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Factors Explaining Long-Term Government Bond Yields in Israel and the OECD[1]

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Factors Explaining Long-Term Government Bond Yields in Israel and the OECD

Noam Michelson and Roy Stein

Abstract

In this study, we analyze the long-term government bond yields in OECD member countries over time and estimate a range of factors that affect these yields, including demographic, economic, and financial variables. The main goal is to identify the specific effects of these explanatory factors, which are divided into three groups: structural factors that dictate the natural interest rate; cyclical factors; and fiscal risk factors, which are based on the probability that countries will be able to service their debt. Using this model, we examine whether credit ratings contain additional information that is taken into consideration by investors. Our findings indicate that due to demographic changes, the natural interest rate dropped significantly and constitutes a cross-border factor that had a significant effect on long-term interest rates. We also found that the low inflation and accommodative unconventional monetary policy throughout our sample period constitute the primary cyclical factors that affected long-term interest rates in recent years. Variance in the development of fiscal risk factors is the main reason for the relative inter-country differences. We found that credit ratings have no effect on yields beyond the effect of the estimated economic factors. However, changes in credit ratings that reflect rising credit risks and changes to and from investment-grade ratings have a significant effect on long-term interest rates.

הגורמים שמסבירים את תשואות האג״ח הממשלתיות הארוכות בישראל ובמדינות ה-OECD

נועם מיכלסון ורועי שטיין

תקציר

בעבודה זו אנו מנתחים את התשואות הממשלתיות הארוכות במדינות ה-OECD על־פני זמן ואומדים את מכלול הגורמים שמשפיעים על תשואות אלה ובכלל זה משתנים דמוגרפים, כלכליים ופיננסים. המטרה העיקרית היא להבחין בין השפעת הגורמים השונים, שנחלקו לשלוש קבוצות: גורמים מבניים, שמכתיבים את הריבית הטבעית; גורמים מחזוריים; וכן גורמי סיכון פיסקלים, שנשענים על ההסתברות שהמדינות תוכלנה לשרת את חובן. על־בסיס מודל זה בחנו אם יש בדירוגי האשראי מידע נוסף שנלקח בחשבון על־ידי ציבור המשקיעים. הממצאים מראים שהריבית הטבעית ירדה באופן מובהק ושהיא מהווה גורם חוצה־מדינות, שהשפיע עקב השינויים הדמוגרפים רבות על הריביות הארוכות. מצאנו גם שהאינפלציה הנמוכה והמדיניות המוניטרית המרחיבה והלא קונבנציונלית, מהווים את הגורמים המחזוריים העיקריים שמשפיעים בשנים האחרונות על הריביות הארוכות. השונות בהתפתחותם של גורמי סיכון פיסקלים בקרב המדינות מהווה את הסיבה העיקרית לשינויים היחסיים בין המדינות. באשר לדירוגי האשראי, מצאנו שמעבר לגורמים הכלכליים שנאמדו, אין לדירוגים עצמם השפעה על התשואות, אולם לשינויים בהם, שמסמנים עלייה בסיכון האשראי וכן בחציית סף הדירוג הספקולטיבי (לשני הכיוונים), יש השפעה מובהקת.

1. Introduction

The enormous rise in government debt in many countries following the COVID-19 crisis increased the importance of examining the cost of sovereign debt, which is reflected in the yield to maturity of long-term government bonds. In the past decade, this yield to maturity, which reflects investors' expectations based on a combination of all economic and financial factors, has fallen significantly to extremely low rates, despite the enormous increase in the debt-to-GDP ratio in most OECD countries. The puzzle of low rates despite high levels of debt-to-GDP has motivated a public debate and research on pricing the cost of debt, the quality of credit ratings, and the estimation of risk factors, especially those implied in long-term government bond yields.

From a local perspective, long-term interest rates fell sharply in Israel, even compared to interest rates in the US, and gap has remained negative for several years, while Israel maintained a positive long-term interest rate differential compared to Europe, mainly because interest rates in Europe fell to within the negative range. More than anything, these developments point to the cross-border differences in economic factors in the past decade. Therefore, in order to estimate the various factors that affect long-term interest rates, it is important to study panel data yields and assess the common factors that affect yields across countries. This study offers a resolution to this puzzle of high leverage rates and low long-term interest rates, which has emerged in the past decade.

This study examines the factors that explain forward yields in OECD countries between 2001 and 2018, which derive from the interest rates on 5- and 10-year nonindexed bonds[1] (below we use the term "long-term interest rates," which constitute an estimate of the cost of government debt).[2]. In line with previous studies on this topic, we found that long-term interest rates are explained by cyclical factors, including central bank interventions, fiscal risk factors, and long-term structural factors that represent the natural interest rate.[3]

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1 When examining government bond yields it is important to distinguish between factors that have a short-term impact and factors that also have a long-term effect. To this end we calculate the nominal 5 to 10 5-years forward yield for each country at each point in time, which measures the expected interest rate over the five-year period that begins five years from the measurement point. The empirical literature refers to this yield as an indicator of cost of long-term government debt.

2 The data we originally sampled for this study included 51 countries and span from 1980 to 2018. However, due to data availability and in order to avoid a number of structural changes that took place during this long period, we decided to focus on a smaller number of countries (OECD members) and a shorter period (from 2001 onwards).

3 The natural interest rate is the theoretical interest rate that at which the desire to save exactly matches the desire to invest in an economy whose prices fluctuate freely. The natural interest rate was first defined by Wicksell (1898) as the interest rate on inflation-adjusted loans.

We also examine the effect of credit ratings on the error terms obtained in the estimation equation that includes all economic factors. Beyond the effect of all the estimated economic factors, such an examination can explain whether and to what extent credit ratings affect the interest rates that reflect the yields investors demand. We find that downward changes in credit ratings and changes that include transitions to and from investment grade ratings explain a portion of the errors obtained in the estimation equation. Neither credit ratings nor credit rating outlooks affect long-term interest rates beyond the effect of the economic factors. These findings support the certification effect and are indicative of the strong connection between financial regulation and international credit agencies' ratings. As a result, a downgrade in credit rating affects a country's cost of capital beyond the impact that economic factors have on these interest rates.

The findings of this study support the empirical findings reported in the literature that investigates the association between long-term interest rates and the factors studied in the current research. The current study, however, uniquely estimates a complete model that distinguishes between structural, cyclical, and risk factors.

In the following section, we review the empirical research literature that explains government bond yields, and show that a broad, comprehensive model offers an important contribution to the empirical literature in this field. In Section 3, we present the methodology used to examine long-term interest rates in two stages—the effect of the economic factors on interest rates, and the effect of credit ratings on the unexplained portion of the interest rates. In Section 4, we describe the data and the sample and present the main results of our estimations. In Section 5, we present the results of sensitivity tests applied to several aspects of the model, and elaborate on the main conclusions. Section 6 is a summary of the study.

2. Review of Literature

It is relatively simple to study the corporate cost of risk, measured by the spread between a corporation's bond yields and the yields of the government bonds in the country in which the corporation operates (with the same maturity), as models are known from the literature, such as the Altman model[4] and the Merton model.[5] Brodesky (2013) used the

[4] Altman, "Financial Ratio, Discriminant Analysis and the Prediction of the Corporate Bankruptcy," *Journal of Finance*, 23 (1968).

[5] Merton, "On the Pricing of Corporate Debt: The Risk Structure of the Interest Rates," *Journal of Finance*, 29 (1974).

Merton model to examine corporate bond spreads in Israel. Estimating a country's cost of debt is, however, much more challenging because no agreed structural model exists and many diverse variables have been proposed as determinants of this cost. The literature on estimating long-term interest rates reports that these rates are not only affected by a country's fiscal and demographic variables, but also by changes in global interest rates, and by country-specific economic risk factors including exchange rates, current account, the inflation environment, monetary policy, and risk appetite (e.g., Giordano et al., 2012).

Carvalho, et al. (2016) investigate the effect of demographic changes on real interest rates and list the following channels of influence: (a) increase in life expectancy increases the desire to save for retirement and consequently creates downward pressure on interest rates; (b) a decline in the rate of population growth has a mixed effect: it increases capital per worker, which decreases the real interest rate, yet it also increases the age-dependency ratio (the ratio of the retired population to the working-age population), which reduces the demand for savings and tends to increase the interest rate. According to their model, increasing life expectancy is the main determinant of the continuous extended decline in the global real interest rate, and since 1990 this factor accounts for between one third and one half of the total decline in these interest rates. In their second joint paper (2017), the authors show that such demographic changes effectively increase the supply of credit relative to demand and therefore necessarily reduce the natural interest rate. According to their estimation, rising life expectancy accounts for the majority of the decline in the natural interest rate, while the decline in birthrates accounts for an additional modest decline. Together, these two effects reduced the natural interest rate by 2 percentage points between 1990 and 2016. In a July 2017 speech, Prof. Stanley Fischer noted that the falling interest rates in many western countries is not merely a cyclical effect but also is the result of the decline in equilibrium global real interest rate.[6] These developments and low global natural interest rate estimations support the secular stagnation hypothesis, which posits that falling real interest rates are led by an increase in the marginal tendency toward saving, concurrently with a decline in investments, a decline in economic growth rate, and a slowdown in price increases (Holston, Laubach and Williams, 2017). This empirical paper presented estimations of the real natural interest rates, which declined following continued demographic changes in many advanced economies, such as aging

[6] Stanley Fischer, "The Low Level of Global Real Interest Rates." Conference to Celebrate Arminio Fraga's 60 Years in Rio de Janeiro, Brazil, July 31, 2017.

of the population and declines in investments and in the relative prices of investment products.

The empirical literature has extensively examined the effect of fiscal policy on government bond yields, focusing on two key variables that represent fiscal policy: total debt-to-GDP ratio, and government deficit (or cyclically adjusted government deficit). Findings indicate a statistically significant and positive association between fiscal policy and long-term interest rates, through four main channels:

(a) crowding out – a large deficit imposes pressure on sources of financing and increases the cost of indebtedness;
(b) asset portfolio balance – a significant increase in government debt requires an increase in long-term interest rates, if investors agree to increase their share in the held asset portfolio;
(c) Inflation expectations – concerns that the central bank will profit from the government's (non-indexed) debts may increase inflation expectations, which in turn will increase non-indexed bond yields;
(d) Insolvency risk – a large debt may create concerns of sovereign insolvency and consequently increase the risk premium implied in bond yields.

Although fiscal policy has been found to be a significant determinant of long-term interest rates, the definitions of this variable vary across studies and are inconsistent. For example, Ardagna et al. (2007) use panel data of government bond yields to explain the effect of government deficit, while Laubach (2009) estimates government deficit forecasts and finds this variable to be statistically significant.

Gruber and Kamin (2012) also examined yields in panel data and found that both government deficit and debt have a statistically significant effect on long-term interest rates, although the effect of deficit is stronger. However, when they examine these factors on forward yields, both indicators of fiscal policy failed to reach statistical significance. In contrast, Poghosyam (2012) examines the effect using economic time series with cointegration and found that the debt-to-GDP ratio affects nominal long-term interest rates. Ardagna et al. (2007) also find that debt has a positive effect on long-term interest rates, but its effect is quadratic rather than linear; the effect is statistically significant only when debt exceeds a certain level.

After the global financial crisis (GFC), increasing empirical evidence showed that fiscal policy's effect varied across countries, and in addition, over time. Empirical studies

began to estimate the reasons for the differences in effects on pricing over time. For example, Jaramillo and Weber (2012) added a volatility index (VIX) to represent global risk, and found that the effect of the debt-to-GDP ratio varies as a function of the risk in the global environment: the greater the risk, the greater debt's effect on long-term interest rates. Baldacci and Kumar (2010) showed that the effect of government deficit and debt depend on structural economic features and on effects stemming from global financial markets.

Two working papers published by the IMF in 2010 and 2012 used panel data from a large number of countries over a long sample period to investigate the association between long-term interest rates, and government deficit and public debt.[7] The main aim of these studies was to examine the effect of government deficit and public debt on these interest rates, especially in view of the consequences of the GFC, after which public debt increased while long-term interest rates declined. These studies identified many variables as having a statistically significant effect on interest rates, but the main variables were GDP per capita, debt/deficit-to-GDP ratio, tax-to-GDP ratio, trade balance, inflation, short-term interest rate, and long-term interest rates in neighboring countries (e.g., Cantor and Packer, 1996). Relatedly, the effect of neighboring countries, specifically co-moves in yield curve fluctuations, was examined in depth in Jotikasthira and Lundblad (2015). These authors argue that yield curve fluctuations across different currencies are highly correlated and stem from macroeconomic shocks transmitted through monetary policy and risk compensation: monetary policy responds to shocks and similarly affects economic variables, which are reflected in long-term interest rates; at the same time, investors' risk appetite and behavior is reflected in long-term interest rates, as well as in other financial asset pricing.

Brender and Ribon (2015) re-estimated (following their 2004 paper with Ber) the effect of government deficit on long-term interest rates in Israel and found that the effect had declined compared to the previous decade. Moreover, cyclically adjusted expected deficit did not have a statistically significant effect. These findings suggest that considerable changes had occurred in investors' bond pricing, and that the determinants of yields to maturity differed from the past.

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[7] Baldacci and Kumar, "Fiscal Deficits, Public Debt, and Sovereign Bond Yields." IMF 10/184 (2010). Poghosyan, "Long-Run and Short-Run Determinants of Sovereign Bond Yields in Advanced Economies." IMF 12/271 (2012).

Following the GFC of 2008, many empirical papers examined various effects of credit ratings on long-term interest rates in numerous countries, and especially the changes in these interest rates.[8] Moreover, in response to the crisis, a broad public and research debate also focused on potential conflicts of interest, and the timing of re-estimation following unexpected events. Despite this criticism, empirical findings show that credit ratings constitute a significant signal for asset pricing, and they serve as inputs in policy design for investors and for regulators worldwide (e.g., Driss et al., 2016). The empirical literature may be divided into two main streams:[9] One focuses on the effect of changes in sovereign and corporate credit ratings, and especially banks, on the cost of debt and capital.[10] The second stream examines the variables that affect corporate credit ratings, especially banks', in an effort to evaluate credit rating quality. Brooks et al. (2004), for example, examined the effect of credit rating change announcements on cost of capital and found a sizable effect when credit ratings were downgraded and little effect when credit ratings were upgraded. Kim and Wu (2008) examined the effect of credit ratings on international capital flows in 51 developing economies and found that new information on credit ratings is positively and significantly correlated with local financial developments. In general, the literature reports that credit ratings—specifically, changes in credit ratings—have an effect on long-term interest rates, which indicates investors' dependency on credit ratings despite the fact that all the relevant economic information is publicly available. Matolcsy and Lianto (1995) argued that credit rating agencies also incorporate companies' accounting information into their ratings, which may suggest that changes in bond ratings do not provide new information to the market. By estimating the effect of annual financial statement data on long-term interest rates, they eliminated credit rating effects and found that only announcements of downgrading conveyed new information to the market. Afik et al. (2014) examined changes in credit ratings on corporate bond yields in Israel and found that credit ratings had no significant effect, with the exception of the period of the GFC (2008–09). They argued that investors in small economies have access to all the relevant information before a change in credit rating is announced and therefore such changes have no effect on pricing.

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[8] Because this estimation involves many econometric challenges, empirical estimations in the literature generally uses case studies to examine the effect of changes in credit ratings.

[9] Tahmoorespour, Zarei, Ariff, Safari and Mansori, "Sovereign Debt and Sovereign Credit Rating: Literature Review." *Journal of Insurance and Financial Management*, 4 (2018), 1.

[10] See Box 1 in the Financial Stability Report in Israel, "The expected effect of a change in Israel's credit rating," December 2018.

Kamisky and Schmukler (2002) argued for an asymmetric effect between credit upgrading and downgrading because many institutional investors are permitted to hold only investment-grade bonds, and therefore regulatory rules directly affect them only when bonds are downgraded. In this context, it is interesting to examine whether credit rating outlooks, which constitute preliminary indications of rating changes, have a similar effect. Steiner and Heinke (2001) argued that negative rating outlooks and rating downgrades both affect prices, and Hull et al. (2004) concluded that negative rating outlooks have a significant effect on credit default swaps (see also Alsakka and Gwilym, 2012). Binci et al. (2020) examined this question using data that included the GFC and found that a rating change preceded by a negative rating outlook has a small effect because the outlook already captured part of the effect. In the current study we examine the association between changes in credit ratings and rating outlooks, and errors obtained from the estimation equation that is based on economic determinants, in order to understand whether credit ratings affect long-term interest rates beyond the total effects of economic determinants.

For more than a decade, monetary policy has been using unconventional tools, especially quantitative easing, in addition to short-term interest rates, which fell to zero or negative rates.[11] The empirical literature examined the effects of unconventional (or non-standard) monetary policy (UMP) and found that economic activity and especially bond prices, are significantly affected through three main channels: increased trade liquidity, signaling, and portfolio balance (Bhattarai and Neely, 2018). The empirical findings that focus on long-term interest rates report statistically significant effects, but the magnitudes found in these studies are significantly sensitive to factors that vary across countries and over time. Papadamou et al. (2020) reviewed the empirical work on the effects of UMP employed by central banks and concluded that the findings concur that bond purchases have a positive effect on bond prices.[12] In the current study, we examine an issue that, to the best of our knowledge, has not been sufficiently investigated in the literature. We do this by estimating all the factors that affect long-term interest rates, distinguishing between three main groups of factors: cyclical factors, structural factors

[11] e.g., Bernanke (2020) and Morris and Shin (2018).

[12] Beyond the direct effect of a central bank's transactions on the yields of the purchased bonds, purchases also affect many financial assets including government bond yields of other countries (Neely, 2015).

that affect the natural interest rate, and fiscal risk factors that represent the sovereign insolvency risk premium.

3. Methodology

3.1 Estimating the effect of the economic factors

The numerous and diverse empirical studies on long-term interest rates are typically divided into two main categories: structural (parametric) estimations, which include a clear definition of long-term interest rates based on the base or natural interest rate (discount factor) and risk factors; and statistical (nonparametric) estimations, which are primarily designed to forecast long-term interest rates on the basis of latent factors that do not represent financial or economic factors. Each method has advantages and shortcomings, and therefore it is impossible to categorically prefer one over the other. Moreover, when the goal is to forecast long-term interest rates for the forthcoming period, the relative precision of statistical models offers a clear advantage, yet provides a limited economic explanation of the effects on long-term interest rates. Therefore, in the current study, as in many other studies that attempt to combine precise estimations and economic explanations, we estimate a model based on economic and financial variables, and also include statistical variables (such as country and time effects) that potentially contribute to an explanation of long-term interest rates.

In this study, we use a model to estimate forward data obtained from 5- and 10-year government bond yields for 29 OECD countries including Israel. Explanatory factors include factors that have been included in several key studies that estimated long-term interest rates. The goal of our estimation is to obtain an estimate of the effects of the economic and financial factors in a large number of countries, distinguishing between structural, cyclical, and fiscal risk factors. The model will also allow us to distinguish between country-specific factors and global factors, and identify the extent to which long-term interest rates are affected by developments that are common to many countries. The use of forward yields (derived from 5- and 10-year yields) allows us to control short-term effects to some degree and to focus on the long-term changes that dictate a country's cost of debt.[13]

[13] The empirical literature adopts this calculation of forward yields as an estimate of the long-term cost of government debt.

We estimate the model using an equation that includes a fixed country-specific effect[14], in addition to the unique economic and financial factors in each country, which vary over time, and demographic and other factors that reflect long-term developments related to the structure of a country's economy and have been found in the literature to have an effect on the natural interest rate. We later replace the long-term developments related to the country's economy structure with a time effect that is shared by all the countries in the sample, in order to show that the long-term developments in interest rates are shared by all the countries in the sample and are not country specific.

Formally, to examine the factors that affect 5 to 10 forward yield ($forward\_5\_10$) across numerous countries and over time, we estimate an equation based on structural variables ("the structural factor equation") that includes cyclical factors, fiscal risk factors, and long-term structural factors:

$$(1) \quad forward\_5\_10_{i,t} = \beta_0 + \beta_1 \frac{Tax_{i,t}}{GDP_{i,t}} + \beta_2 \frac{Debt_{i,t}}{GDP_{i,t}} + \beta_3 short\ real\ IR_{i,t} + \beta_4 Inflation_{i,t} + \beta_5 CB_{purchases_{i,t}} + \beta_6\ \Delta\log\left[\frac{GDP_{i,t}}{POP_{i,t}}\right] + \beta_7(current\ account) + \beta_8 \Delta REER + \beta_9 dep_{ratio} + \beta_{10} \frac{GDP_{i,t}}{POP_{i,t}} + \delta_c country + \varepsilon_{i,t}$$

where forward yields are explained by three categories of factors:

1. fiscal risk factors: tax-to-GDP ratio, debt-to-GDP ratio;
2. cyclical factors: short-term real interest rate determined by monetary policy; previous-year inflation rate; the share of government bonds value purchased by central banks out of the country's outstanding government debt in the previous year; GDP per capita growth; current account surplus; and change in real-effective exchange rate;
3. structural factors that represent long-term changes in each of the countries in the sample. These variables include GDP per capita and demographic situation, represented by the dependency ratio of retired-age (over 65) and working-age (20-64) populations.

[14] A fixed country effect reflects the unique factors in play in each country, e.g., the structure of the financial system during the sample period, and assumes that these effects did not change over the sample period. For Israel, fixed country effects might be geopolitical risk on the one hand, and gas reserve discoveries and trading liquidity risks on the other hand. Although these factors may vary over time, accounting for time-country fixed effects is econometrically non-valid.

Dummy variables for each country were added to the equation to represent fixed country effects. We clustered standard deviations at the country level to account for country-specific variability.

3.2 Examining the effect of changes in credit ratings

We examine whether the information that is available to investors who consider trading in government bonds is based exclusively on fundamental economic and financial factors or is also based on credit ratings. An examination of credit ratings or changes in ratings on the residual terms obtained from the structural factor equation—i.e., the difference between the yields estimated using the equation and the actual yields to maturity—allows us to examine this research question. If we obtain evidence of a statistically significant effect, we can argue that investors price government bonds also on the basis of credit ratings, in addition to economic factors. It is important to understand that although credit ratings do not seem to convey new information, and merely present analyses of known information, it is nonetheless possible that credit rating agencies manage to incorporate information that is not captured in economic data or that they provide a more comprehensive and professional analysis of the financial risks involved, and this information affects investors.

The following information is used to examine the effect of credit ratings, in addition to the effect of the factors estimated in the structural factor equation:

$$(2) \qquad \hat{\varepsilon}_{i,t} = a_0 + a_1 Rate_{i,t} + a_2 \Delta_{POS} Rate_{i,t} + a_3 \Delta_{NEG} Rate_{i,t} + a_4 IG\ to\ non_{IG\,i,t} + a_5 non\_IG\ to\ IG_{i,t} + \vartheta_{i,t}$$

where $\hat{\varepsilon}_{i,t}$ is the residual term from the first stage of the estimation, $Rate_{i,t}$ is the mean credit rating[15], $\Delta_{POS} Rate_{i,t}$ is the size of the change if positive (and 0 otherwise), and $\Delta_{NEG} Rate_{i,t}$ is the size of the change if negative (and 0 otherwise). We also include the dummy variable ($IG\ to\ non\_IG$), which is 1 if the country's existing rating falls below investment grade, and a second dummy variable ($non\_IG\ to\ IG$) that is 1 if the credit rating increases from non-investment grade to investment grade.

[15] See Appendix 1 for an explanation of how we converted credit ratings to a continuous variable.

4. Data and Findings

In addition to a description of the data included in this study, we present the results of the estimation of the two equations described in Section 3. We describe the main findings from the structural factor equation and offer an analysis of these factors for the cases of Israel, Germany, and the US. We then describe the results of the credit rating estimation and examine whether and how credit ratings affect long-term interest rates.

4.1 The data and the sample

Our database includes all the variables listed in Table 1 for the period from 2001 to 2018. To eliminate noise from our empirical results as far as possible, we sampled a relatively uniform population that includes only current OECD members. After removing two outlier observations[16], our database comprised 436 observations representing an unbalanced panel of 29 countries including Israel.

Table 2 presents the basic descriptive statistics of the variables for the entire sample, and Table 3 presents the descriptive statistics for Israel and other selected countries. These statistics reflect the fundamental differences between countries, and especially between Israel and other countries. Israel's average debt-to-GDP ratio is higher than the sample mean, and its tax-to-GDP ratio is also relatively high. Japan has a very high debt-to-GDP ratio while its tax-to-GDP ratio is relatively low. In Israel (and in South Korea), the age-dependency ratio and GDP per capita are relatively low compared to the remaining countries in the sample, and Israel's real interest rate is higher. Israel's short-term interest rate is also relatively high although its inflation rate is not high and its mean forward yield is relatively high. The mean credit ratings of Israel and South Korea are also relatively low compared to the mean of our sample.

Of the 29 countries in our sample, the central banks of 16, including 10 countries subject to ECB Banking Supervision, conducted a government bond purchase program as a monetary policy measure designed to supplement interest rate adjustments. Purchases are measured as the gross purchase amount per year as a percentage of the country's total bond debt at the end of the previous year. This variable is 0 in countries and in years with

[16] Greece in 2013, during its severe debt crisis, when forward yields approached -20; and Ireland in 2015, when its GDP increased by 26.3 percent due to changes related to the contribution of multinational firms to its national accounting. See https://www.oecd.org/sdd/na/Irish-GDP-up-in-2015-OECD.pdf.

no purchases. Of the 436 observations in our database, 77 include government bond purchases and the mean (median) purchase is approximately 5 (4.5) percent.

4.2 Results

We divide the main findings into two parts. The first part focuses on the results of the equation used to estimate the effect of the structural factors, which are divided into three groups: cyclical factors, fiscal risk factors, and structural factors, represented in Equation (1). The second part focuses on the results of the equation used to estimate the effect of credit ratings and changes therein on the residual terms obtained from the first equation.

4.2.1 *The economic factors that explain long-term interest rates*

The estimation results are presented in Table 4. The effects of the explanatory variables are consistent with our expectations and with other studies in the literature. With respect to fiscal risk factors, debt-to-GDP ratio has a significant positive effect on long-term interest rates, while the tax revenues to GDP ratio has a strong negative effect. In terms of the variables that reflect monetary policy and the inflation environment, monetary policy and previous-year inflation rate, which are reflected in the central banks' real short-term interest rates, each have a significant effect; of the two, inflation has a stronger positive effect on long-term interest rates, but short-term changes have only a partial effect on long-term interest rates. Central bank government bond purchases also have a significant negative effect on long-term interest rates. According to our estimation, when central banks purchase one percent of the outstanding government debt, it reduces long-term interest rates by 10 basis points.[17]

Current account surplus, which is also a cyclical economic variable, has a significant positive effect on forward yields. This finding seems to contradict the basic view that a current account surplus reflects a country's greater relative economic strength or greater competitive advantage compared to its trade partners, and as a result will have lower interest rates. However, according to Maltriz (2012), the coefficient of the correlation between current account surplus and yields may also be positive, a result that reflects a country's inability to borrow money abroad, which increases interest rates relative to

[17] Bhattarai et al. (2021) found that an increase in one standard deviation in Federal Reserve purchases reduces 10-year treasury bond yields by 10 base points, but their finding (which focuses exclusively on the US and long-term treasury bond yields) cannot be compared with our finding, which includes a large number of countries and examines the effects on forward yields.

neighboring countries. In contrast, an appreciation of the real effective exchange rate was found to have a negative effect on yields. This finding is consistent with the view that the strength of a country's currency reflects the strength of its economy, and the probability that it will service its debt. When the change in the effective exchange rate (which also represents the economy' competitive advantage over its trading partners) is positive (that is, when the currency appreciates), the condition of its business sector deteriorates because each export unit generates less income. Therefore, a currency appreciation in response to an increase in a country's risk premium will lead to an increase in long-term interest rates. We stress that inflation, which is affected by changes in exchange rates, especially in small, open markets, is estimated within this model and therefore the secondary effect of exchange rates on long-term interest rates is obtained mainly through the risk premium channel.

GDP per capita growth, which is also a cyclical variable, has a significant negative effect on long-term interest rates: the quicker GDP increases relative to population growth, the more value the economy generates, which will increase its supply of credit relative to demand, and will therefore reduce long-term interest rates.

The age-dependency ratio and per capita GDP are structural factors that reflect the natural interest rate. The higher an economy's per capita GDP and the higher its age-dependency ratio (increased life expectancy and low natural population growth), the lower long-term interest rates will be, reflecting a lower natural interest rate. By multiplying the coefficients and values in each country, we obtain the natural interest rate in each country, and the global natural interest rate is calculated as the mean of the interest rate, weighted by GDP per capita (Figure 1). Figure 1 shows that the global natural interest rate[18] is currently 3.9 percent, have dropped by 2.3 percentage points since 2001. The downward tendency evident in Figure 1A is observed in all countries.

We focus the discussion of the findings on the three groups of explanatory variables: cyclical factors, fiscal risk factors, and structural factors. This distinction allows us to examine the developments in long-term interest rates over time in each of the countries in our sample. We will concentrate on Israel, Germany, and the US. Figure 1B presents

[18] We assume that the country-specific dummy variables reflect unobserved structural factors and are therefore included in the calculation of the natural interest rate of that country. However, it is possible that several of the unobserved factors actually reflect fiscal risk factors that are based on investors' assessments of the strength of a country's legal and financial institutions. In such a case, inclusion of the dummy variables in the calculation of the natural interest rate is not justified, and in 2018 this interest rate would be lower by 50 base points.

the forward yields and long-term interest rates estimated for each country, in annual terms. Figure 1B shows that the estimation equation has good explanatory power for long-term interest rates in these three countries.

4.2.2 *Main findings for Israel*

Figure 2 presents the changes in the contribution of each category of factors to long-term interest rates in Israel, relative to 2001, based on the estimates obtained from the structural factor equation. The decline in long-term interest rates in Israel, which occurred over the majority of the sample period, is primarily explained by cyclical and structural factors, with only a limited contribution of fiscal risk factors. The total contribution of fiscal risk factors, which include debt-to-GDP ratio and tax-to-GDP ratio, shows no significant change over time, because these factors created contrasting effects that set each other off: Debt-to-GDP ratio declined over the sample period but tax-to-GDP declined in 2008, 2009, and 2018 due to direct tax cuts.[19]

In Israel, the most influential cyclical factor is monetary policy and inflationary environment, which jointly reduced long-term interest rates to a significant extent. Monetary policy reduced long-term interest rates primarily in the years following the GFC, and negative inflation rates played a dominant role in 2015 and 2016. In 2018, inflation rose slightly, slightly increasing interest rates, but this effect was offset by monetary policy. Bond purchases by the central bank had a significant effect in 2008 and contributed to the reduction of approximately 35 base points in the long-term interest rates that year. The increase in the current account caused some rise in long-term interest rates, which partially offset the effects of monetary policy and inflationary environment. In contrast to the current account, changes in real exchange rates had a significant impact but their contribution to long-term interest rates was negligible despite the continued appreciation of the shekel over the sample period.

The two structural factors estimated in the structural factor equation reduced long-term interest rates in Israel. They operated over the entire sample period and their negative impact on interest rates was 2.1 percentage points.

[19] See Bank of Israel Annual Reports for the years 2008, 2009, and 2018.

4.2.3 *Main findings for the US*

In the US, long-term interest rates were greatly influenced by the rise in fiscal risk factors, whose contribution between 2009 and 2018 totaled 1.1 percentage points (Figure 3). Increased risk stemmed mainly from the significant rise in debt-to-GDP ratio that commenced in 2008. Cyclical factors only slightly offset the positive effect of fiscal factors on long-term interest rates. Among the cyclical factors, inflation is the primary factor that pulled long-term interest rates downward. Bond purchases by the central bank also had an offsetting effect and at their peak (2012), bond purchases contributed to a decrease of approximately 0.8 percentage points in long-term interest rates that year. The two structural factors estimated in the structural factor equation reduced long-term interest rates. These factors operated over the entire sample period and their negative impact on interest rates reached 2.7 percentage points, which was greater than their impact in Israel.

4.2.4 *Main findings for Germany*

In Germany, fiscal risk factors had a limited impact on the changes in long-term interest rates (relative to 2001), and reached no more than one half of a percentage point in the years following the 2008 crisis (Figure 4). The debt-to-GDP ratio increased, but was offset by the increase in tax revenues to GDP. Cyclical factors, however, held long-term interest rates low in the post-GFC period, and their negative effect in 2018 was close to one percentage point. Their contribution in 2018 was more moderate than the contribution of cyclical factors in Israel, which reached 2 percentage points. Inflation and accommodative monetary policy in Germany (which included bond purchases by the ECB) contributed significantly to a reduction in long-term interest rates, but a considerable part of monetary policy's effect was offset by the positive current account. The structural factors estimated in the structural factor equation had a strong impact on long-term interest rates in Germany and reduced interest rates by approximately 3.5 percentage points over the sample period. These factors had a much greater impact on long-term interest rates in Germany than in Israel or the US.

4.2.5 *Findings from the estimation of credit ratings*

After an estimation of the factors that affect long-term interest rates showed very strong explanatory power, our next question is whether investors, assuming they are well aware of the underlying economic factors, nonetheless continue to attribute importance to sovereign credit ratings and take this information into account in their investment strategies. As a signal to investors and portfolio managers, sovereign credit ratings, which represent a government's ability and willingness to meet its obligations to its lenders, may affect the cost of capital. If investors heed credit ratings, we would expect sovereign credit ratings or changes therein to affect the residual terms in the structural factor equation. A significant effect of credit ratings would indicate that these ratings contain additional information for investors, which is used to adjust long-term interest rates in addition to the adjustments based on the information implied in economic factors.

The dependent variable in Eq. 2 is the residual term from the estimation of the structural factor equation.[20,21] As seen in column 1 of Table 5, a credit downgrade has a significant impact on residual terms, while a credit upgrade has no effect. Of the dummy variables that reflect rating changes to and from investment grade, the effect is significant and in the expected direction (column 2). This result is also obtained when including the credit rating itself, whose effect is not statistically significant (column 3).

It is worth noting that while the credit rating itself is not statistically significant and contained no surplus information beyond the information contained in economic factors, a downgrade has a statistically significant effect, and this effect is especially significant and strong in cases in which credit ratings changed to and from investment grade. In those cases, the total impact on long-term interest rates was approximately 1 percentage point.[22]

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[20] To confirm that the residual terms are not diverging, we performed two panel data unit root tests. Although there are many tests, many of them require a balanced panel. Because our data do not represent a balanced panel, we performed only the Im-Pesaran-Shin test (2003) and the Choi test (2003). In these tests, the null hypothesis is rejected but the meaning is that the variable has no unit root in at least one panel unit.

[21] Other studies also analyze the deviation of realized value of a variable from its predicted value, based on fundamental factors. Gilchrist and Zakrajšek (2012), for example, define excess bond premium (EBP) as the difference between the average spread in the corporate bond market and the predicted spread based on based on fundamental factors, and link this difference to economic variables.

[22] A change in rating is defined as a change of five units and therefore, according to Eq. 2, a downward rating increases interest rates by 5 times 0.06 (approx. 30 basis points). To this we add the coefficient of the dummy variables of a downgrade from investment grade, approx. 70 basis points, and we obtain 1 percentage point in total.

This outcome is consistent with the certification effect known from recent literature (e.g., Drago and Gallo, 2017). The literature reported that this effect is caused by the following:

- Regulatory enforcement of debt management requirements by international financial entities in each rating class affects the demand for debt. Consequently, a downgrade in credit rating may trigger adjustments to portfolio risks and reduce the demand for domestic government bonds;
- Beyond regulatory requirements, a downgrade in a sovereign credit rating may affect the volume of credit financial lenders can offer as a result of the capital requirements to which they are subject. As a result, the total supply of debt in that economy declines;
- Declining yields of government bonds following a downgrade in the sovereign credit rating may also adversely affect corporations that hold such bonds;
- When a credit rating falls below investment grade, institutional investors may be required to sell their holdings in these bonds, and when bonds are upgraded to investment grade institutional investors may purchase them;
- According to the regulatory regime in the countries in our sample, investment-grade bonds must be included in price indices and as a result are held by ETFs and tracker funds.

5. Specifications and Sensitivity Tests

5.1 Estimating the natural global interest rate

In the estimation equation we replaced the two structural variables that represent long-term effects with time effects that are shared by all the countries in our sample. Time effect is expected to be a better estimate of the global natural interest rate in the case that the correlation of the development in structural factors across countries is greater and the effect of these factors is greater. The following estimation will be termed "the time effect equation":

$$(3)\quad forward\_5\_10_{i,t} = \beta_0 + \beta_1 \frac{Tax_{i,t}}{GDP_{i,t}} + \beta_2 \frac{Debt_{i,t}}{GDP_{i,t}} + \beta_3 short\ real\ IR_{i,t} + \beta_4 Inflation_{i,t} + \beta_5 CB\_purchases_{i,t} + \beta_6\ \Delta\log\left[\frac{GDP_{i,t}}{POP_{i,t}}\right] + \beta_7(current\ account) + \beta_8 \Delta REER\ + \gamma_k year + \delta_c country + \varepsilon_{i,t}$$

The results of the estimation are presented in Table 6. We compare the derived contribution of each factor to the development of Israel's long-term interest rates to the contributions derived based on the results of the estimation of the structural factors equation (Table 4). The effect of the fiscal risk factors and the cyclical factors on long-term interest rates in Israel is similar in both equations, but the effect is slightly stronger in the time effect equation (Figure 5). The time effect, which reflects the interest rate shared by all the countries in the sample, shows a significant, long-term decline that increased in recent years: Between 2011 and 2018, this interest rate dropped by approximately 2 percentage points, and by a total of 2.8 percentage points from the beginning of the sample period.[23] A similar picture emerges with respect to the two structural factors that we include in the structural factor equation, which reduced forward yields and contributed to a mean decline of 2.3 percentage points in the countries in the sample.[24]

Based on the time effect, the country-specific effect, and constant term obtained from the time effect equation, we calculate the global natural interest rate using the GDP-weighted mean natural interest rate of each country (Figure 6). After a decline of 2 percentage points since 2001, the estimated natural interest rate at the final point in time in our sample (2018) is 2.8 percent, which is 1.1 percentage points lower than the interest rate obtained from the estimation based on the structural factors equation. To gain additional support for the argument that the time effect reflects the global natural interest, we estimated a specification that includes the structural variables (age-dependency ratio and GDP per capita) and the time effect, and the results indicate that the time factor in this estimation is neither statistically significant nor does it show a monotonic change. This finding reinforces our argument that, as a result of the changes in the long-term variables, which are expressed in the structural variables, the time effect loses its explanatory power when the specification also contains structural variables.

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[23] It is important to note that this interest rate, which reflects the global interest rate, also includes the changes in the risk premium that stem from changes in the risk appetite (the price of one risk unit) of investors in financial assets. It is possible that in recent years, risk appetite rose (and the price of risk declined respectively), especially since riskless interest rates dropped below zero. Therefore this estimation of the global interest rate may indicate a steeper decline.

[24] It has been recently argued that the growing income inequality, which creates a significant increase in the demand for savings, may create downward pressure on the natural interest rate (e.g., Mian et al., 2021; Rachel and Smith, 2017). We examine the possibility of including the Gini index of income inequality, but this index is missing for a large portion of the countries and the years, and its inclusion would eliminate approximately one half of the observations in the sample.

5.2 Sensitivity tests for the fiscal risk factors

Following conventional practice, we examine several other variables that represent fiscal risk factors: In addition to debt-to-GDP ratio, we also examine government deficit and structural deficit as additional or alternative variables for tax revenues to debt ratio. We found that inclusion of cyclically adjusted deficit eliminates the effect of tax revenues to debt ratio and that cyclically adjusted deficit has a statistically significant negative effect. We should also stress that when cyclically adjusted deficit is included, the effect of debt-to-GDP ratio remains statistically significant, and the estimated magnitudes are similar to those found in other studies (Laubach, 2009; Poghosyan, 2012).[25] Since debt-to-GDP ratio is the result of cumulative debt and GDP growth, when deficit is included alongside debt-to-GDP ratio this variable effectively represents *non*-structural deficit because structural deficit is translated into a constant increase in debt-to-GDP ratio. In any case, the results for the natural interest rate and the effects of changes in credit ratings remain the same. Because we have more observations for tax revenues to GDP ratio, replacing this variable with structural deficit does not change the results although it does reduce the number of observations. We therefore preferred to use tax revenues to GDP ratio as the explanatory variable in the structural factor equation.

We examine the non-linear effect of debt-to-GDP ratio on long-term interest rates and found that only its linear effect is statistically significant and the coefficient of the quadratic form of debt-to-GDP ratio is not statistically significant. We also examine whether the direction of the effect of current account deficit is a function of exchange rate changes by including an interaction term of these two variables. The interaction term is not statistically significant and the coefficients of the two terms separately remained unchanged.

5.3 Sensitivity tests for credit rating effects on residual terms

We add a time effect and a country-specific effect to Eq.2, which explains the residual terms from Eq. 1 using changes in credit ratings, and find that credit ratings have no significant effect. This finding leads to the conclusion that the certification effect, which we also found in this study, did not change over time and did not significantly vary across

[25] This is true mainly for debt to GDP ratio. The size of the coefficient of the deficit is closer to the lower values found in previous research.

the countries in our sample. It is important to stress that the countries in our sample have adopted global regulatory frameworks based on Basel and Solvency.

We examine Eq. 2 using the residual terms from the time effect equation as the dependent variable. The results are largely the same as in Table 5 (in which the dependent variable is the residual term from the structural factor equation) with one exception: credit rating has a statistically significant effect on the residual terms, but this effect is extremely small and significant at the relatively low significance level of 0.1.

We also examine the possibility that credit rating outlooks affect long-term interest rates, either in addition to or in lieu of credit ratings. In the equation that estimates the association between credit ratings and residual terms, we therefore include two dummy variables: The first obtains 1 when a ratings outlook issued by at least one credit rating agency reflects an improvement (e.g., from "stable" to "positive"), and 0 otherwise. The second dummy variable obtains 1 when a ratings outlook reflects a downgrade and 0 otherwise. Various specifications (columns 1-3, Table 7) show that changes in ratings outlooks generally have no statistically significant effect, while the effects of changes in credit ratings and changes to and from investment grade remained without change. In columns 4–7 in Table 7, we examined whether changes in credit ratings are a function of positive or negative previous-year ratings outlooks. Including previous-year outlooks (columns 4–5) does not change the effects of the remaining variables, although including an interaction term of credit downgrade (upgrade) and negative (positive) previous-year outlook (columns 7–8) indicates that a change in rating has no statistically significant effect in itself, yet the effect of a change to and from investment grade remained statistically significant. This finding reinforces the support for the certification effect, as it indicates that if complete or partial information about a change in rating is conveyed by a similar outlook, the change in rating has no effect when it is announced. However, changes to and from investment grade lead to changes related to regulatory requirements and therefore have a statistically significant impact on the residual term.[26]

In another examination we test the persistence of residual terms and whether the effect of the explanatory factors is eliminated when a lagged term of the dependent variable is included as an explanatory variable. Findings show that only one quarter of the lagged dependent variable has an effect, while the remaining variables that were found to be

[26] The results are very similar when we used the residual terms from the time effect equation.

statistically significant remained with the same signs, albeit at slightly lower statistical significance.

6. Summary and Conclusion

In this study we estimated all the factors that affect the estimated cost of government debt, calculated from the forward yields that are based on government bond yields in OECD countries between 2001 and 2018, distinguishing between three groups of factors: structural factors, which affect the natural interest rate; cyclical factors; and fiscal risk factors. In this manner it is possible to understand the economic determinants of the various development trajectories of long-term interest rates in each of the OECD countries. The findings of this study support the associations reported in the research literature in various fields that estimates the links between long-term interest rates and the various factors examined in this study. This study is unique in its examination of a complete model that includes all the relevant variables, distinguishing between structural, cyclical, and fiscal risk factors.

The clear conclusion from this study is that the effect of structural factors on long-term interest rates significantly declined in many countries, which led to a decline of 2.3 percentage points in the global natural interest rate. Nonetheless, the structural factors that reflect the natural interest rate account for the main differences in long-term interests rates across the countries in our sample: interest rates are higher in countries with a relatively low age-dependency ratio and low GDP per capita. Changes in cyclical factors are relatively correlated among countries and make a limited contribution to country-specific developments, yet make a significant contribution to the decline in long-term interest rates in the sample period. Government bond purchases by central banks significantly reduce the cost of debt (bond purchases of 1 percent of the government debt reduce the cost of debt by 10 base points). The two main cyclical factors are inflation and short-term real interest rates. In contrast, developments of fiscal risks show very high variance across countries and constitute the main explanation for the cross-border differences over the sample period.

Based on the equation that uses economic factors to estimate long-term interest rates, we examined whether credit ratings, and specifically changes therein, affect long-term interest rates beyond the explanatory economic factors. Our findings show that a credit downgrade, and especially a change in rating from or to investment grade, has a

statistically significant effect on long-term interest rates. When the change in rating includes a change from or to investment grade, the effect of the change reaches one percentage point for each direction, however other rating changes affect interest rates only when the change represents a downgrade and in that case the effect is merely 30 basis points. Credit ratings in themselves and changes in ratings outlooks were not found to affect long-term interest rates, even in the case of negative outlooks. Our findings confirm the argued certification effect, which occurs when financial regulatory requirements rely on ratings published by credit rating agencies. For example, a change in rating, and especially a change to or from investment grade, requires supervised financial entities to adjust their holdings according to the risk reflected in credit ratings, and also requires adjustments to the weights of sovereign bonds in international bond indices.

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Tables and Figures

Table 1 – Variables and sources

This table presents the names of the variables and the sources of the data used in this study.

Variable	Term	Source of data	Notes
10-year government bond yield to maturity	y_10y	Bloomberg and OECD	Local currency, non-indexed
5-year government bond yield to maturity	y_5y	Bloomberg	Local currency, non-indexed
5-10-year forward rate	$forward\_5\_10$	Calculated	$100 * \left(\frac{(1 + y\_10y/100)^2}{1 + y\_5y/100} - 1\right)$
Central bank interest rate	$monetary\_IR$	IMF, Bloomberg, and OECD	For Euro Bloc countries - ECB interest from the year in which the country became a member of the Euro Bloc
Inflation	$Inflation$	World Bank	
Real short-term interest	$short\ real\ IR$	Calculated	$monetary\_IR - Inf$
Bond purchases by CBs	$CB\_purchases$	Central bank websites	Percentage of government bonds purchased by the central bank per year divided by total government debt in the previous year
Debt-to-GDP ratio	$\frac{Debt}{GDP}$	IMF	
Tax revenue-to-GDP ratio	$\frac{Tax}{GDP}$	ICTD / UNU-WIDER Government Revenue Dataset 2020	Total tax revenue, excluding social contributions. Data for 2018 are missing for several countries. 2017 data was used for this year as well
Real GDP growth rate	$\Delta \log(GDP)$	World Bank	Multiplied by 100
Population growth rate	$\Delta \log(POP)$	World Bank	Multiplied by 100
GDP per capita growth rate	$\Delta \log\left(\frac{GDP}{POP}\right)$	Calculated	$\Delta \log(GDP) - \Delta \log(POP)$
Log GDP	$\log\left(\frac{GDP}{POP}\right)$	World Bank	
Change in real exchange rate	$\Delta \log(REER)$	Bruegel Institute	Calculated for 172 countries, multiplied by 100. A positive value reflects currency appreciation
Current account surplus/deficit	current account	OECD	Positive value represents surplus

Age-dependency ratio	*dependence ratio*	OECD	Ratio between population aged 65 and over to working-age population (20-64)
Country in the Euro Bloc	*euro*	ECB	Dummy variable obtains 1 for each year in which the country is a member of the Euro Bloc
Credit rating	*Rate*	https://tradingeconomics.com / and other internet sources	Mean numerical sovereign rating (conversion table appears in Appendix 1)
Ratings outlook	*Outlook*	https://tradingeconomics.com / and other internet sources	Indicator of positive, negative, or neutral forecast issued by credit rating agencies. The variable obtains 0 when the outlook is stable in all three rating agencies, 1 if the outlook is positive in at least one credit rating, and (-1) if the outlook is negative in at least one credit rating. No cases exist in which one agency issues a positive outlook and another agency issues a negative outlook.

Table 2 – Descriptive statistics by country and all years

This table presents the descriptive statistics of the variables used in this study. The section on the left presents descriptive statistics for all observations, while the section on the right presents descriptive statistics of the mean values for each country.

	all observations			country means		
variable	N	Mean	Sd	N	Mean	sd
y_10y	436	3.80	2.52	29	3.89	2.11
y_5y	436	3.14	2.83	29	3.16	2.30
forward_5_10	436	4.47	2.64	29	4.65	2.51
monetary_IR	436	2.06	2.39	29	2.09	1.78
inflation	436	2.03	1.91	29	2.10	1.53
short real IR	436	2.06	2.39	29	-0.01	0.78
CB_purchases	436	0.87	2.39	29	0.86	1.03
Debt / GDP	436	59.60	38.51	29	58.58	36.27
Tax / GDP	436	0.25	0.06	29	0.25	0.07
Δ log(GDP)	436	1.99	2.52	29	1.98	1.28
Δ log(POP)	436	0.62	0.62	29	0.62	0.57
Δ log(GDP / POP)	436	1.36	2.45	29	1.36	1.12
log(GDP / population)	436	10.46	0.31	29	10.44	0.29
Δlog(REER)	436	0.14	4.82	29	0.07	1.20
current account	436	-0.01	4.75	29	0.12	4.27
dependence ratio	436	0.26	0.07	29	0.26	0.06
Euro	436	0.41	0.49	29	0.41	0.49
Rate	436	85.65	17.54	29	83.98	17.15

Table 3 – Descriptive statistics of selected countries, all years

This table presents descriptive statistics of the variables used in this study for selected countries.

country		y_10y	y_5y	Forward _5_10	Monetary _IR	inflation	short real IR	CB_ purchases	Debt / GDP	Tax / GDP	Δ log (GDP)	Δ log (POP)	Δ log (GDP / POP)	Log (GDP / population)	Δlog (REER)	current account	Dependence ratio	Euro	Rate
Israel	Mean	5.00	4.13	5.87	2.74	1.60	1.14	0.19	72.41	0.27	3.27	1.88	1.39	10.30	-0.16	2.22	0.19	0.00	75.93
	SD	2.30	2.72	2.27	2.50	1.78	2.30	0.79	10.67	0.01	1.78	0.33	1.73	0.17	5.04	1.76	0.01	0.00	3.53
Germany	Mean	2.62	2.01	3.23	1.47	1.46	0.01	1.32	43.14	0.22	1.36	0.06	1.29	10.58	0.25	5.64	0.33	1.00	100.00
	SD	1.64	1.74	1.58	1.35	0.64	1.15	2.76	4.95	0.01	2.22	0.19	2.21	0.21	2.80	2.46	0.03	0.00	0.00
USA	Mean	3.36	2.63	4.10	1.37	2.12	-0.75	1.17	66.11	0.19	1.91	0.81	1.10	10.79	0.01	-3.49	0.23	0.00	99.26
	SD	1.08	1.27	1.02	1.64	1.10	1.44	2.34	20.19	0.01	1.49	0.10	1.52	0.15	4.66	1.33	0.02	0.00	0.85
Japan	Mean	0.97	0.44	1.51	0.15	0.13	0.02	3.39	160.29	0.17	0.83	-0.02	0.85	10.46	-2.59	2.93	0.39	0.00	86.76
	SD	0.57	0.42	0.76	0.10	0.95	0.95	3.65	33.12	0.01	1.93	0.11	1.94	0.14	8.43	1.17	0.07	0.00	5.73
South Korea	Mean	4.29	3.96	4.61	2.92	2.54	0.38	0.00	29.17	0.18	3.78	0.42	3.36	10.27	0.55	3.02	0.16	0.00	78.70
	SD	1.50	1.45	1.56	1.13	1.14	1.07	0.00	6.83	0.01	1.63	0.08	1.60	0.22	7.59	2.29	0.03	0.00	6.99

Table 4 – Results of estimating the structural factor equation to explain forward rates

This table presents the results of the regression that estimates the effect of the explanatory variables that appear in Table 1 on the 5-10-year forward rates of government bonds in each country. Standard deviations are aggregated by country.

	Dependent variable: 5-to-10-year forward interest rate
Tax / GDP	0.0387***
	(0.006)
Debt / GDP	-16.0239***
	(4.403)
Short real IR	0.3574***
	(0.076)
Inflation	0.5577***
	(0.081)
Bond purchases by CBs	-0.1063***
	(0.035)
Δ log(GDP / POP)	-0.1641***
	(0.023)
Current account	0.0838***
	(0.022)
Δlog(REER)	-0.0227**
	(0.008)
Dependence ratio	-15.3551***
	(3.309)
log(GDP / population)	-3.2865***
	(0.616)
Euro	0.1527
	(0.244)
Constant	43.1549***
	(6.722)
Country FE	Yes
Observations	436
Adjusted R-squared	0.91

* Statistically significant at 0.1 level; ** statistically significant at 0.05 level; *** statistically significant at 0.01 level.

Table 5 – Estimating the effect of credit ratings on the residuals

This table presents the results of the estimation of the factors that explain the residual terms obtained from the equation in Table 4. The explanatory factors include a positive change in credit rating, a negative change in credit rating, credit rating, an indicator of a change from non-investment-grade to investment grade, and an indicator of the opposite change. Standard deviations are aggregated by country.

	Explained variable: Residual terms from the equation in Table 4		
	(1)	(2)	(3)
Δ POS_Rate	0.0117 (0.04)	0.0375 (0.041)	0.0285 (0.042)
Δ NEG_Rate	-0.0609** (0.027)	-0.0619*** (0.019)	-0.0574*** (0.019)
Rate			-0.0059 (0.009)
IG to non-IG		0.6986*** (0.213)	0.6712*** (0.229)
non-IG to IG		-0.9349** (0.383)	-0.9718** (0.377)
Constant	-0.0056** (0.003)	-0.0057*** (0.002)	0.578 (0.883)
Observations	436	436	436
Adjusted R-squared	-0.00212	0.0209	0.02228

* Statistically significant at 0.1 level; ** statistically significant at 0.5 level; *** statistically significant at 0.01 level.

Table 6 – Results of the estimation of the time effect equation to explain forward yields

This table presents the results of the regression that estimates the effect of the explanatory factors that appear in Table 1 on 5-10-year forward yields in each country. Standard deviations are aggregated by country.

	Dependent variable: 5-to-10 year forward interest rate
Tax / GDP	0.0339***
	(0.005)
Debt / GDP	-7.8959
	(5.669)
Short real IR	0.3869***
	(0.114)
Inflation	0.4399***
	(0.111)
Bonds purchases by CBs	-0.0793**
	(0.033)
Δ log(GDP / POP)	-0.1872***
	(0.035)
Current account	0.0750**
	(0.028)
Δlog(REER)	-0.0337***
	(0.008)
Euro	-0.6361*
	(0.315)
Year 2002	0.0439
	(0.146)
Year 2003	-0.0355
	(0.39)
Year 2004	-0.0805
	(0.301)
Year 2005	-1.0730***
	(0.241)
Year 2006	-1.1151***
	(0.287)
Year 2007	-0.8832***
	(0.265)
Year 2008	-0.7485*
	(0.413)
Year 2009	-1.1538***
	(0.338)
Year 2010	-0.4429
	(0.36)
Year 2011	-0.7064*
	(0.394)

Year 2012	-1.6843***
	(0.388)
Year 2013	-1.7512***
	(0.393)
Year 2014	-2.0562***
	(0.346)
Year 2015	-2.8119***
	(0.368)
Year 2016	-3.0706***
	(0.415)
Year 2017	-2.4347***
	(0.437)
Year 2018	-2.7810***
	(0.401)
Constant	4.5603***
	(1.075)
Country FE	Yes
Observations	436
Adjusted R-squared	0.92

* Statistically significant at 0.1 level; ** statistically significant at 0.5 level; *** statistically significant at 0.01 level.

Table 7 – Persistence of credit rating effects on the unexplained portion of forward rates

This table presents the results of the estimation of the factors that explain the residual terms obtain from the equation in Table 4. Beyond the explanatory factors appearing in Table 5, we add (in various specifications) a positive and negative change in outlook, lagged outlook, and an interaction term between positive (negative) outlook in the previous period and a positive (negative change) in the credit rating. Standard deviations are aggregated by country.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ POS_Rate	0.0154	0.0411	0.0301	0.0492	0.0388	0.1119	0.0968
	(0.043)	(0.043)	(0.045)	(0.042)	(0.043)	(0.09)	(0.096)
Δ NEG_Rate	-0.0612**	-0.0621***	-0.0568***	-0.0633***	-0.0595***	-0.0673	-0.0651
	(0.027)	(0.019)	(0.018)	(0.02)	(0.02)	(0.062)	(0.063)
Rate			-0.0067		-0.0067		-0.0058
			(0.009)		(0.009)		(0.01)
IG to non-IG		0.7008***	0.6685***	0.7043***	0.6797***	0.7194***	0.6985***
		(0.212)	(0.23)	(0.215)	(0.227)	(0.236)	(0.249)
non-IG to IG		-0.9366**	-0.9815**	-0.9300**	-0.9824**	-0.8464**	-0.8984***
		(0.381)	(0.373)	(0.381)	(0.372)	(0.331)	(0.322)
+Δ outlook	0.0455	0.0419	0.0223				
	(0.107)	(0.107)	(0.107)				
-Δ outlook	0.0999	0.1031	0.1224*				
	(0.063)	(0.065)	(0.071)				
Lag(positive outlook)				-0.1326	-0.1394	-0.0157	-0.0336
				(0.111)	(0.109)	(0.14)	(0.155)
Lag(negative outlook)				-0.0527	-0.0854	-0.0346	-0.0641
				(0.098)	(0.109)	(0.105)	(0.119)
+Δ POS_Rate × lag(positive outlook)						-0.1061	-0.0956
						(0.102)	(0.107)
-Δ NEG_Rate × lag(negative outlook)						0.0039	0.0051
						(0.053)	(0.053)
Constant	-0.0057**	-0.0058***	0.6613	0.0029	0.672	-0.0005	0.5797
	(0.002)	(0.002)	(0.903)	(0.016)	(0.94)	(0.019)	(0.964)
Observations	436	436	436	436	436	436	436
Adjusted R-squared	-0.004	0.01925	0.02159	0.0185	0.02077	0.01978	0.02082

* Statistically significant at 0.1 level; ** statistically significant at 0.5 level; *** statistically significant at 0.01 level.

Figure 1: Estimations of the natural interest rate

This figure presents the estimated natural interest of Israel. The estimation is based on the product of the coefficients of GDP per capita and age-dependency ratio in Israel in each year, and country-specific dummy variables and the intercept obtained from the equation in Table 4. The gray area marks a 95% confidence interval.

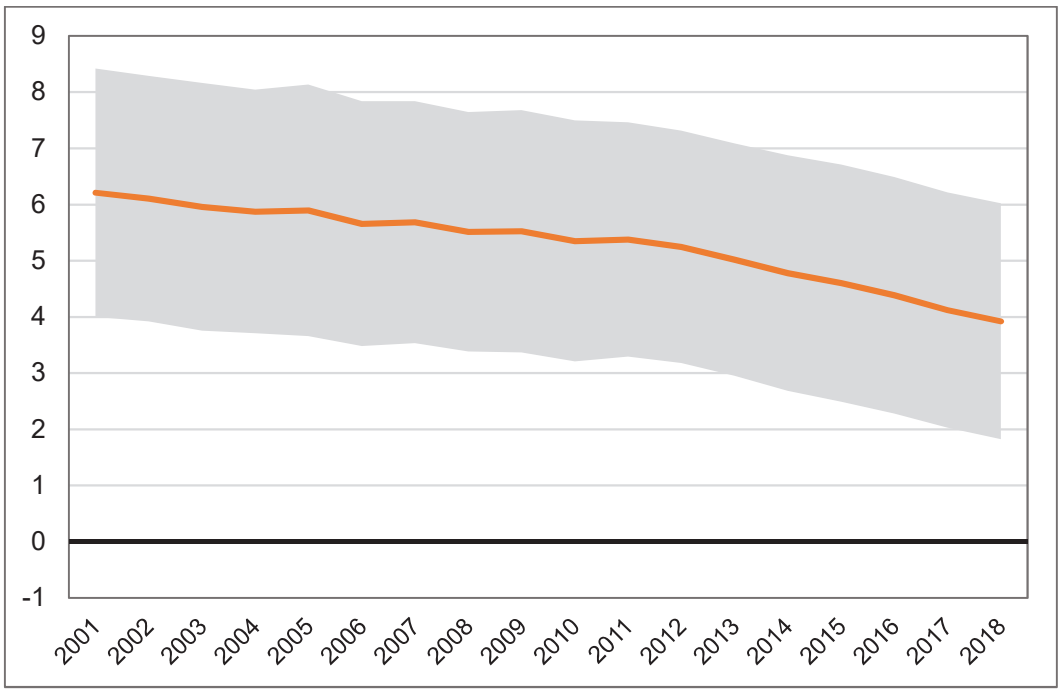


Figure 1A: Estimated natural interest rate - International comparison

This figure presents the estimated natural interest of each country in the sample, with a focus on Israel, the US and Germany. The estimation is based on the product of the coefficients of GDP per capita and age-dependency ratio in each country, each year, plus country-specific dummy variables and the intercept obtained from the equation in Table 4. The average line is obtaining by averaging the natural interest rate in each country and each year using GDP weights.

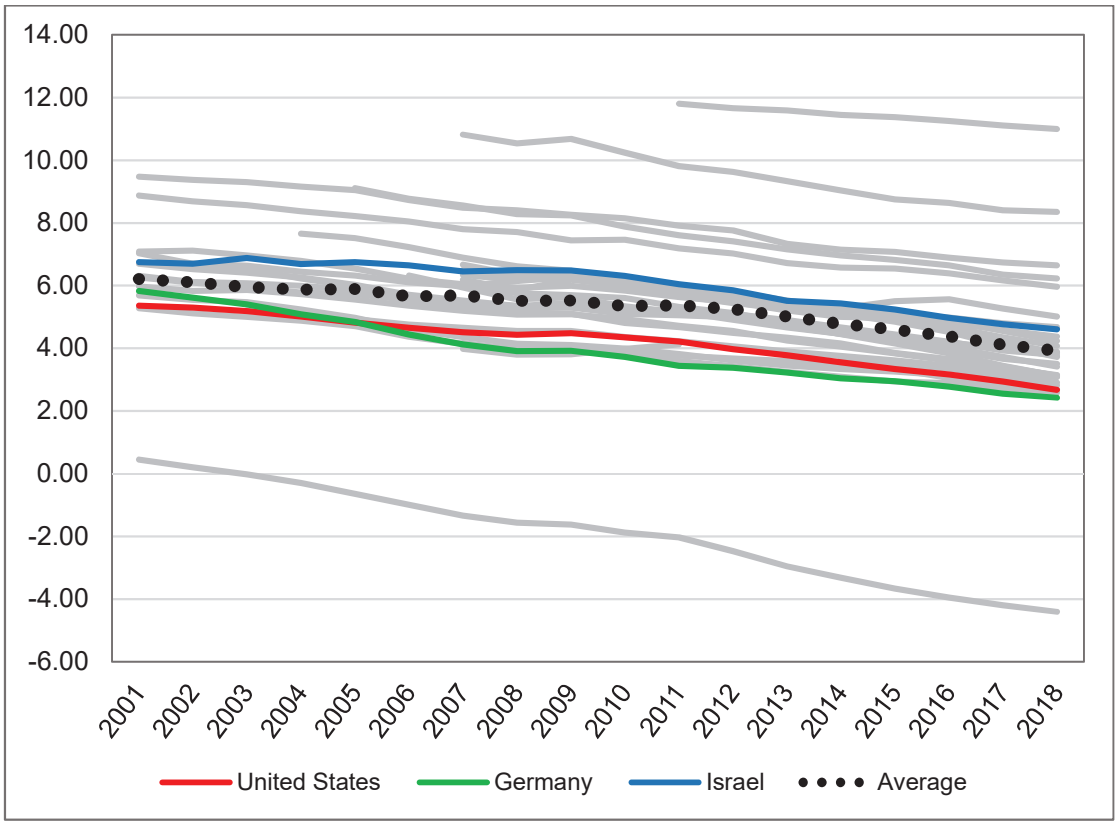


Figure 1B: Effective and predicted forward yields in Israel, US, and Germany, 2001-2018

This figure presents effective forward yields and predicted yields based on the estimations obtained in Table 4.

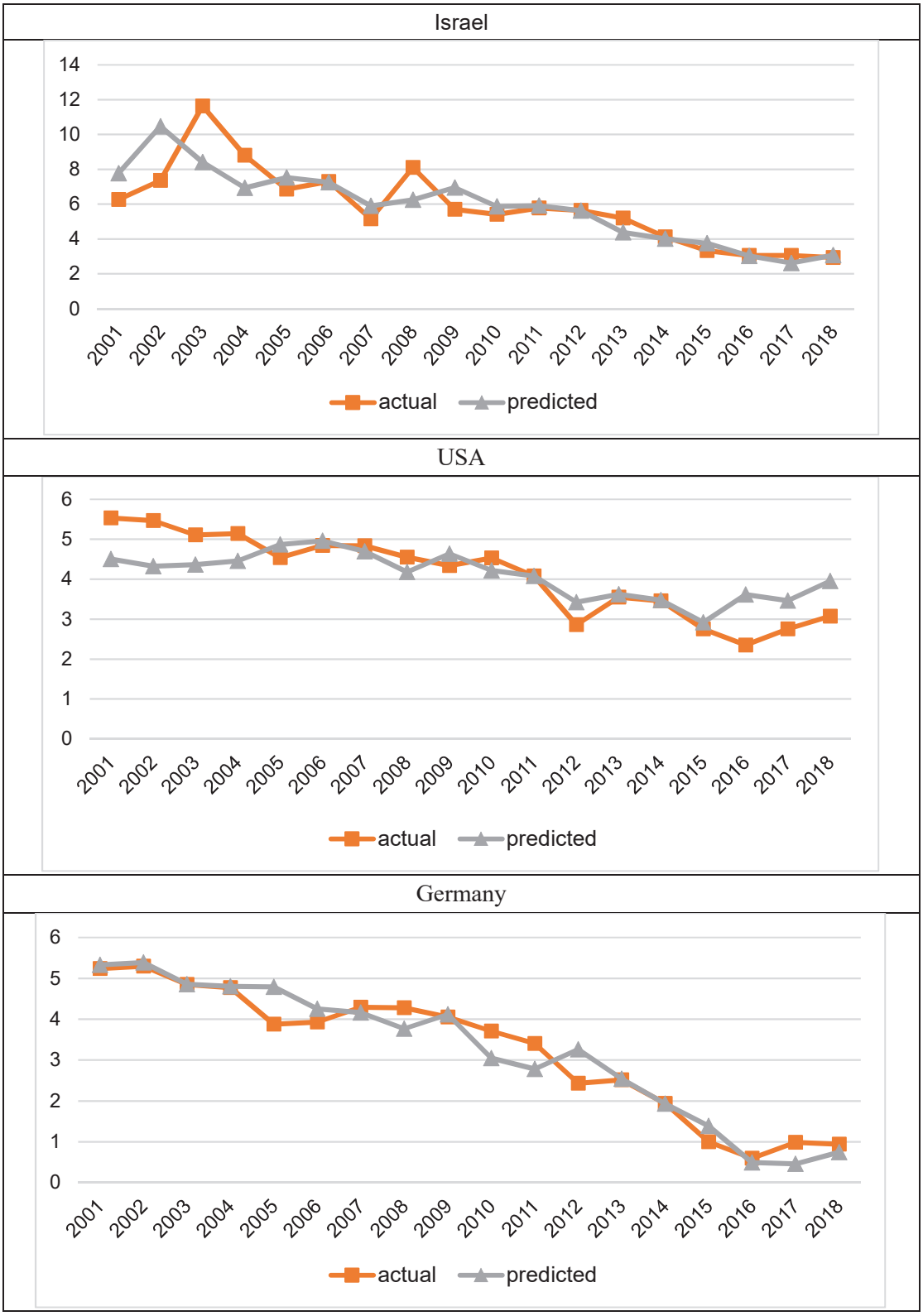


Figure 2: Contribution to changes in forward yields over time, Israel, 2001-2018

This figure presents the contribution of various factors to changes in the forward yield in 2018 compared to the yield in 2001. Estimations are based on the equation in Table 4. Fiscal risk factors include debt-to-GDP ratio and tax-to-GDP ratio. Cyclical factors include short-term real interest rate determined by monetary policy; previous-year inflation; central bank purchases of government bonds as a percentage of total government bond debt in previous year; GDP per capita growth; current account surplus; and change real-effective exchange rate. Structural factors are country effect, intercept, GDP per capita, and demographic situation represented by the age-dependency ratio.

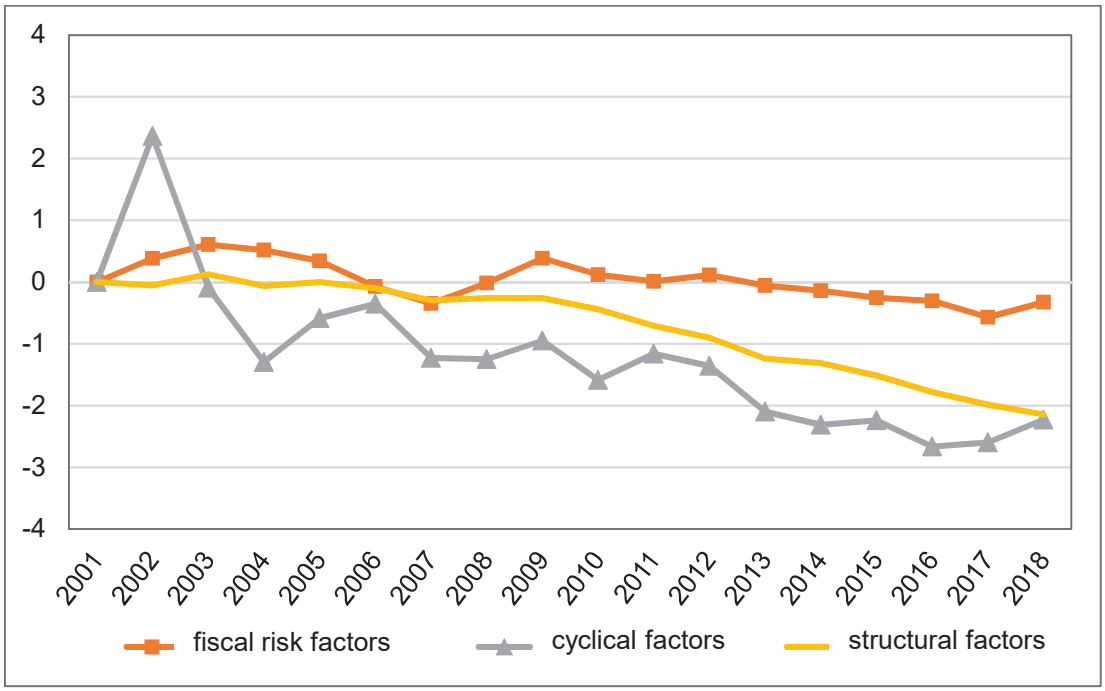


Figure 3: Contribution to changes in forward yields over time, US, 2001-2018

This figure presents the contribution of various factors to changes in the forward yield in 2018 compared to the yield in 2001. Estimations are based on the equation in Table 4. Fiscal risk factors include debt-to-GDP ratio and tax-to-GDP ratio. Cyclical factors include short-term real interest rate determined by monetary policy; previous-year inflation; Federal Reserve purchases of treasury bonds as a percentage of total treasury bond debt in previous year; GDP per capita growth; current account surplus; and change real-effective exchange rate. Structural factors are country effect, intercept, GDP per capita, and demographic situation represented by the age-dependency ratio.

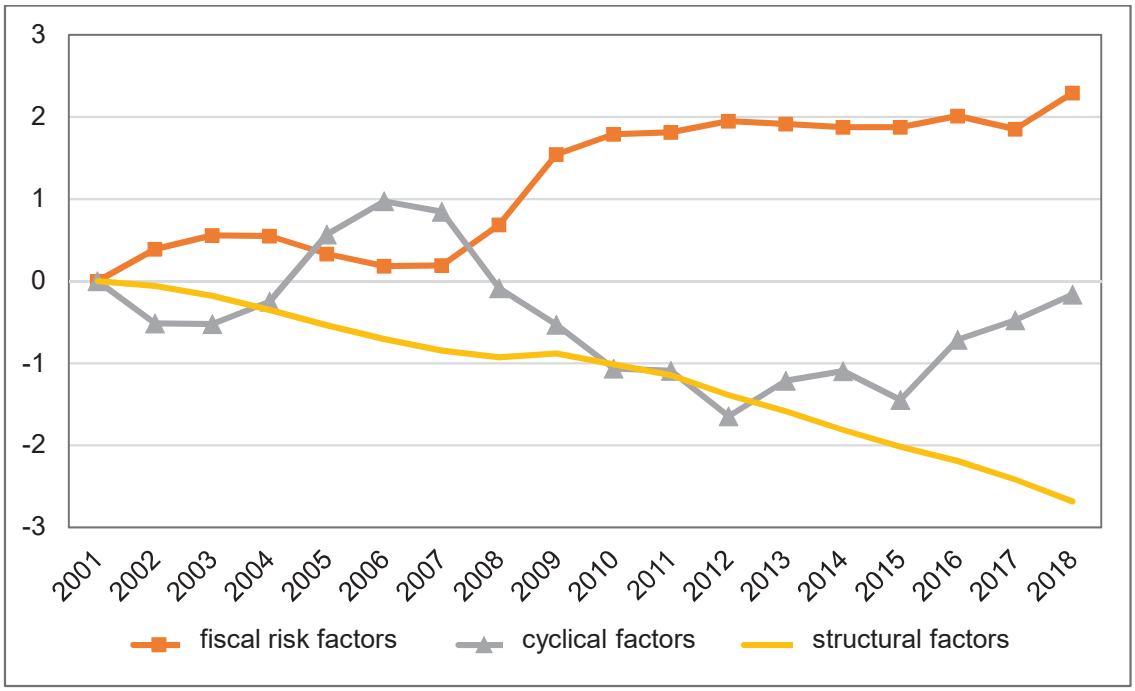


Figure 4: Contribution to changes in forward yields over time, Germany, 2001-2018

This figure presents the contribution of various factors to changes in the forward yield in 2018 compared to the yield in 2001. Estimations are based on the equation in Table 4. Fiscal risk factors include debt-to-GDP ratio and tax-to-GDP ratio. Cyclical factors include short-term real interest rate determined by monetary policy; previous-year inflation; central bank purchases of government bonds as a percentage of total government bond debt in previous year; GDP per capita growth; current account surplus; and change real-effective exchange rate. Structural factors are country effect, intercept, GDP per capita, and demographic situation represented by the age-dependency ratio.

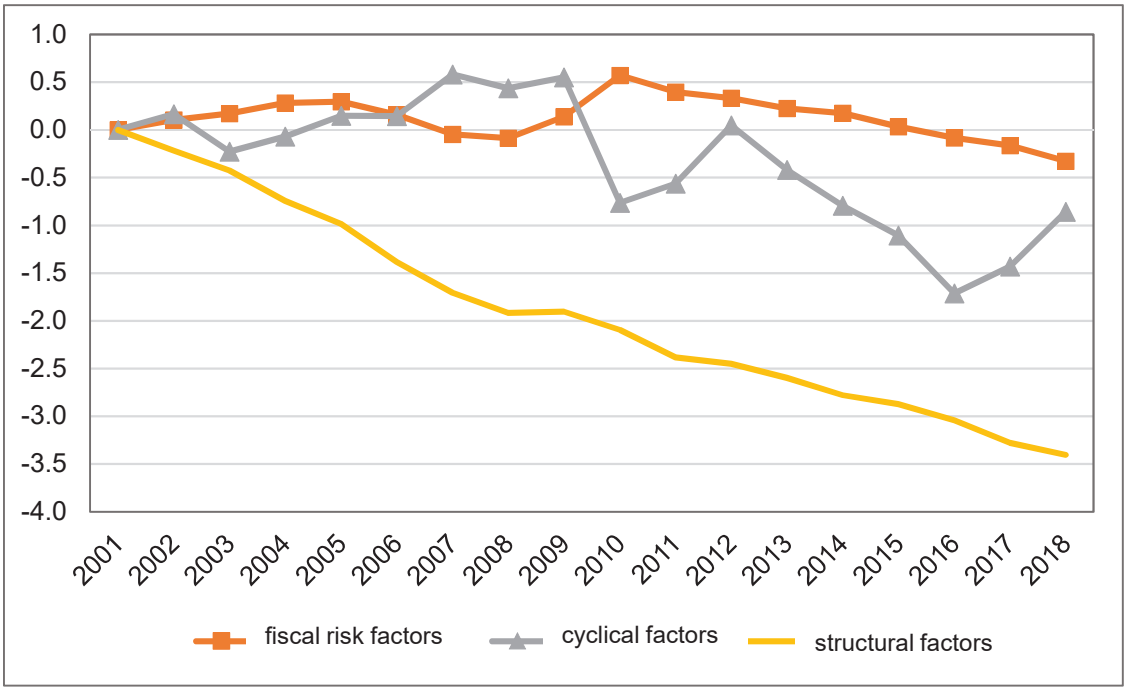


Figure 5: Contribution to changes in forward yields over time, Israel, 2001-2018, estimation with time effect

This figure presents the contribution of various factors to change in the forward yield in 2018 relative to 2011. Estimations are based on the equation in Table 6. Fiscal risk factors include debt-to-GDP ratio and tax-to-GDP ratio. Cyclical factors include short-term real interest rate determined by monetary policy; previous-year inflation; central bank purchases of government bonds as a percentage of total government bond debt in previous year; GDP per capita growth; current account surplus; and change real-effective exchange rate. Structural factors are time, country effect, and intercept.

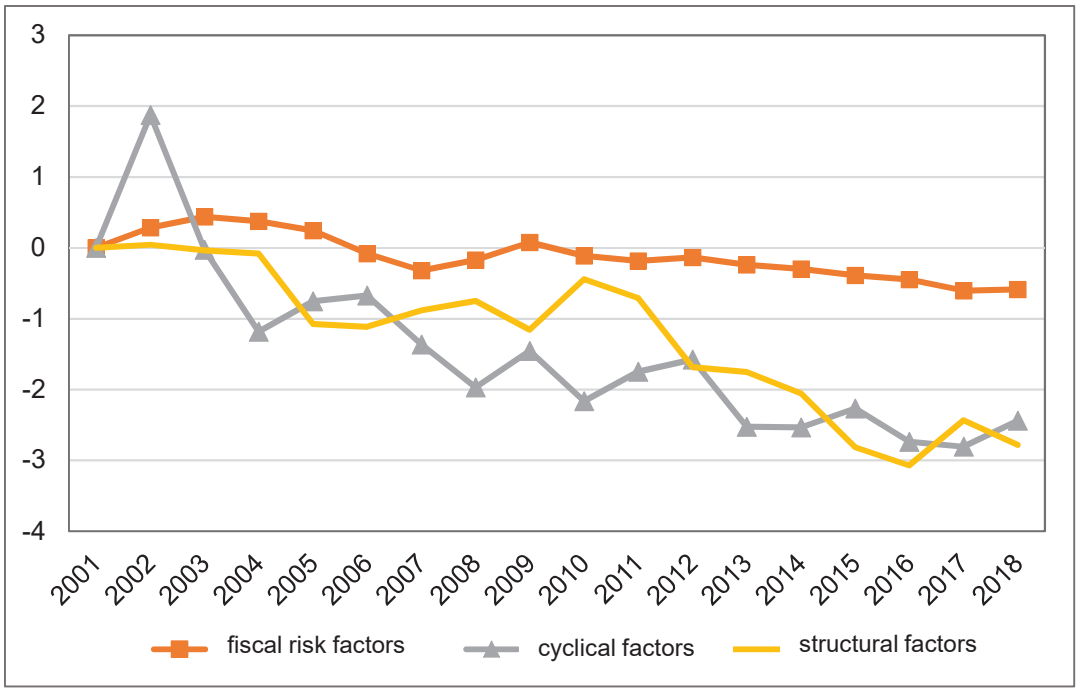
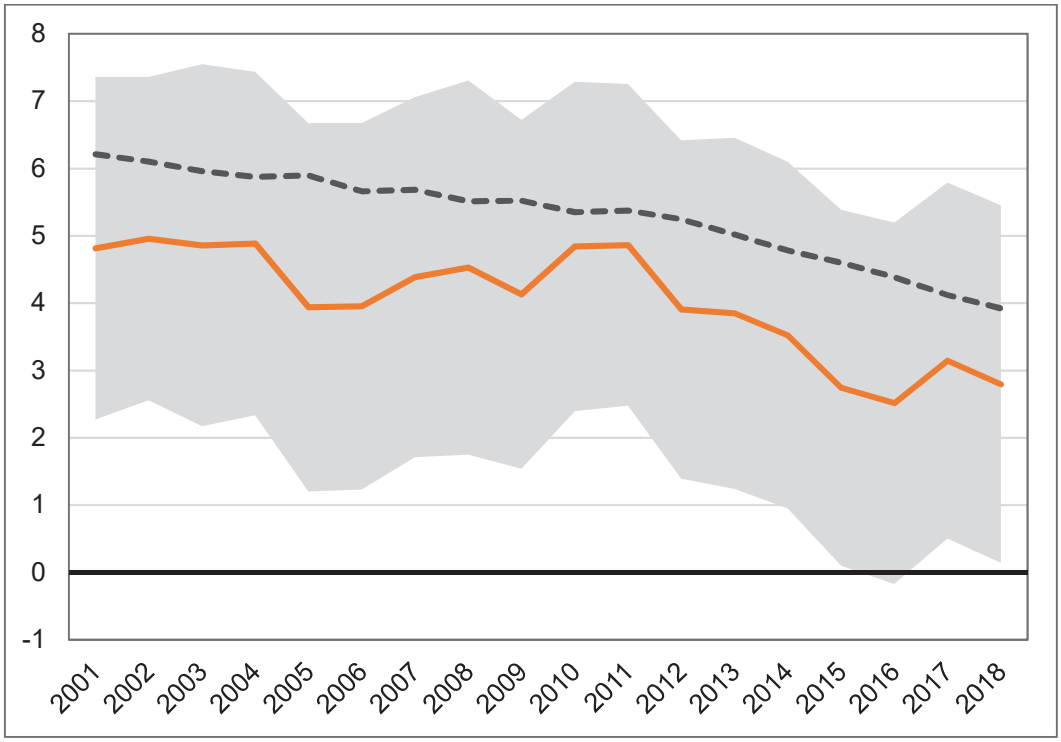


Figure 6: Estimation of the natural interest rate

This figure presents the estimated natural interest rate (red line), obtained from the weight mean (GDP weights) of the product of the coefficients of the dummy variables for time, the dummy variables for country, and the intercept, based on the equation in Table 6. The gray area represents the 95% confidence interval. The dashed line is the estimated natural interest that appears in Figure 1.



Appendix 1: Conversion table of credit ratings

Description	Fitch	Moody's	S&P	Scale
Prime	AAA	Aaa	AAA	100
High grade	AA+	Aa1	AA+	95
	AA	Aa2	AA	90
	AA-	Aa3	AA-	85
Upper medium grade	A+	A1	A+	80
	A	A2	A	75
	A-	A3	A-	70
Lower medium grade	BBB+	Baa1	BBB+	65
	BBB	Baa2	BBB	60
	BBB-	Baa3	BBB-	55
Non-investment grade	BB+	Ba1	BB+	50
Speculative	BB	Ba2	BB	45
	BB-	Ba3	BB-	40
Highly speculative	B+	B1	B+	35
	B	B2	B	30
	B-	B3	B-	25
Substantial risks	CCC	Caa1	CCC+	20
Extremely speculative		Caa2	CCC	15
In default with little prospect for recovery		Caa3	CCC-	10
		Ca	CC	7.5
		C	C	5
In default	DDD	/	D	0
	DD	/		
	D			