in developed markets from their current high level raises emerging markets' long-maturity yields by another 0.1. Chinn and Frankel (2004) find that US interest rates affect those in Europe more strongly than in the opposite direction and that the expected public debt/GDP ratio (based on OECD forecasts) has a 0.05–0.16 effect on yields in different European countries. Dell'erba and Sola (2013), using common factors, find that global monetary and fiscal policy explain more than 60 percent of the variance of long-term interest rates in a panel of OECD countries and that the inclusion of these factors mitigates the effect of domestic factors on yields.

Short-term interest, reflecting monetary policy, is commonly cited as one of the variables that explains yields. Several studies focus on examining the effect of monetary policy on yields. Hanson and Stein (2012) find that monetary policy affects real forward yields in the US. A 1 percentage point increase in the nominal two-year yield on the day of an FOMC announcement on monetary policy is reflected in a 45 basis-point increase in real ten-year forward yields; this is interpreted as a change in the term premiums of the bonds. Turning to the UK, Hanson and Stein report similar results. Arora and Cerisola (2001) ask whether US monetary policy affects spreads between US Treasury yields and those of emerging-market sovereign paper. Their preliminary examination shows that ten-year Treasury yields affect these spreads with a coefficient of 0.5–1.5. When the Fed rate is included as an explanatory variable, a significant effect is obtained: a significant coefficient of 0.2–0.6 for most countries. The reason may be that higher interest rates in the US make it hard for borrower states to repay their debts, thereby amplifying the risk priced into their paper.

The purpose of this study is to examine the effect of various factors—fiscal policy, monetary policy, domestic activity, and the global environment, on real government bond yields to various terms. The analysis will be pursued within the framework of a model that allows nonlinear effects of some of the variables. The estimation method, based on the Smooth Transition Regression (STR) model proposed by Teräsvirta (2004), allow the effect

of the variable of interest to us to be dependent on the value of another variable or to vary over time.

The model presented, allowing the effect of the US rate to vary over time, elicits an increase in the effect of this variable on yields from the second half of the 2000s decade onward, against the background of growing globalization in capital markets and, in particular, of the crisis that began in 2008.[2] The effect of US interest on yields was 0–0.15 at the beginning of the 2000s but increasedduring the period to 0.2 in ten-year yields and up to 0.4–0.6 in middle maturities.

A nonlinear estimation reveals that a 1 percentage point increase in the public debt/potential GDP ratio had in the beginning of the period an upward effect of 0.05 percentage point on ten-year yields and of 0.01–0.03 percentage point on shorter maturities, and that the effect of the debt/potential GDP ratio on yields has gathered strength since the beginning of the global crisis, to 0.07-0.1 to the respective maturities. An attempt to test a nonlinear effect of public debt on yields as a dependency on the state of the global economy (the VIX index for US product growth) did not yield meaningful results. It is possible that the relatively low level of Israel's public debt diminishes the importance that the markets attribute, in the short term, to the effect of the global environment on the riskiness of this debt.

Unlike research that we performed about a decade ago, here we find no significant (positive) effect of the expected (cyclically adjusted) deficit and the deficit target on yields. Examining the effect of the expected and unexpected components of IBOI separately, we find that an expected 1 percentage point change in IBOI triggers a 0.6 percentage point increase in the one-year rate and a 0.2 percentage point increase in the ten-year rate. The unexpected part of the interest rate has an stronger effect than the expected part has. The analysis shows that much of the decline in short-maturity yields in mid-decade traces to rate-cutting, whereas the decrease in the public debt (relative to potential GDP) explains much of the decline in middle- and long-maturity yields. Finally, global economic developments contributed to changes that occurred in yields to all terms and at all times, particularly since the onset of the global crisis in 2008.

This study has seven parts. Part 2 presents a simple model for the description of the factors that affect real yields. Part 3 describes the data; Part 4 presents the estimation method and reports its outcomes. Part 5 estimates the contributions to yields and changes in yields during the estimation period, Part 6 compares the results of this study with those obtained in a study written a decade ago, and Part 7 concludes.

2. The Model

The model presented is based on that of Sargent (1969), expanded at several levels: an modification to real yields as against nominal ones (due to the large proportion of CPI-indexed government bonds in the Israeli market) and an adjustment to the possibility of partial or full Ricardian equivalence—i.e., that private savings will respond to a change in expected public debt—and of a contractionary effect of fiscal loosening on domestic

[2] We also examined a dependency of the extent of the effect of US interest on global yields, with the American VIX index and change in the MSCI global share index as the proxies. The results, however, were usually insignificant.

investment. We allow for the possibility of an effect of risks attributed to the expected public debt by including this factor in the equations that describe savers' and investors' behavior. Finally, we allow foreign interest rates and global risk to have an effect insofar as the economy is open to capital flows.

The transmission of fiscal policy to bond yields follows two paths. The first path, a direct one, is the simultaneous effect of the supply of and demand for investment sources. When the public debt is larger (or its savings are smaller), the supply of sources for domestic investment decreases and therefore their price—the interest paid on them—rises. In other words, the larger the government deficit, the more debt must be raised from the public; the resulting increase in the supply of bonds lowers the price of the bonds and, therefore, raises their yield.

The second path operates by means of consumers' and investors' expectations. When a present or future deficit grows, the public debt is expected to increase; this raises the likelihood of future taxation and, for this reason, may affect investment and consumption decisions. The more permanent the deficit is expected to be, the stronger the effect on the future debt it will have. A temporary deficit, in contrast, is unlikely to affect the debt much and, therefore, will not affect yields via this transmission mechanism. A larger public debt also increases the risk of government default. Consequently, the expected public debt affects the decisions of investors—domestic and foreign—and of savers.

The real yield on government bond $R_{m(t)}$ in the money market may be described as follows:

$$(1) \qquad R_{m(t)} = R_{e(t)} + [R_{m(t)} - R_{e(t)}]$$

The first factor in the equation, $R_{e(t)}$, is the "benchmark" equilibrium interest rate, which depends on the fundamentals of the economy. The second factor describes the difference that may exist between market yields and benchmark equilibrium yields at some point in time. The deviation of real actual (market) yields from benchmark yields is influenced by monetary policy and the real short-term interest rate that is derived from it in accordance with expectations.

Therefore, Equation (1) may be rewritten as:

$$(1') \qquad R_{m(t)} = R_{e(t)} + [k_0 + k_1(ib_{(t)} - \overline{ib}) + k_2\pi^e_{(t)}] \qquad k_1 > 0,\ k_2 < 0$$

where $ib_{(t)}$ is the nominal interest rate set by the central bank as against long-term nominal rate $\overline{ib}$, and π^e are short-term inflation expectations.

The equilibrium interest rate is determined on the basis of investment demand and savings supply. The investment demand equation may be written in the form of an "accelerator model," in which investment *I* depends positively on change in product Δy (see, for example, Mehra, 1994) and negatively on interest. In addition, as described above, investment may be (positively) dependent on current and expected public savings, as expressed in the expected public debt (DG^{exp}) if it affects productivity in the economy and the perceived likelihood of future taxation. Importantly, *I* is investment demand and not actual investment (which includes involuntary investment in inventories).

(2) $$I_{(t)} = g_0 + g_1 \Delta y_{(t)} + g_2 R_{e(t)} + g_3 DG^{\exp}{}_{(t)} \quad g_1 > 0, \;\; g_2 < 0, \;\; g_3 \leq 0$$

Private savings (SP) depend positively on interest and negatively on present public savings and expected public savings, the latter of which may be expressed as the expected public debt. The extent of the effect of present and future public savings on individuals' behavior depends, as stated, on how "Ricardian" the individuals are:

(3) $$SP_{(t)} = s_0 + s_1 R_{e(t)} + s_2 DG^{\exp}{}_{(t)} \qquad s_1 > 0, \quad -1 \leq s_2 \leq 0,$$

Capital inflows (FF) depend positively on the difference between the real current domestic interest rate[3] and the real interest rate abroad, R_f. We assume that capital flows depend on the prevailing market interest rate at the time, R_m, and not on the benchmark rate. We also assume that the economy is not totally open to capital flows and that, therefore, interest differentials exceeding the risk premium may exist in the short term. If the economy is completely open to capital flows, domestic interest will equal the rate abroad plus the risk premium and would not be affected by the other variables. Finally, it is assumed that the public debt, which affects sovereign risk, and a risk originating in global or geopolitical factors (*Global*) will have a negative effect on capital inflows.

(4) $$FF_t = f_1(R_{m(t)} - R_{f(t)}) + f_2 DG^{\exp} + f_3 Global \qquad f_1 > 0, \quad f_2 < 0, \quad f_3 < 0$$

At equilibrium, the following should obtain:

(5) $$SP_t + SG_t + FF_t = I_t$$

An equality between savings and domestic investment demand will set the equilibrium interest rate. By solving Equation (5) and substituting the relations that originate in the previous equations (and omitting index *t*), we get:

(6) $$R_m = a_0 + a_1(ib - \overline{ib}) + a_2 \pi^e + a_3 SG + a_4 DG^{\exp} + a_5 R_f + a_6 Global + a_7 \Delta y$$

where:

$$a_0 = \frac{(g_0 - s_0 - f_0) + (s_1 - g_2)k_0}{(s_1 + f_1 - g_2)}, \quad a_1 = \frac{(s_1 - g_2)k_1}{(s_1 + f_1 - g_2)}, \quad a_2 = \frac{(s_1 - g_2)k_2}{(s_1 + f_1 - g_2)}, \; a_3 = \frac{-1}{(s_1 + f_1 - g_2)},$$

$$a_4 = \frac{g_3 - s_2 - f_2}{(s_1 + f_1 - g_2)}, \; a_5 = \frac{f_1}{(s_1 + f_1 - g_2)}, \; a_6 = \frac{-f_3}{(s_1 + f_1 - g_2)}, \quad a_7 = \frac{g_1}{(s_1 + f_1 - g_2)}.$$

The denominator of each coefficient is positive because the first two components are positive and the third one (the effect of interest on investment demand) is negative. Since capital flows depend on the actual interest rate (and not the benchmark rate), a direct relation between short-term interest (of the Bank of Israel) and the long-term rate is obtained. Given $g_2 \leq 0$, $s_1 \geq 0$, and $k_1 \geq 0$, the effect is always positive (or zero).

[3] Assuming the existence of purchasing power parity, capital flows can be expressed as dependencies on real interest spreads.

The size and sign of a_4, the coefficient of expected government savings, depend on the extent to which private savings and investment respond to a change in a_4 and the extent to which the economy risk depends on government savings. The more closely individuals' behavior corresponds to Ricardian equivalence (the closer s_2 is to -1), the greater the effect of expected government savings on private savings and the more a_4 will offset the effect of a_3, the direct effect of government savings on interest rates.[4]

The more strongly a decrease in expected public debt affects an increase in investment (a larger g_3 in absolute terms), the more interest rates will rise (or fall less, when a_4 is smaller than 0). Conversely, the more a decrease in expected public debt mitigates the economy risk, the more interest rates will tend to fall due to the increase in capital inflows. In the estimation that follows, we examine a representation of the fiscal situation by using the actual expected deficit and, alternatively or additionally, by using expected debt.

The equilibrium interest rate is positively affected by an increase in output that stimulates investment demand. A higher foreign interest rate is reflected in higher domestic interest commensurate with the extent of the economy's openness to capital flows, represented by coefficient f_1. An increase in global risk is reflected in an increase in interest.

3. Data[5]

a. Real Yield

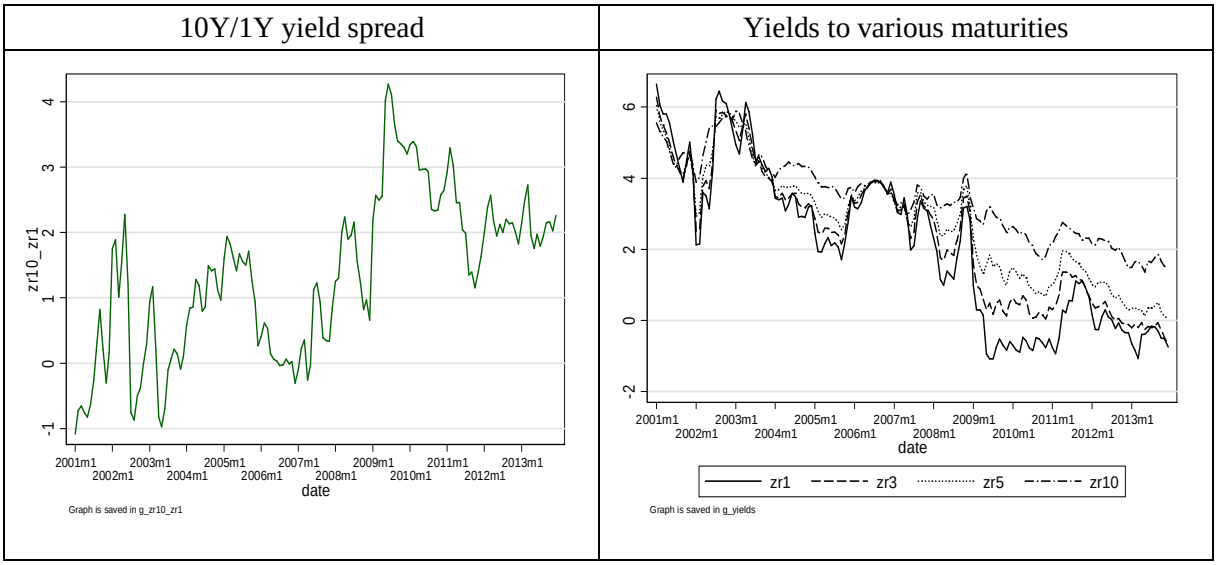
The magnitude that we wish to explain is the real yield on government bonds to various maturities. Figure 1, describing the development of yields between 2001 and September 2013, shows that yields have been declining for all maturities since 2003 but have done so more steeply to short maturities and much less aggressively in ten-year instruments.[6]

[4] Alesina et al. (1998) and Alesina et al. (2012) note that, under certain circumstances, the effect of the change in public savings may prompt a stronger response of aggregate demand in the opposite direction. At issue in their studies is the total effect on consumption demand, investment demand, and capital inflows—not only the effect on private savings.

[5] Table 1 presents the basic statistical characteristics of the data that we are using.

[6] Data on seasonally adjusted real yields (that take account of the seasonality of the Consumer Price Index, on the basis of which coupon is indexed) have been available since 2008. The difference between the adjusted series and the original one, which we are using, are not large and are smaller to longer maturities. Since these data are available only for a small part of the review period, we omit them in this study.

Figure 1: Real Government Bond Yield, 2001–2013



Zr1—real 1Y yield; zr3—to 3Y; zr5—to 5Y; zr10—to 10Y

The real ten-year interest level at the end of the period is the lowest, at least since the middle of the 1980s. The spread between the long-maturity yield and the short-maturity yield, i.e., the slope, shown on the left-hand side of Figure 1, widened steadily over the past decade. This trend emphasizes that different factors affect yields to different maturities at different levels of strength.

b. Fiscal Policy

In accordance with the model shown above, one might expect the deficit to have a direct effect on yields due to the government's need to raise more money in bond issues. One might also expect the size of the expected public debt to affect yields due to its effect on the risk attributed to the debt and the possible need to impose taxation in the future (Ricardian equivalence). Accordingly, this study examines fiscal policy via two main alternative indicators:

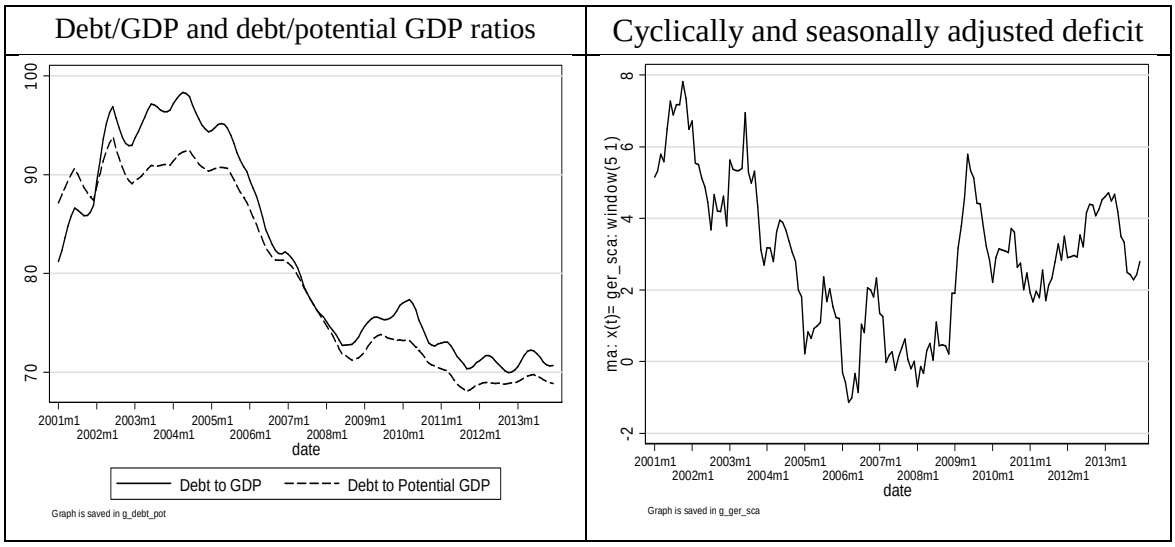
1. *The cyclically and seasonally adjusted government deficit to GDP*—cycle adjustment is accepted in the literature because even as the deficit changes in accordance with the business cycle, such changes are temporary and may not reflect long-term government policy. Therefore, they should not affect the risk premium and the public's estimations of its future tax burden. Seasonality adjustment is needed because we wish to test the data at more than an annual frequency and because Israel's expenditure and tax and other revenues have a sizable seasonal component.

The use of the cyclically adjusted deficit obviates, or at least mitigates, the possibility of endogeneity in the deficit due to the effect of the business cycle on deficit size via the cyclical response of tax collection.[7]

[7] Since yields may be positively dependent on the growth rate, a negative correlation between deficit size and interest rates may be found, possibly impairing the ability to correctly estimate the (positive) relation between the deficit and yields. The inclusion of change in output and short-term interest as explanatory variables in the equations that we will estimate makes such a possibility less problematic.

2. *The public debt/GDP ratio* reflects future government liabilities and the future burden on the public.[8] Below the debt is examined relative to both actual and potential product.[9]

Figure 2: Cyclically and Seasonally Adjusted Government Deficit in Actual and Potential GDP, Six-Month Moving Average



The fiscal variables in Figure 2 are shown in six-month moving averages. One may see that the debt and the deficit developed similarly until around 2009 but afterwards the deficit rose whereas the debt/GDP ratio flatlined and actually trended downward mildly. This outcome reflects the decline of the deficit to an environment supportive of stability in the debt/GDP ratio and the funding of some of the deficit in 2012 by means other than an increase in debt.[10] It is also evident that the debt/potential GDP ratio steadier in 2000–2006—years of tumult in the business cycle—than the actual debt/GDP ratio and was lower from 2008 onward, when the global crisis left activity in a relatively sluggish state.

The variable that we wish to include as the source of an effect on yields is the *expected* government deficit, from which the *expected* debt, which also depends on the extent of permanence attributed to the deficit, is derived. Many studies in various countries use government-published deficit forecasts (e.g., Gruber and Kamin, 2012); Israel, however, provides no credible data on this parameter at the requisite frequency. Therefore, as in many papers in the literature, we include the forward deficit or debt—actual data for the months following the month estimated—as an estimate of the expected deficit or debt. In doing so, we assume that the public had the ability to predict the deficit and debt that came about.

[8] The debt is measured in nominal terms, with no adjustment to market prices of bonds and no discounting of the debt to on the time of future liability.

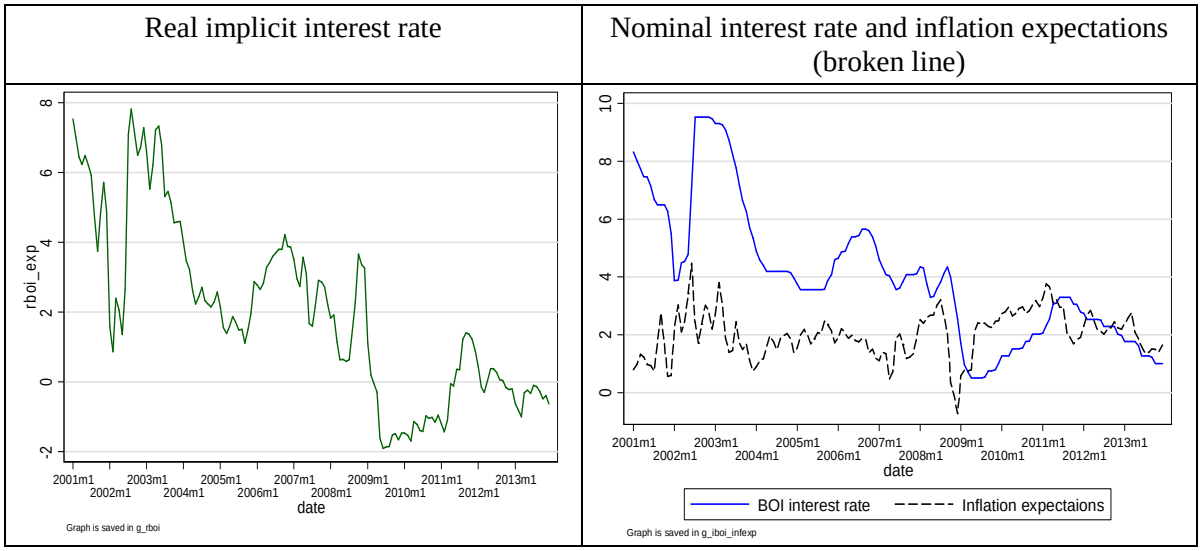
[9] The increase in potential GDP each year was calculated on the basis of the long-term average (since 1974) of the increase in per-capita GDP plus the rate of population increase that year. An alternative calculation based on GDP per capita in main working ages and the rate of increase in this population yields very similar results.

[10] For a breakdown of the factors that affect the public debt in addition to the deficit, see Table 6.7 in Chapter 6 of the 2012 Bank of Israel *Annual Report*.

c. Monetary Policy

Since the late 1990s, Israel monetary policy has been managed under an inflation target regime, principally by means of the interest rate set by the Bank of Israel (IBOI), which serves as a benchmark for nominal short-term rates.[11]

Figure 3: Bank of Israel Interest Rate, 2001–2013



Generally speaking, the Bank of Israel nominal rate has been trending downward since the late 1990s due to the slowing of expected inflation, particularly at the beginning of that period but also afterward, as the downward trend of the real implicit ("breakeven") rate demonstrates (Figure 3).[12] One may notice that the development of the implicit real rate closely resembles the development of the real one-year-ahead yield on government bonds.

d. Domestic activity

According to the model presented, the rate of increase in domestic activity affects yields via its effect on investment demand. Faster growth stimulates investment demand, abetting higher interest. In one of the estimations, we also included the spread between actual and potential GDP. The underlying trends captured by the variable of growth and the variable that measures the GDP gap are perceptibly similar. In the model estimated, we also included an indicator of the effect of the security situation—deviation of inbound tourism from its long-term trend—as a proxy for sovereign risk (Figure 4).[13]

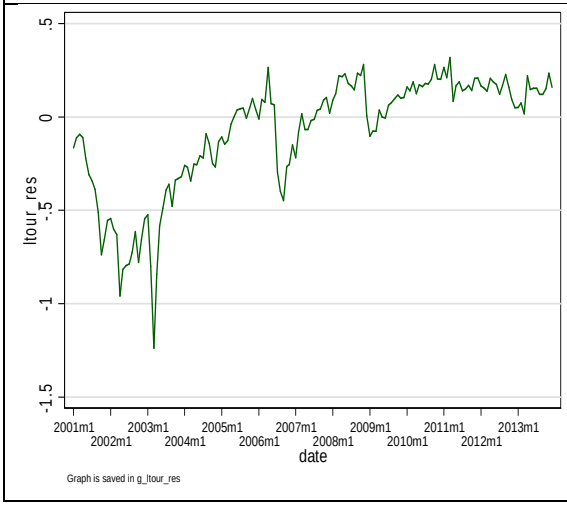
[11] The Bank of Israel has also intervened in the foreign-currency market on various occasions, particularly after 2008, and in the long-maturity bond market for a brief time in 2009. Here we omit all reference to these monetary policy tools apart from including a dummy variable in the estimation for BOI's intervention in the bond market.

[12] The use of this term here is not accurate because we subtract inflation expectations to the coming year from the nominal Bank of Israel rate, which is set for the upcoming month. However, it is a good enough approximation to describe the trend in recent years.

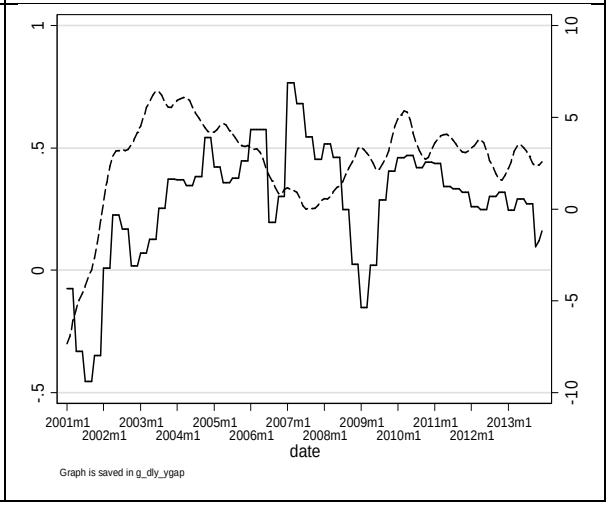
[13] For an example of the use of this variable as a control for the security situation, see Mazar (2013).

Figure 4: Indicators of Domestic Activity, 2001–9.2013

Inbound tourism deviation from trend



GDP change in past 6 months (solid line, left axis) and GDP gap in past 6 months (broken line, right axis)



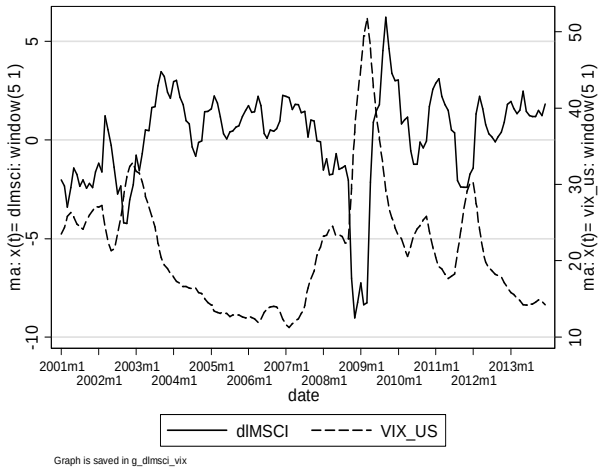
e. The Global Environment

Israel is a small economy that is open to both trade and capital flows. Therefore, one would expect the global environment—real and financial—to have a direct effect on the development of Israel yields beyond its effect via GDP growth and monetary policy. This effect is included in the model presented and is tested in the empirical analysis that follows.

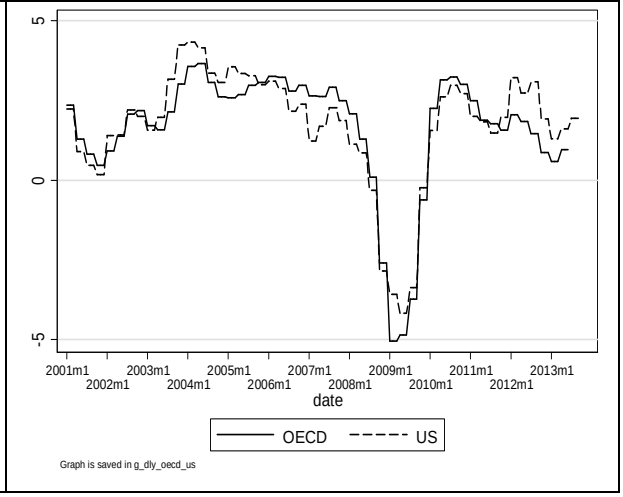
The data in Figure 5 emphasize the effect of the global financial crisis on real global activity and global financial indicators, i.e., a decrease in the global MSCI share index and an upturn in risk as measured by the VIX index. Since yields abroad have a considerable effect on the domestic capital markets, it also stands to reason that they will affect government bond yields. The estimation that follows includes the VIX index as an indicator of the global environment.

Figure 5: Global Environment Indicators, 2001–9.2013

Financial environment—change in MSCI index (solid line, left axis) and VIX



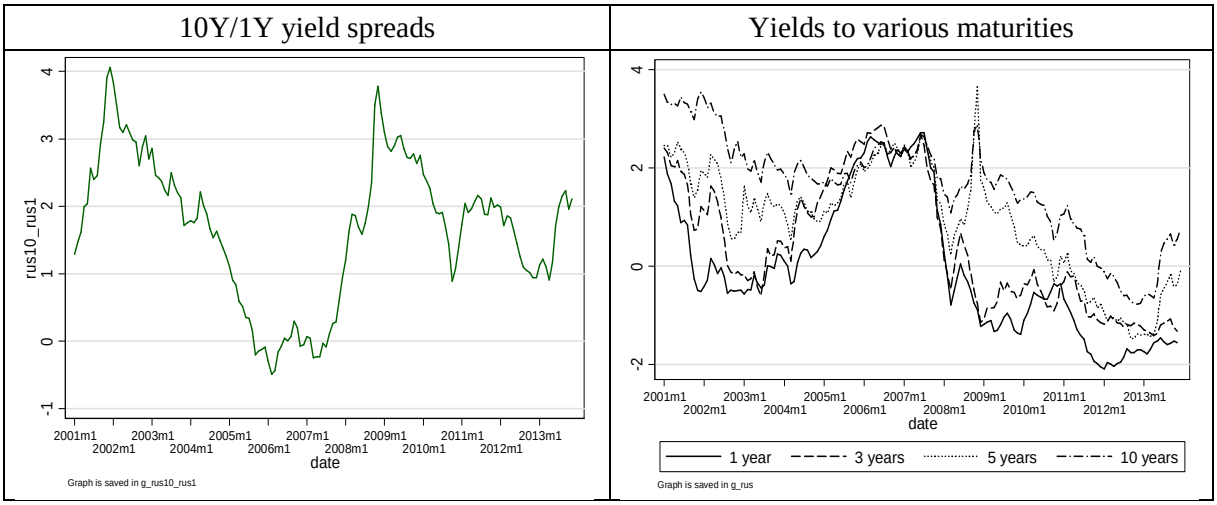
Real activity—annual change in US GDP (broken line) and OECD GDP (solid line)



US Treasury yields to various maturities are used as an indicator of risk-free yields abroad. For the real ten-year yield, US ten-year CPI-indexed Treasury bonds provide data for the entire research period. Since there are no indexed bonds to shorter terms,[14] we estimate real yields on one-year, three-year, and five-year US instruments by subtracting from the nominal yield the change in the US core CPI for the past relevant term (one year, three years, five years) to get an estimate of expected inflation in coming years.

Real US yields are typified by a downward trend that features stronger downward volatility for shorter terms. Since 2008, the implicit real yields to 1Y and 3Y have been negative; since 2012, real yields to longer terms have been negative as well. Unlike developments in Israel (Figure 1), the spread between the real ten-year yield and the one-year yield (Figure 6, left side) is typified not by an upward trend but by acute volatility and no trend whatsoever.

Figure 6: US Real Yields to Various Terms, 2001–9. 2003



4. The Estimation and Its Results

a. Estimation Method—Nonlinear Effects

Our estimation framework is constructed in a way that allows some variables to have nonlinear effects on real yields. In particular, we investigate the possibility of the existence of such effects for fiscal policy, in accordance with findings in the literature, and of foreign interest because the openness of Israel's economy and the global economic environment changed markedly during the sample period.[15]

Teräsvirta (2004) proposes the specification of an estimation equation that allows the explanatory variables to have nonlinear effects. The formulation accomplishes this by making the effect of these variables on the dependent variable depend on the value of another variable, including the time variable. The proposed method reveals, via estimation, changes in the effect of the examined variable and the speed in which the change occurs.

[14] For real five-year yields, data have been available since 2003.

[15] In a previous draft, we also tested for a nonlinear effect of inflation in the behavior function of the Bank of Israel. The effect was found to contribute little to the estimation of bond yields and is omitted here.

Unlike the threshold approach, in which the change in effect takes place stepwise in the magnitude of the effect at a given point,[16] a gradual change is possible here and its graduality is estimated as well. This approach, known as Smooth Transition Regression (STR), is briefly described below in accordance with Teräsvirta (2004).

The model may be written in general as follows:

$$(7) \qquad y_t = \eta x_t + \left(\phi + \theta G(\gamma, c, s_t)\right)' \mathbf{z}_t + u_t, \quad t = 1,..,T$$

where x is a vector of explanatory variables and **z** is a vector of the explanatory variables for which we wish to allow nonlinear effects. η, θ, and φ are vectors of coefficients. $u_t \sim iid(0,\sigma^2)$ are the residuals. The transition function, $G(\gamma, c, s_t)$, is a function of the transition variable s_t. γ is the slope variable and c is the location variable. Namely, the effect of **z** depends on the value of variable s and the rate of changes in the coefficient depends on γ. Generally speaking, c may be a vector, meaning that the effect of z changes more than once.

It is conventionally assumed that the variance function is a general logistical function from the following form:

$$(8) \qquad G(\gamma, c, s) = \left[1 + \exp\left(-\gamma \prod_{k=1}^{K} (s_t - c_k)\right)\right]^{-1} \quad , \gamma > 0$$

Although this general formulation allows for K points of change, it is customary and reasonable to assume K=1 or K=2. When γ=0, function G is constant and the model becomes a simple linear one. When $\gamma \to \infty$, function G tends to 1 and a one-time threshold switching model, from coefficient φ to coefficient $\theta + \varphi$, is obtained.

Variable s_t may be one of the variables included in **z**; alternatively, it may be the time variable or any other variable. In other words, the size of the effect of variable z_i on y depends on the value of another variable, s. This formulation of nonlinear effects by means of the STR framework recurs in many studies in diverse disciplines. We mention only a few of them, such as Noggueira and Leon-Ledesma (2011), who use the method to examine nonlinearity in the transmission from exchange rate to prices in Mexico. They find that the more unstable the economy is, as expressed in the Mexico–US interest spreads, the stronger the transmission will be. They explain this by stating that businesses are willing to absorb less of an increase in costs and a blow to profitability in a riskier environment.

Bredin, Hyde, and Reilly (2009) investigate nonlinear effects of the macroeconomic situation on share prices in six countries. The global situation, reflected in the MSCI global share index, expresses the relation between macroeconomic and financial variables, on the one hand, and share prices, on the other. Gerlach and Lewis (2013) use the STR method to examine the European Central Bank's near-zero-interest monetary policy before and after the financial crisis and ask whether the effects of the variables that determine interest—product, inflation, money supply, and exchange rate—changed in response to the crisis. Using time as the transition variable, they find a change in October–November 2008, immediately after the Lehman Brothers collapse reduced interest smoothing from almost 1

[16] See, for example, Ardagna, Caselli, and Lane (2004).

to 0.7. Alternatively, using a transition variable that represents the difference between actual GDP and the GDP trend as a proxy for the state of economic activity, they obtain similar results.

Linearity check: before formulating the detailed nonlinear model, one must determine whether a model that deviates from linearity is needed at all. For this purpose, Teräsvirta (2004) proposes to test the linearity hypothesis against a model that includes Taylor expansion to the third degree:

$$(9) \qquad y_t = \beta_0 \mathbf{z}_t + \sum_{j=1}^{3} \beta'_j \tilde{\mathbf{z}}_t s_t^j + u^*_t, \qquad t = 1,.., T$$

If $\mathbf{z}_t$ is a partial vector of z and is assumed to be nonlinear, the null hypothesis will be $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$. Since under null hypothesis $u_t^* = u_t$ the statistical test has an asymptotic distribution of χ^2 with *3m* degrees of freedom (m = the number of variables for which nonlinearity is checked), the use of distribution *F~(3m,T-4m-1)* is recommended for small samples.

We checked for a nonlinear model in which both public debt and US interest are multiplied by the time variable. Ultimately, this formulation was found the most suitable for describing nonlinearity (Table 5); and found that the null hypothesis (linearity) may be rejected at a high significance level for yields to all terms.

Estimating the parameters: the parameters of the STR model are estimated by maximum likelihood. When *c* and γ are given, the model is linear in these parameters.[17] Therefore, one may construct a grid of c and γ values and, for each pair, estimate the equation or equation system, and select the c,γ pair that yields the minimum sum of squared residuals (SSR).[18]

b. Bank of Israel Interest Rate Equation

We use the Bank of Israel interest rate (IBOI) as a proxy for the effect of monetary policy on yields. This rate is expected to affect both short- and longer- maturity yields because it affects the short-maturity yields of which the long-maturity yields are composed. In addition, the more permanent the current monetary policy is perceived, the more likely it is that it will strongly affect yields to longer maturities. As a preliminary stage, we estimate a simple equation to describe IBOI in order to distinguish between the expected and unexpected parts of the interest policy and to ask whether each of these components affects yields differently. The use of an estimated interest rate alleviates concern about interest endogeneity, i.e., the possibility that the explanatory variable is influenced by the dependent variable, long-maturity yields.

[17] Seemingly, one could also estimate c and γ along with the rest of the coefficients in a nonlinear system. Van Dick, Teräsvirta, and Franses (2002) note that is very hard to obtain an accurate estimate of γ; therefore, it may seem insignificant. Accordingly, one may find a grid approach to the preliminary estimation of γ and c in some studies that use the STR method.

[18] Since it is a system of equations that is being estimated, we test for the c and γ values that yield the smallest possible RMSE of each equation, given the same y and γ values for the other equations in the system.

IBOI is affected by domestic and global economic conditions generally and by activity, the inflation environment, and foreign interest particularly. To identify the effects of these economic factors on IBOI and, in turn, on yields, we estimate an interest behavior equation. This is done to describe the actual behavior of IBOI and the factors that influence it, and not to specify BOI's tastes or utility function.

By estimating the equation, one may distinguish between the expected interest level, the one elicited by the estimated equation, and the "surprise"—the residual of the interest rate estimated. One may include each of these elements separately and examine its effect on real yields. In addition, by describing IBOI via the factors that affect it, we may attribute their direct and indirect effect on real yields to economic factors other than monetary policy. For example, we may distinguish between domestic effects on interest—inflation and activity—and effects of foreign provenance and examine the indirect effect of these components on real yields to longer maturities.

IBOI is determined in accordance with economic conditions. In the accepted formulation, it is dependent (positively) on the deviation of inflation or inflation expectations from their target and (positively) by the level of activity or the deviation of this level from a state of full employment. Since IBOI does not tend to change sharply , it is also conventional to include the lagged rate in order to express the tendency to gradual rate adjustments ("interest smoothing"). Furthermore, since Israel is a small and open economy, an overly wide spread between domestic and global interest rates will trigger large capital flows and abrupt exchange-rate changes. Therefore, one may also include foreign interest as a factor that policy bears in mind in setting the interest rate. Beyond its direct effect through the medium of the capital markets, foreign interest may indirectly affect real yields to various terms via its effect on determining IBOI. We also attempted to include in the IBOI equation the deviation of the government deficit (seasonally and cyclically adjusted) from the average during the estimation period. However, we found that even though the effect of this factor is significant throughout the sample period, it is insignificant in the estimation of a partial sample starting in 2003. Therefore, the formulation we preferred omits the government deficit. The domestic output gap and short-term US interest are rather strongly correlated, at 0.5. Therefore, the inclusion of the US rate renders the effect of the product gap on IBOI insignificant. Nevertheless, we chose to use the formulation that appears in Column (2) of Table 2, which includes both the domestic product gap and the US interest rate.

To determine whether the intensity of the effect of different variables on IBOI remains stable across the sample years, we estimated a seven-year rolling regression that includes the explanatory variables in the specification that appears in Column (2) of Table 2.[19]

Figure 7 presents the results for the short and long terms.[20] The effects of US interest and the deviation of inflation expectations from target are significant across the entire sample; domestic activity, in contrast, is significant mainly in early samples. Examination

[19] We also checked for a formulation that includes the effect of the government deficit on yields and found that its inclusion weakens the effect of the product gap for some periods.

[20] Namely, the effect of the explanatory variables, including their indirect effect of via lagged IBOI. The indirect effect includes a dynamic calculation for a twelve-month period that reflects the presence of the lagged interest rate in the Bank of Israel interest rate equation.

of the coefficients in the long term stresses the increase in importance of the deviation from the inflation target in the early 2000s and the steep decrease in its coefficient afterwards.

In estimating real bond yields, we include separately the expected part of IBOI, that elicited by the estimation, and the residual (unexpected). To reflect the surprises that occurred in policy, we estimated the equation without referring separately to the aberrant interest changes that took place in late 2001. Thus, the surprises are expressed in large deviations at these times (Figure 8).

Figure 7: Rolling Estimation of Bank of Israel Interest Rate

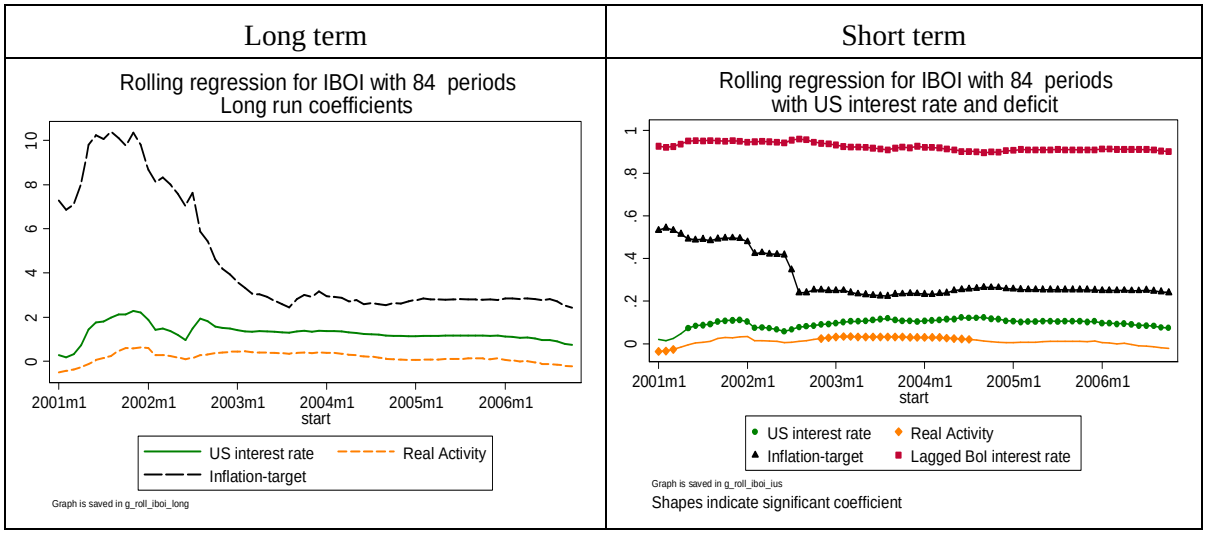
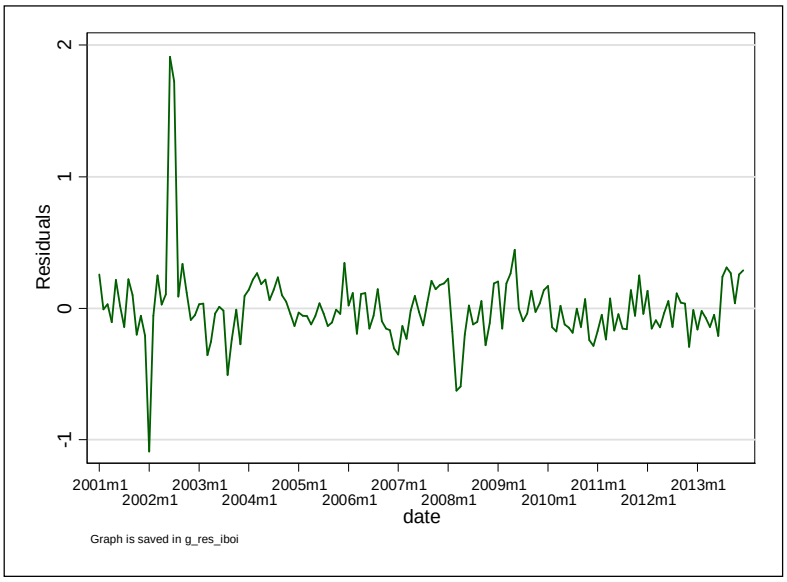


Figure 8: Deviations from Estimated Bank of Israel Interest Rate—the Unexpected Portion, 2001–2013



c. Linear Estimation of the Factors that Affect Government-Bond Yields

Before testing whether the intensity of the relations that explain real-yield behavior varies over time, we estimated a system of linear equations for one-year, three-year, five-year, and

ten-year yields using the Seemingly Unrelated Regressions (SUR) method, which takes account of the possibility of a correlation among the deviations of the four equations in the system.[21] The equations were estimated for the period starting in the beginning of 2001 and ending in September 2013. We began the estimation in 2001 because the long-term inflation target of price stability, defined as an annual inflation rate of 1–3 percent, went into effect that year. The results are shown in Tables 3 and 4.

The change in GDP, IBOI, and inflation expectations, the real yield on US Treasury bonds, a fiscal variable, the American VIX index as an indicator of international financial risk, and a deviation in inbound tourism from the long-term trend as a proxy for change in the security situation were included in the equations in accordance with the theoretical model presented. Also included was a dummy variable for the period from February to August 2009, when the Bank of Israel intervened in the bond market.

The Bank of Israel interest rate (**IBOI**) was included and deconstructed into an expected part, based on the foregoing estimation, and a deviation from the expected interest rate—the policy surprise. The estimation shows that the effect of expected and unexpected interest is significant to all terms and that the longer the term, the less intensive it is. Its effect on the expected interest rate, the part based on the estimation, is (significantly) smaller than its effect on the interest surprise.

The effect of fiscal policy, according to the foregoing model, may be reflected in the effects of both the deficit and the expected debt. Accordingly, we tested various specifications that included public debt relative to expected potential GDP[22] in the coming six months[23] and the cyclically adjusted government deficit. The deficit may have a concurrent effect on yields due to its influence on the government's funding needs at the time; additionally, it may have an effect of a magnitude that varies in tandem with the extent of permanence attributed to it. The estimated effect of the deficit relative to that of the debt may allude to the extent of permanence that is attributed to changes in the deficit. The more permanent a change in the deficit is perceived, the more strongly it will affect the expected debt, i.e., the closer it will be to 1. A deficit perceived as temporary will probably have little effect on the expected debt. (See Brender, 2009, and reference in Baldacci and Kumar, 2010.)

The estimation presented in Tables 3 and 4 and additional specifications that include different versions of expected or past deficits, not shown in the tables, show that the public debt provides a positive and significant explanation for yields, whereas the inclusion of the deficit does not deliver good results and sometimes acquires a negative sign in the short run, contrary to expectations.[24] This outcome may indicate that the public learned from its experience in 1997, 2002–2003, and 2009 that even when budget deficits balloon, the government takes corrective action against them eventually; therefore, large deficits do not

[21] A Breusch-Pagan test for a correlation among the residuals was found to be significant at a 0.00 percent level. Thus, the hypothesis that the residuals are non-correlated among the equations may be rejected.
[22] The results for the debt/actual GDP ratio are similar and are not shown here.
[23] The use of expected six-month-forward debt instead of expected one-year-forward debt allows for the inclusion of more observations in the estimation with no major change in the values of the explanatory variable.
[24] Alternatively, we attempted to include the underlying deficit (net of interest payments) as an explanatory variable. Since the underlying deficit is closely correlated with the total deficit, however, this formulation, like the other alternatives, did not yield better results.

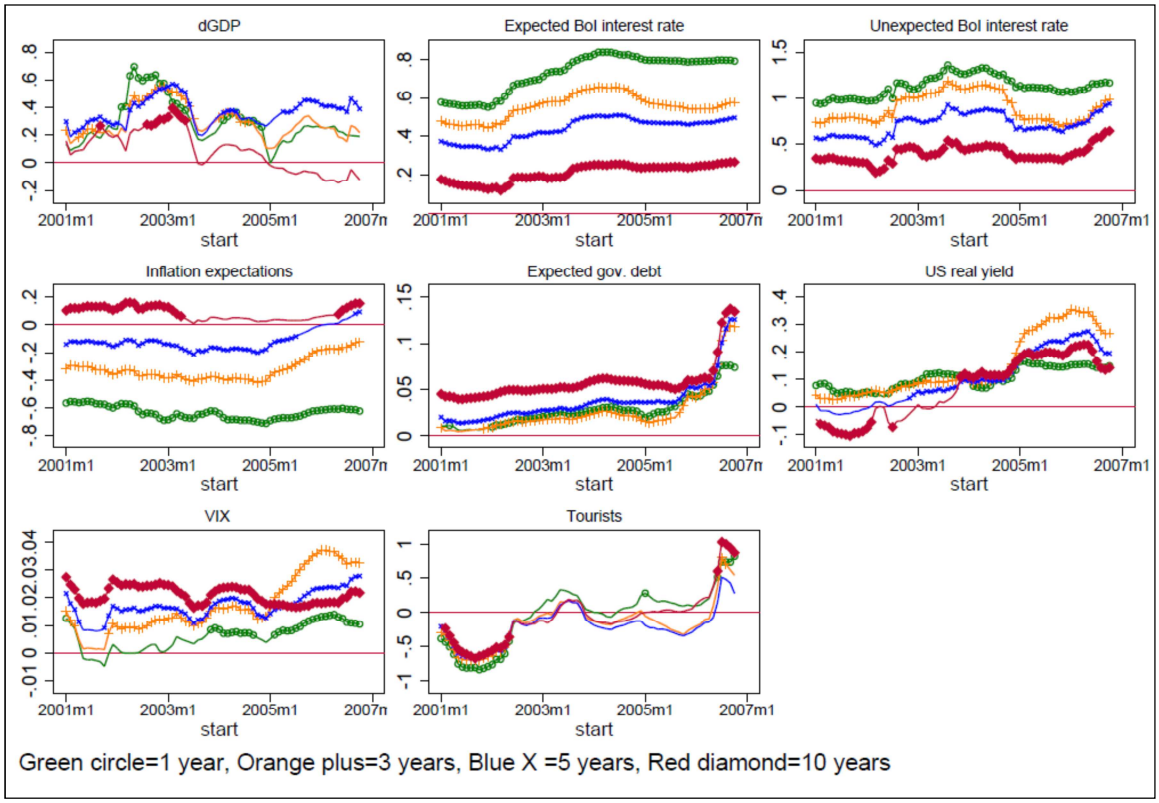
imply that the debt/GDP ratio will continue to rise in the long run. Similarly, when deficits were unexpectedly small—in the early 1990s, in 2000, and in the middle of the previous decade—the government adopted programs that pushed them up.

The signs of the coefficients of the other variables in the equation that includes public debt are as expected. Thus, a positive change in GDP has an upward effect on yields whereas a wider GDP gap exerts a downward effect; higher inflation expectations lower real yields (with the effect of IBOI, included in the equation, taken as a given); an increase in the US yield to a given term tends to raise the domestic yield to the same term greater global risk and a worsening domestic security situation also tend to raise yields; and the dummy variable for Bank of Israel intervention in the market has no significant effect on short-maturity yields but unexpectedly acquires a positive sign in long-maturity yields.

Examination of the residuals of each of the equations in the system by means of a Dickey-Fuller test shows that the hypothesis that they are non-stationary may be rejected.

Rolling regression: to examine the coefficients of the linear estimation of the yields, we ran a rolling regression covering eighty-four months (seven years). The results are shown in Figure 9.

Figure 9: Rolling Regression for Yields



*The date given denotes the end of the first month included in each regression.

It may be seen that changes in GDP have a positive significant effect on only some of the yields and during part of the period; the effect of IBOI—estimated and predicted—becomes somewhat stronger during the period. The effect of the public debt is positive and significant throughout the period and gets stronger in the samples that begin in mid-decade. Variables relating to abroad are usually significant—the effect of US interest gets much

stronger from 2005 onward whereas that of the VIX index is relatively constant. The security situation is meaningful only in the first part of the sample. In regard to some of these findings, we test below, as part of the nonlinear estimation, the possibility that the public debt and US interest have varying long-term effects on real government-bond yields.

d. Non-Linear Estimation of Yields

On the basis of the results of the rolling estimation across subperiods, we used the STR approach to test whether the effect of the fiscal variable and foreign interest on yields depend on the state of global activity or on long-maturity variables. In preliminary attempts, not presented here, we also asked whether a global risk effect, measured on the basis of the American VIX index or of other indicators of the global economic environment, e.g., change in the MSCI global share index or the US GDP growth rate, might modify the effect of public debt or foreign interest on yields. The results obtained were neither meaningful nor significant. However, the inclusion of the time variable[25] as an indicator of long-term changes in the global environment, particularly after the crisis period, and of changes in the Israeli economy's relations with the rest of the world due to its being opened to capital flows, yielded significant results showing considerable intensification of the effect of foreign interest and other public debt on yields, resembling the upturn observed when the linear rolling regression was run (Figure 9). All other variables in the estimation that have only to a linear effect were included. The results of the estimation using this specification are shown in Table 5.[26]

Effect of the public debt: studies abroad (e.g., Jaramillo and Weber, 2012) show that when the evaluation of risk abroad rises, the fiscal situation has a stronger effect on government-bond yields. The sovereign debt of fiscally better-off countries is in greater demand at times of general global risk because the risk attributed to high-debt countries or, conversely, the "confidence" attributed to the bonds of countries that are in better fiscal shape, is more meaningful at such times.

Again using the STR method, we checked for the possibility that the intensity of the effect of public debt on government-bond yields depends on the global environment. For the period checked, starting in 2001, significant results were not obtained. An increase in the American VIX index, an accepted metric of the risk that financial market players attribute to the markets, does not amplify the effect of the public debt significantly. A positive change in the MSCI index, which mirrors the behavior of the global equity markets, mitigates the effect of the debt—but not meaningfully.[27] An attempt to include the deficit as a multiplying variable that affects the extent of the response to yields to debt did not elicit significant results.[28]

[25] The time variable receives the value of 0 on first observation (January 2001) and the value of 1 on last observation (September 2013).

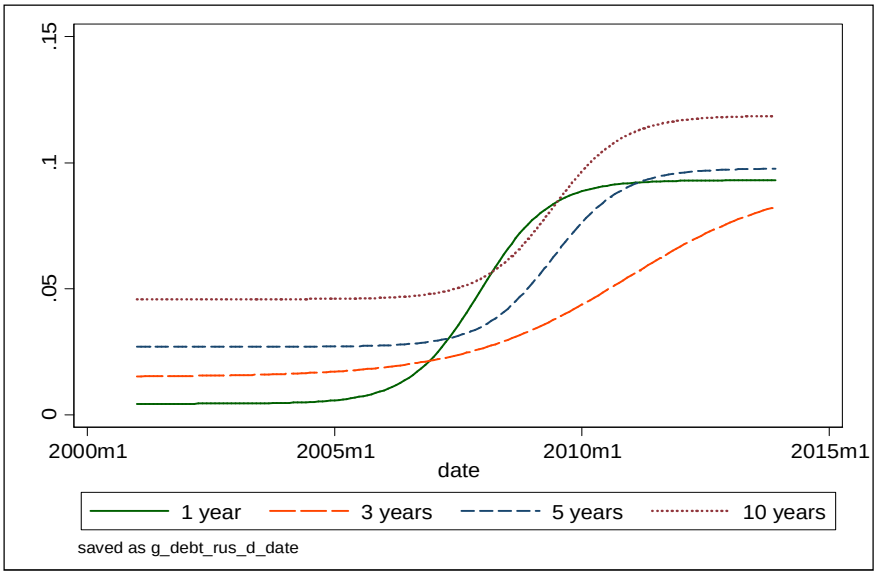
[26] When the system of equations with only one nonlinear effect—of interest rates or of the fiscal variable—was estimated, the effect obtained for each of these variables did not change. The estimation including both nonlinear effects improves the explanatory power of the equations slightly.

[27] The CDS premium—the risk premium priced into government bonds—provides an indication of a specific sovereign risk to Israel. However, since CDS exists only since August 2004, it cannot be used for the years in our investigation.

[28] An attempt to include the level of debt as a variable that multiplies the level of the deficit also failed to deliver reasonable results.

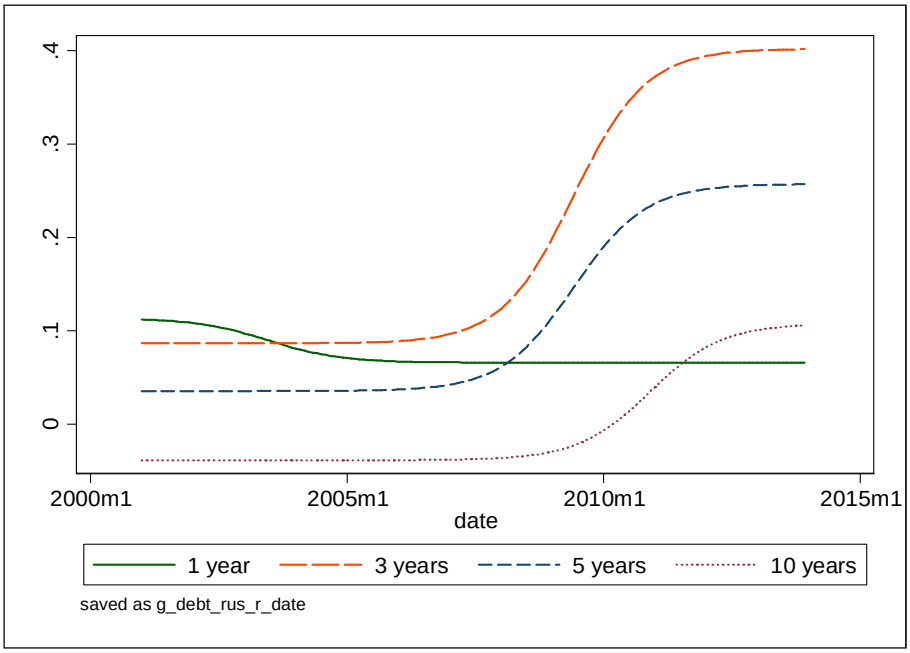
The inclusion of the time variable (on a 0–1 scale) as a factor influencing on the intensity of the relation between public debt and yields revealed a meaningful upturn in the effect of the debt in the second part of the period, mainly after 2008. The effect of public debt (relative to potential GDP), which ranged from 0 for short-term yields to 0.05 for the ten-year yield in the first 2000s decade, climbed to 0.07 for short-term yields and to more than 0.1 for ten-year yields after 2009 (Figure 10). The effect obtained at the beginning of the period resembles, qualitatively, that obtained in studies abroad. The effect found at the end of the period, however, exceeds that obtained in studies abroad, which relate to an earlier period and make no provision for a change in the effect. Evidently, the effect of public debt on yields is not sensitive to short-term changes in the global risk indices due to its relatively low level. The overall change in the global environment after the crisis, however, caused the debt's effect on yields to increase.

Figure 10: Effect of the Government Debt/Potential GDP Ratio on Yield as a Function of Time



The effect of US interest: similarly, we found that the effect of US interest on local yields intensified in the second part of the period to all maturities other than one-year (Figure 11). The effect of short-term interest on the one-year yield is around 0.1 but the effect on longer maturities ballooned from close to 0 in the first half of the 2000s to 0.15–0.3 in recent years.

Figure 11: Effect of US Interest on Yields as a Function of Time



The effect of monetary policy: the results obtained resemble those obtained a decade ago by Ber, Brender, and Ribon (2004). As expected, IBOI affects short terms with coefficients of 0.5–0.6, but it also has a significant 0.2 effect on the ten-year yield, largely reflecting the effect of policy on the short segment of this yield. (Below we also examine an effect on forward yields.) This outcome also resembles that presented by Kahn, Kandel, and Sarig (2002), who use a VAR system to estimate the effect of a change in IBOI on nominal and real sovereign yields to one-year, five-year, and ten-year maturities and on inflation expectations as derived from the capital markets. The effect they find is 0.4 on the real one-year yield, with a smaller increase in the nominal yields and a decline in inflation expectations. Kahn, Kandel, and Sarig also find a weaker effect on yields to longer maturities.

According to the estimation, unexpected interest, i.e., surprises in monetary policy, has a positive and significant effect, its coefficient exceeding that of the expected part of the policy. Inflation expectations have a negatively signed effect, suggesting that one may treat them as approximating the effect of the real interest rate, "derived" from monetary policy, on CPI-indexed yields.

Another variable that affects real yields is changes in GDP (in the past half-year), with a coefficient of 0.3 on yields to various maturities.[29] The 0.01–0.02 coefficient with the VIX index is reflected in the addition of 0.4 percentage point to the upturn in the short-maturity yield and of up to 0.8 percentage point in longer-maturity yields, due to the increase in the index from 20 on average before the late-2008 crisis to 60 afterward. A downward deviation in inbound tourism from the trend, our proxy for the security situation, has no significant effect to most maturities. The dummy variable for the Bank of Israel's

[29] The equations accommodate the GDP variable in the form of a monthly mean. In terms of the annual rate of change (multiplying by 12), the coefficient obtained is 0.03.

intervention in the bond market in 2009 manifests in a negative effect on the one-year yield and an insignificant effect on yields to longer maturities.

Comparing the nonlinear and the linear specifications for goodness of fit, we found a major improvement in the overall fit, particularly in recent years. The error across the entire sample, reflected in RMSE, declined from 0.3–0.38 in the linear estimation to 0.25 in the nonlinear one. Figures A1a and A1b in the Appendix illustrate the improvement in fit in recent years by juxtaposing the estimated values with actual yields.

e. Estimation of the Factors that affect Forward Yields

To better understand how fiscal and monetary policies affect yields, we also tested forward yields. Following the approach in Ber, Brender and Ribon (2004), we calculated forward yields using the Expectations Theory. This approach presumes that the long-maturity yield reflects an average of the expected yields to the forward short term, meaning that the long-maturity yield can be reduced to its short-maturity components. More explicitly, one may write the yield at time t on a bond to n periods as:

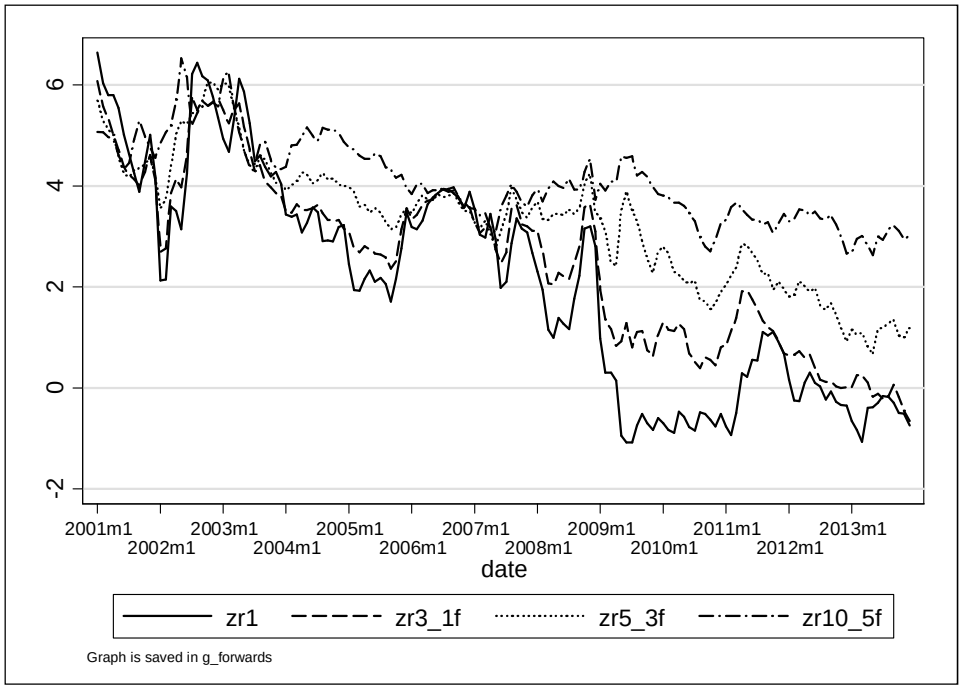
$$(10) \qquad (1+r_{t,t+n}) = \prod_{i=1}^{n}(1+E_t r_{t+i-1,t+i}) + \theta$$

where θ is the term premium. The forward yield between term t+k and term t+n, assuming a zero term premium, is calculated as:

$$(11) \qquad (1+r_{t+k,t+n}) = \left(\frac{(1+r_{t,t+n})^n}{(1+r_{t,t+k})^k}\right)^{1/(n-k)}$$

We chose to calculate forward yields to 1–3 years (i.e., for years 2 and 3), 3–5 years, and 5–10 years. The results (Figure 12) show a marked decrease in short-maturity yields that declines in intensity as the term is prolonged. The forward yield for years 5–10 declines a little, from 5 percent to 3 percent, whereas the one-year yield plummets to around zero (Figure 12).

Figure 12: Forward Yields, 2001–2013



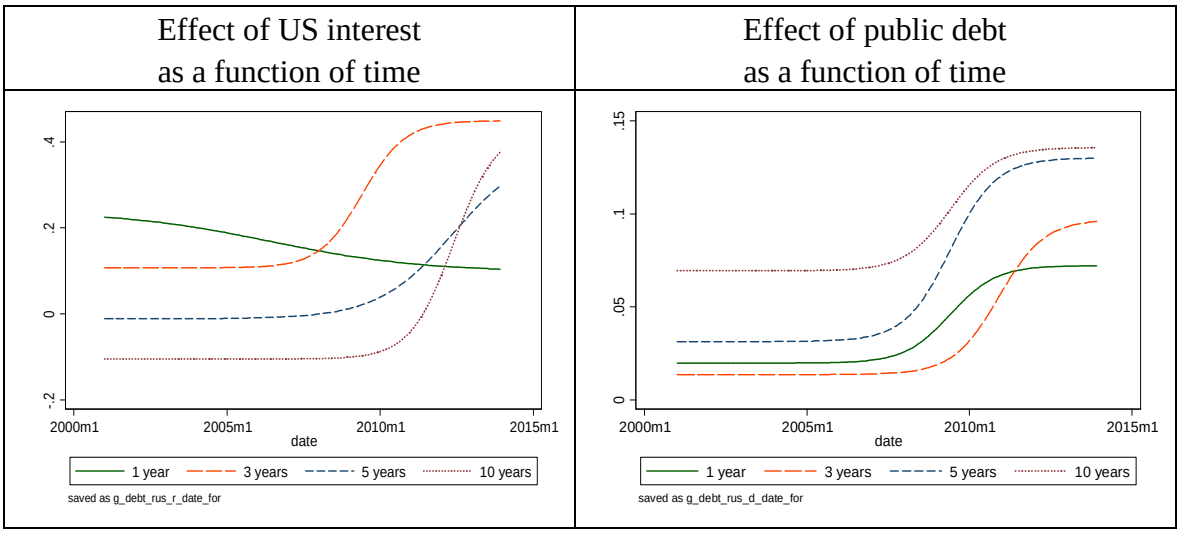
We estimated a system of equations for forward yields, in both linear and nonlinear versions, that parallels the system estimated for total yields. The results obtained for forward yields correspond qualitatively to those in the estimation of total yields. For both forward and total yields, it was found that the non-linear estimation improves the quality of fit, particularly in recent years. (See Figures A2a and A2b in the Appendix.)

An important finding is that IBOI significantly affects the medium term—up to five years—as well. To the longest term, 5–10 years, its estimated effect is insignificant, whereas the unexpected portion has a relatively large significant positive effect of 0.16.

It was found that the effect of fiscal policy, manifested in the expected ratio of debt to potential GDP in the coming half-year, is greater to farther maturities and significant to all forward maturities. Much as in the estimation of total yields, the effect of the debt on these yields has increased considerably in recent years. The effect of US interest on domestic forward yields also grew in the second half of the period to all terms except for one year, in which it was 0.2 across the entire period (Figure 13).

The rest of the results obtained resemble those obtained in the estimation of total yields. The rate of change in GDP has a positive effect on forward yields; the GDP gap has a negative effect. An increase in the VIX index contributes to an increase in sovereign forward yields. The effect of a dummy variable for Bank of Israel intervention in the bond market in 2009, which was negative or insignificant for total yields, is positive and significant for longer-maturity forward yields, unexpectedly.

Figure 13: Concurrent Change in the Effect of US Interest and the Government Debt/Potential GDP Ratio on Forward Yields



Checking the stationarity of the residuals of the estimated value from the actual data in the estimation of forward yields, to all maturities, it was found—as in the estimation of total yields—that the hypothesis that all of them are I(0) cannot be rejected.

5. Estimated Contributions to Real Yields and Real Yield Change

a. Contribution of Fiscal and Monetary Policy

The non-linear yield estimates may be used to calculate the estimated contribution of fiscal policy and monetary policy, as represented in the equations, and of the other explanatory variables.

We chose to decompose the direct effect of the explanatory variables into four groups—fiscal policy, monetary policy, the domestic economic environment, and the global economy—plus the unexplained residual. To test the effect of the two policies, the analysis here includes only their direct effects. Thus, the effect of foreign interest in the analysis is the direct effect of this factor on yields; its effect on monetary policy and, through this mechanism, on yields is excluded. Farther on, separate attention is given to the effects of domestic and global factors, including their indirect effects.

The effect of **fiscal policy** includes that of the expected public debt. The effect of **monetary policy** includes IBOI—the expected rate according to the estimation and the unexpected portion—and inflation expectations. The effect of **real activity** is reflected in the effect of change in GDP together with that of deviations from the inbound-tourism trend, which serve as a proxy for the security situation.[30] The direct effect of the **global environment** includes the real US interest rate to the corresponding maturity. What remains is the residual that none of these factors explains.

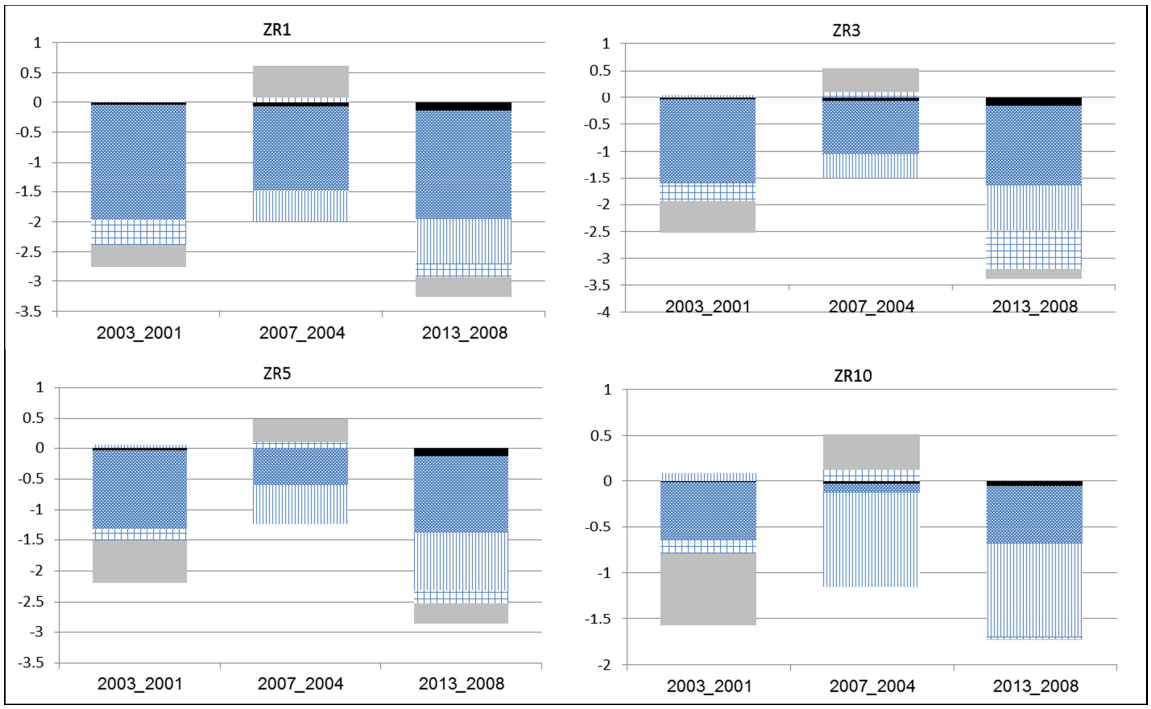
[30] The contribution to yield of deviations of inbound tourism is about one-tenth of the contribution of the change in GDP.

Contribution to Total Yields

To examine the contribution of fiscal policy, monetary policy, real activity, and the global economy, to changes in yields, we divided the investigation period into three subperiods. The first subperiod, from 2001 to the end of 2003, was typified by relatively large government deficits and debt and also high nominal and real short-term interest rates (derived from Bank of Israel policy). In the second subperiod—2004-2007—the government deficit and debt began to decline and the nominal Bank of Israel rate was around 5 percent. From 2008 onward, the government deficit rose again but in a manner that allowed the debt/GDP ratio to remain stable and low. The dominant factor at this time was the effect of the global financial crisis that broke out in late 2008. Figure 14 presents the results.

It may be seen that monetary policy made a major contribution to changes in yields in most subperiods and that, as expected, the effect was stronger to shorter maturities. Between 2004 and 2007, as the debt/GDP ratio contracted from nearly 100 percent to 75 percent, fiscal policy had a powerful effect on the downward movement of yields, particularly in long maturities. The effect of fiscal policy also remained strong in recent years due to the increase in its coefficient.

Figure 14: Contributions to Change in Real Yields, 2001–9. 2013—in Three Subperiods



* Black = real activity; vertical bars = fiscal; blue dots = monetary; gray = residuals

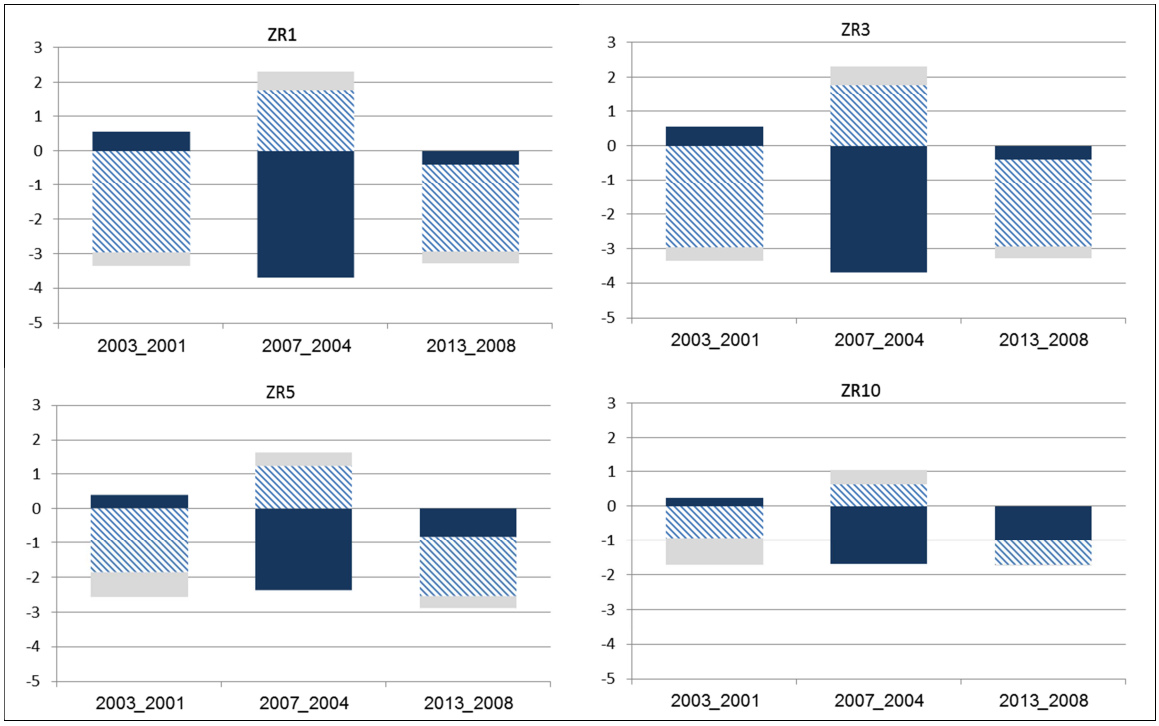
Of the total decline in yields during the ten-year period—from a high of 4.9 percent on average in 2003 to 1.6 percent on average in 2013 (through September)—the decline in the GDP-debt ratio explains around 2 percentage points, IBOI another 0.8 percentage point, and real activity and global activity a mere 0.1 percentage point each.

b. Contributions of Global and Domestic Factors

The total effect of the explanatory variables on yields may be decomposed into the effect of global factors, exogenous to the Israeli economy, and that of domestic factors—real and monetary policies and developments. Since we also estimate (in a preliminary equation) the factors that affect monetary interest, the expected monetary policy, which is included in the yield equations, may be represented by the factors that affect it. These factors may be decomposed into domestic factors—inflation and activity—and one global factor, US interest.[31]

The division of the period into three subperiods reveals the salient contribution of domestic factors to long-maturity yields in 2004–2007 and in the last subperiod. The global factors affect changes in yields in all three subperiods and to all terms.

Figure 15: Contributions of Domestic and Global Factors to Changes in Real Yields, 2001–9. 2013—in Three Subperiods



* Dark blue = domestic factors; diagonal lines = global factors; gray = residuals

6. Comparison with Results Obtained for 1991–2001 Data

Ber, Brender, and Ribon (2004) tested the effect of fiscal and monetary policy on real government bond yields in 1991–2001 by estimating a system of linear equations that included variables similar but not identical to those in the current estimation.

[31] The Bank of Israel interest equation also includes lagged interest; therefore, one must also relate to the factors that affected the setting of the interest rate in the past. Since the coefficient of lagged interest is close to 1 (0.925), the effect lingers for many periods. We chose to insert the lagged effect of the global factors to twelve periods back and to assign all the rest of the (measured) residual to domestic factors. This method yields an underestimate of the effects of the global factors on interest and, in turn, on yields.

The main difference between the studies is the period examined. The estimation period in the earlier study was mainly the 1990s, ending in 2001; that in the current study begins in 2001 and ends in 2013. The main characteristics of the period examined in the earlier study were an upward trend in real yields, a volatile government deficit of around 4 percent of GDP, and a perceptible decrease in the debt, mostly at the beginning the period, to around 80 percent of GDP. Monetary policy during most of this time was typified by rate-hiking to as much as 5 percent. These differences aside, the characteristics of the Israeli economy and its relations with the global economy were very different from those in the present study. The domestic financial markets are much more firmly integrated into their global counterparts now, for reasons including the elimination of supervisory restrictions and the impact of global developments—technological and other—that strengthened relations and correlations in developments among markets around the globe.[32] Consequently, domestic policies also became more dependent on global developments and policies—particularly monetary ones—abroad. The research period in the present study captures the global financial crisis that began in 2008, an important factor in the development of markets around the world, including Israel's, and in its effect on policies involved at home and abroad.

In both the 2004 paper and the present one, it was found that fiscal and monetary policy affected real government-bond yields to the various terms. The main variables that characterized fiscal policy in the 2004 study, however, were the government deficit and deficit target; in the present study, in contrast, the public debt was found to be the variable that best describes the effect of policy on yields. It had a significant effect to all maturities; the effect of the deficit was not significant. The public appears to have learned during the intervening decade not to make too much of the government's multiannual deficit targets, which are repeatedly revised (Bank of Israel *Annual Report* for 2012, Chapter 6), and to changes in the cyclically adjusted deficit, since this parameter fluctuates within a relatively narrow band and quickly re-converges after any deviation. For this reason, the debt/GDP ratio, which reflects both the long-term policy trend and the future payback burden, is the variable that has the steadier effect.

The effect of monetary policy, represented by the Bank of Israel interest rate (IBOI) less inflation expectations, remained strong in the period investigated in this study, and the strength of its effect on yields to the various maturities—past and forward yields alike—remained basically unchanged. In both studies, monetary policy was found to have a significant if small effect on forward yields to longer maturities. Such was the case even though the inflation environments in the two studies were markedly different—price stability today as against the earlier period, which was typified by disinflation attained through the central involvement of monetary policy.

An important difference between the periods is the strength of the effect of real US interest. In the earlier study, which included data up to 2001, this effect was significant only when it was included, starting in 1998, and was relatively weak. In the current study, its effect is significant and stronger for all terms, reflecting the growing integration of the Israeli economy into the global markets. It was also found in the current estimation that the

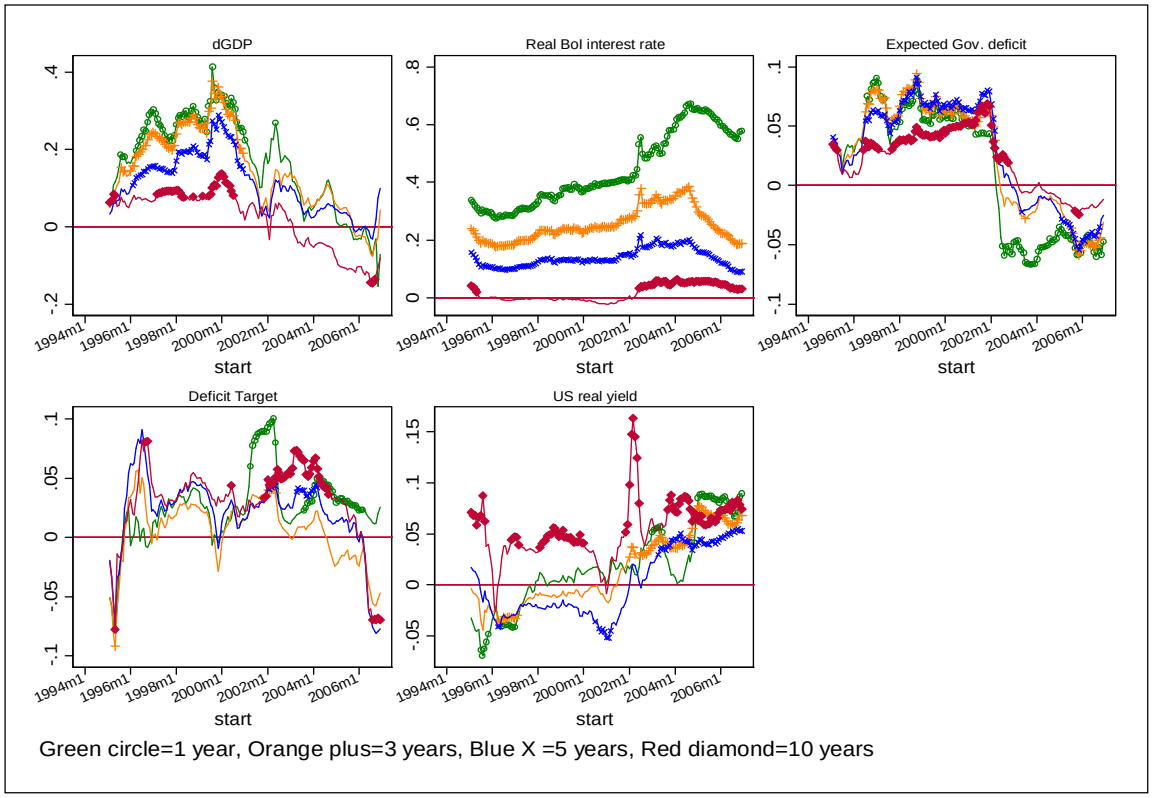
[32] See Table 7C.1 in Chapter 7C of the Bank of Israel *Annual Report* for 2013.

variables that reflect the global environment, such as the risk index (VIX), affect domestic yields. This index was neither included nor tested in the earlier study.

We re-estimated in the current study, the system of equations as it was specified in the previous studyusing a seven-year rolling regression starting in 1995.[33] The main specification of the earlier estimation included IBOI less inflation expectations, the expected government deficit, change in GDP, US interest from 1998 onward, the deficit target, immigration flow, and the dependent variable at a lag. The results remained basically the same.

The effect of the Bank of Israel's short-term interest rate on yields to various maturities has grown over the years. Conversely, the effect of the government deficit (first line on the left) is insignificant in the later segment of the sample to most terms, including the ten-year estimates. This contrasts with the findings of the earlier study. The effect of the deficit target is insignificant in most of the sample, to all terms. One may also see that the effect of US interest gathered strength and became significant in the later samples, as the domestic economy opened up and the global crisis unfolded (Figure 16).

Figure 16: Coefficients in Rolling Regression (Short-Term) as Formulated in the 2004 Study, 1995–2013*



*The years refer to the time at which the estimated sample began. The coefficients relate to the short term (irrespective of the effect of the lagged dependent variable).

[33] In the earlier study, the estimation began in August 1991. Revisions of the National Accounts definitions limit the present study to an estimation beginning in 1995.

7. Conclusion

This study examined the effect of domestic fiscal and monetary policies, economic activity, and the global environment on the real yields of Israel government bonds to various maturities in 2001–2013, using an estimation technique that allows variables to have a non-linear effect. In practice, fiscal policy and foreign interest were indeed found to have non-linear effects on yields.

It was found that fiscal policy, proxied by the ratio of debt to potential GDP, affected yields; furthermore, the effect intensified as maturity lengthens and as the investigation period proceeded. At the end of the period, a 1 percentage point increase in the public debt/potential GDP ratio added 0.12 percentage point to ten-year yields and 0.05–0.1 to yields to shorter maturities. Until the global financial crisis, the effect of the public debt was around 0.05 on long-maturity yields and 0.01–0.03 to shorter maturities, much like the results obtained in other countries. The non-linear estimation allows for a change in the effect over time with no need to set a breaking point in advance.

Unlike the study performed a decade ago, we find no effect of the expected deficit (cyclically adjusted) on yields. This may indicate that the public, learning from its experience in 1997, 2002–2003, and 2009, knows that even when the budget deficit balloons, the government will take corrective action within a certain time and that when the deficit sinks to low levels, it will face upward pressure, as happened in the middle of the previous decade. Therefore, one cannot infer from changes in the deficit that the path of the debt/GDP ratio will change commensurately over time.

We found that monetary policy has a positive effect on yields to all maturities—from 0.6 to one year to 0.2 to ten years. The "surprise" element in monetary policy (the part not explained by the IBOI rate equation) has a stronger effect than the expected (estimated) portion. The direct effect of US yields on medium- and long-maturity domestic yields increased from 0–0.1 in the first half of the previous decade to 0.1–0.4 in recent years. In the interim the domestic economy was opened to capital flows and the correlation among markets around the world became stronger, particularly during the global crisis. An increase in global financial risk, proxied by the American VIX equity market index, abets an increase in domestic yields. The analysis shows that the decrease in monetary interest explains much of the decline in short- and middle-maturity yields that occurred in the middle of the decade, whereas the decrease in the public debt/GDP ratio explains much of the decline in long-maturity yields. Finally, it is found that global factors made a major contribution to changes that occurred in yields at all times and to all maturities.

Table 1: Basic Statistics, 2001–2013

	Mean	S.D.	Minimum	Maximum
Domestic yields				
1Y CPI-indexed govt. bond yield	2.1	2.2	-1.1	6.6
3Y CPI-indexed govt. bond yield	2.4	1.9	-0.7	6.3
5Y CPI-indexed govt. bond yield	2.8	1.6	0.1	6.0
10Y CPI-indexed govt. bond yield	3.4	1.2	1.4	5.9
1Y–3Y govt. bond forward yield	2.6	1.7	-0.7	6.1
3Y–5Y govt. bond forward yield	3.3	1.3	0.7	6.0
5Y–10Y govt. bond forward yield	4.1	0.8	2.6	4.0
Macroeconomic variables				
Nominal Bank of Israel rate	4.0	2.3	0.5	9.5
Inflation expectations 1Y ahead (from capital market)	2.0	0.8	-0.7	4.5
Seasonally and cyclically adjusted deficit (pct. of GDP)	2.9	3.1	-6.3	13.2
Government debt (pct. of GDP)	81.9	10.1	69.0	100.5
Monthly change in GDP (6-month avg.)	0.3	0.2	-0.5	0.8
Actual/potential GDP gap (pct.)	2.8	2.4	-5.8	8.2
(Log) deviation of inbound tourism from trend	-0.1	0.3	-1.2	0.3
Abroad				
1Y CPI-indexed Treasury bond yield	-0.0	1.4	-2.1	2.7
3Y CPI-indexed Treasury bond yield	0.4	1.3	-1.4	2.9
5Y CPI-indexed Treasury bond yield	0.9	1.2	-1.5	3.7
10Y CPI-indexed Treasury bond yield	1.6	1.1	-0.8	3.5
1Y–3Y CPI-indexed Treasury bond forward yield	0.7	1.3	-1.3	3.1
3Y–5Y CPI-indexed Treasury bond forward yield	1.7	1.8	-1.9	10.8
5Y–10Y CPI-indexed Treasury bond forward yield	2.3	1.2	-0.2	5.3
VIX index	21.3	9.1	10.8	62.6

Table 2: Bank of Israel Interest Rate Equation,* 2001.1–2013.9

	1	2	3
Intercept	(0.06)	0.15	0.22
GDP gap, 2-quarter avg., at 2-period lag	-.02	(-0.01)	(-0.02)
Deviation of inflation expectations 1Y ahead, at 1-period lag, from inflation target	0.31	0.34	0.34
Deviation of 1Y U.S. nominal interest rate from avg.		0.08	0.10
Deviation of expected government deficit (seasonally and cyclically adjusted) from avg., 12 months ahead			0.03
Lagged Bank of Israel interest rate	.988	.969	.954
R^2	.983	.985	.986
RMSE	.308	.291	.288

* All coefficients other than those in parentheses are 5% significant.

Table 3: Yields, 2001.1–2013.9, with Government *Deficit, Linear* SUR Estimation *

	R1	**R3**	**R5**	**R10**
Intercept	.338	(-.02)	.449	1.64
Change in GDP, 6-month moving avg. at 1-period lag	(.148)	.473	.549	.387
Bank of Israel interest rate—estimated	.708	.582	.491	.290
Bank of Israel interest rate—residual	1.04	.723	.604	.423
Inflation expectations 1 year ahead	-.688	-.379	-.200	(-.061)
Real yield on U.S. Treasury bonds to corresponding maturity	.184	.241	.236	.173
Government deficit/GDP, avg. 6 months ahead, deviation from mean	-.056	-.053	(-.033)	(-.022)
U.S. VIX index	.009	.024	.013	.011
Deviation of inbound tourism from linear trend	-.938	-.973	-.920	-1.10
Dummy variable for Bank of Israel intervention in bond market, February–August 2009	(-.057)	(.047)	.128	.158
R^2	.979	.968	.948	.888
RMSE	.314	.326	.357	.382

* All coefficients other than those in parentheses are 5% significant.

Table 4: Yields, 2001.1–2013.9, with Government *Debt, Linear* SUR Estimation *

	R1	**R3**	**R5**	**R10**
Intercept	.378	(.044)	.481	1.71
Change in GDP, 6-month moving avg. at 1-period lag	.472	.812	.817	.587
Bank of Israel interest rate—estimated	.650	.525	.424	.213
Bank of Israel interest rate—residual	.946	.630	.512	.333
Inflation expectations 1 year ahead	-.610	-.304	-.105	.066
Real yield on U.S. Treasury bonds to corresponding maturity	.184	.220	.195	.099
Government deficit/GDP, avg. 6 months ahead, deviation from mean	.039	.043	.055	.068
U.S. VIX index	.014	.026	.024	.026
Deviation of inbound tourism from linear trend	-.350	-.327	(-.098)	(-.100)
Dummy variable for Bank of Israel intervention in bond market, February–August 2009	(-.051)	(.055)	.129	.149
R^2	.985	.976	.967	.942
RMSE	.267	.281	.285	.273

* All coefficients other than those in parentheses are 5% significant.

Table 5: Yields, 2001.1–2013.9, *Non-Linear* SUR Estimation of U.S. Interest and Government Debt *

	R1	**R3**	**R5**	**R10**
Intercept	.814	.897	1.19	2.35
Change in GDP, 6-month moving avg. at 1-period lag	.304	.329	.348	(.117)
Bank of Israel interest rate—estimated	.641	.517	.419	.197
Bank of Israel interest rate—residual	.945	.747	.579	.379
Inflation expectations 1 year ahead	-.569	-.326	-.094	.111
Real yield on U.S. Treasury bonds to corresponding maturity	.114	.087	(.035)	(-.038)
Real yield on U.S. Treasury bonds to corresponding maturity***time variable**	(-.048)	.315	.221	.146
Gamma	7	7	7	7
Threshold time	2003m7	2009m6	2009m6	2010m12
Government debt/ potential GDP, avg. 6 months ahead, deviation from mean	(.004)	.015	.027	.046
Government debt/ potential GDP, avg. 6 months ahead, deviation from mean***time variable**	.089	.078	.071	.073
Gamma	7	3	7	7
Threshold time	2007m12	2010m12	2009m6	2009m6
U.S. VIX index	.010	.013	.015	.022
Deviation of inbound tourism from linear trend	(-.254)	-.281	(-.097)	(-.113)
Dummy variable for Bank of Israel intervention in bond market, February–August 2009	-.101	(-.046)	(.030)	(.061)
R^2	.987	.985	.975	.953
RMSE	.249	.224	.247	.245

* All coefficients other than those in parentheses are 5% significant.

Table 6: Forward Yields, 2001.1–2013.9, with Expected Government Debt, Relative to Potential GDP, *Linear* SUR Estimation *

	F1	**F3_1**	**F5_3**	**F10_5**
Intercept	.371	(-.190)	1.09	3.16
Change in GDP, 6-month moving avg. at 1-period lag	.414	.992	.884	(.153)
Bank of Israel interest rate—estimated	.642	.464	.262	(.002)
Bank of Israel interest rate—residual	.942	.465	.289	.172
Inflation expectations 1 year ahead	-.597	-.148	.161	.296
Real yield on U.S. Treasury bonds to corresponding maturity	.211	.258	.101	-.079
Government deficit/potential GDP, avg. 6 months ahead, deviation from mean	.038	.042	.073	.088
U.S. VIX index	.015	.038	.028	.031
Deviation of inbound tourism from linear trend	-.377	-.340	(.096)	(-.148)
Dummy variable for Bank of Israel intervention in bond market, February–August 2009	(-.060)	.110	.271	.151
R^2	.985	.959	.905	.859
RMSE	.262	.338	.381	.308

* All coefficients other than those in parentheses are 5% significant.

Table 7: Forward Yields, 2001.1–2013.9, *Non-Linear* SUR Estimation of U.S. Interest and Government Debt *

	R1	**R3**	**R5**	**R10**
Intercept	.613	.919	1.78	3.43
Change in GDP, 6-month moving avg. at 1-period lag	.264	.313	.204	(-.190)
Bank of Israel interest rate—estimated	.634	.454	.232	(-.017)
Bank of Israel interest rate—residual	.949	.626	.303	.157
Inflation expectations 1 year ahead	-.564	-.177	.211	.379
Real yield on U.S. Treasury bonds to corresponding maturity	.239	.108	(-.011)	-.104
Real yield on U.S. Treasury bonds to corresponding maturity***time variable**	(-.141)	.342	.398	.534
Gamma	2	7	4	7
Threshold time	2006m6	2009m6	2012m5	2012m5
Government debt/ potential GDP, avg. 6 months ahead, deviation from mean	.020	.014	.031	.069
Government debt/ potential GDP, avg. 6 months ahead, deviation from mean***time variable**	.052	.083	.099	.066
Gamma	7	7	7	7
Threshold time	2009m6	2010m12	2009m6	2009m6
U.S. VIX index	.010	.016	.028	.030
Deviation of inbound tourism from linear trend	-.411	-.292	(-.055)	(-.111)
Dummy variable for Bank of Israel intervention in bond market, February–August 2009	-.112	(-.039)	.144	.085
R^2	.987	.978	.931	.884
RMSE	.246	.249	.326	.279

* All coefficients other than those in parentheses are 5% significant.

Appendix

Figure A1a: Real Yields—Actual (Thin Line) and Estimated (Thick Line) by *Linear* Estimation

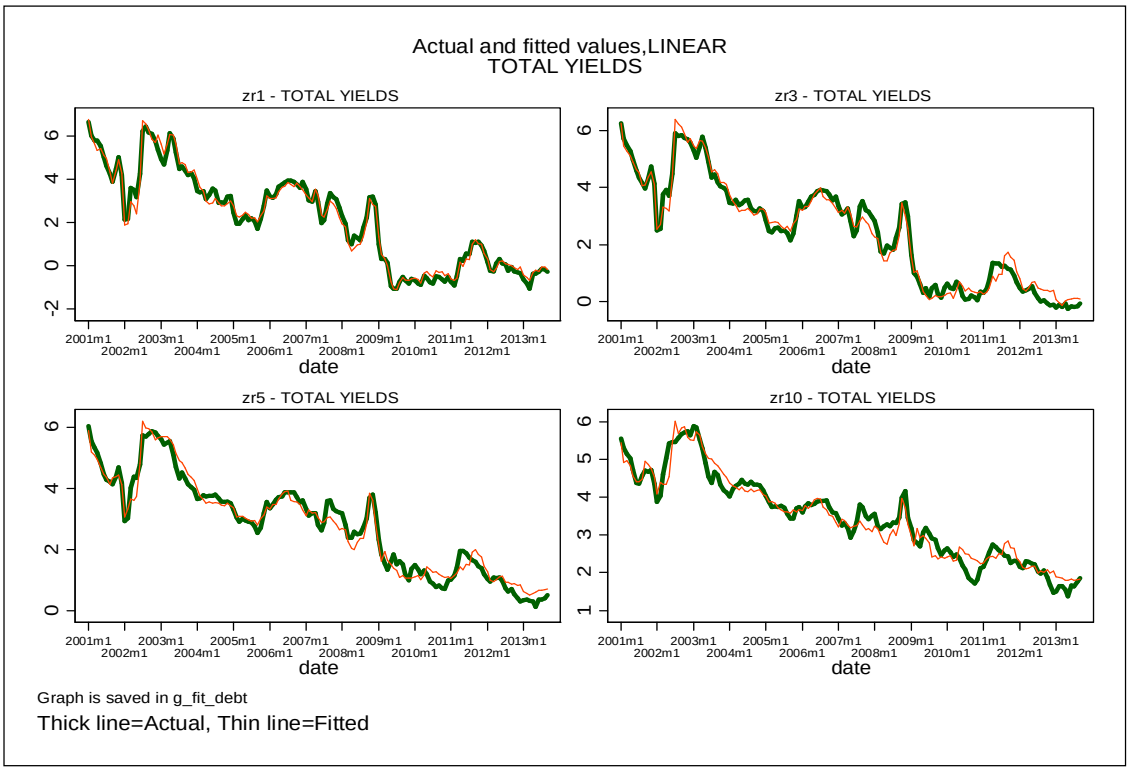
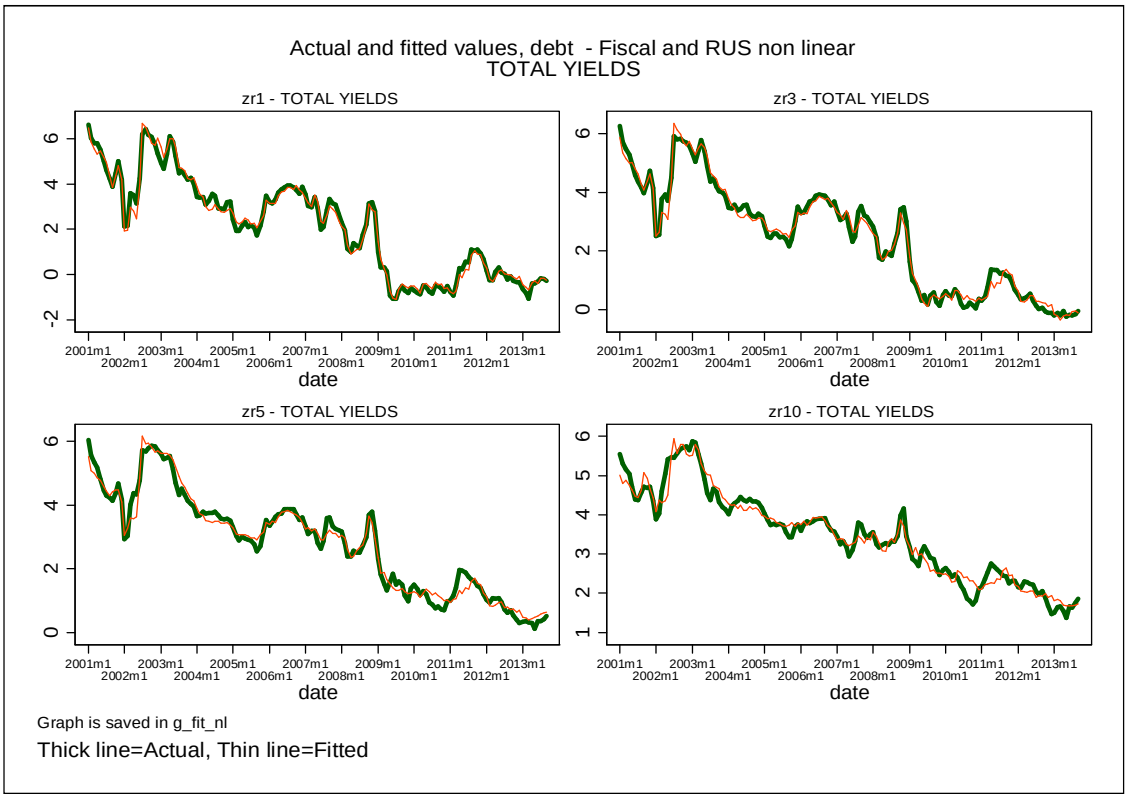


Figure A1b: Real Yields—Actual (Thin Line) and Estimated (Thick Line) by *Non-Linear* Estimation for Debt and U.S. Interest



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