Inflation Targeting and Predictive Power of Term Spreads

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Many studies have investigated the predictive contents of the term spreads for future inflation and real activity since the 1990s, which was the time when some countries adopted inflation targeting (IT). As notable as the number of studies are the diversity and heterogeneity of the empirical findings on this issue across countries and over time. In this paper, we attempt to assess whether IT is responsible for the changes in the forecasting power of the term spreads for inflation. If future inflation is anchored to the target rate under an IT regime, then changes in the spread would contain information other than the future inflation, thereby reducing the predictive contents for future inflation. We test this hypothesis by (1) comparing the forecasting power of the term spread for inflation in a group of inflation-targeting countries before and after adopting IT and (2) comparing this power with the forecasting power in a group of countries that have not adopted IT. Findings support the hypothesis overall, but results are weakened when the interest rate is included in the forecasting equation.

Keywords: Inflation targeting, Term spread, Predictability, Monetary policy

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I. Introduction

Over the past two decades, many studies have analyzed whether the yield spread contains predictive contents for future real activity and inflation in many industrialized countries. The empirical evidence for the predictive power of the yield spread for real activity is relatively strong, but the predictive power for future inflation appears to have decreased significantly or disappeared over time in most countries. In this paper, we show that the adoption of inflation targeting (IT) is responsible for the time variation in the predictability of inflation using the term spread in relation to that of output growth across countries and over time.

Around the 1980s, the term structure of interest rates emerged as an active major research topic in several academic fields. The modern asset pricing literature pertaining to the factors underlying the term structure was initiated by the work of Vasicek (1977) and Cox, Ingersoll, and Ross (1985). From a theoretical point of view, the forward-looking nature is inherently an essential characteristic of the bond yields, and many empirical studies have investigated the predictive power of the term structure for the future output growth and inflation since the 1990s. Another recent body of research, the macro-finance literature that started in the 2000s, primarily focuses on the relationship among the level, slope, and curvature factors in the term structure and the macro-variables, such as inflation target of the central bank, actual inflation, and real activity. Rudebusch and Wu (2008), Hördahl, Tristani and Vestin (2006), and Bekaert, Cho, and Moreno (2010) found that the level factor, which is primarily driven by the short-term interest rates, accounts for much of the inflation target or the long-run inflation rate, whereas the slope, which is often proxied by the term spread, has a marginal relationship with inflation or real activity.

The keys to understanding the term structure are the dynamics of the short-term nominal interest rates and the expectation formation of the market participants on future short-term interest rates, both of which are heavily influenced by monetary policy. Most industrialized countries replaced their primary monetary policy instrument, monetary aggregates, with the short-term interest rate in the 1980s. This policy change implies that the equilibrium of short-term interest rates is directly controlled by the central bank. Accordingly, the long-term bond market participants have changed the way they form expectations of future short-term interest rates. This explains that the objective, instrument, and conduct of monetary policy have been taken into account in a vast majority of research papers in the aforementioned literature.

Another important change in the history of monetary policy is that several developed countries adopted IT in the early 1990s, shifting the preference of the central bank toward stabilizing future inflation variations. Various aspects of IT framework exist, as discussed by Bernanke and Mishkin (1997), but a central implication is that a successful implementation of IT would be able to anchor the expectations of the future inflation rates of private agents to the target inflation rate. This in turn leads to changes in the information composition embedded in the long-term bond yields. However, few studies systematically investigated the effects of IT on long-term bond yields and the changes in the information structure underlying the predictable contents of the term structure for output growth and inflation.

This issue is the main topic that we want to address in this paper. Specifically, we want to identify the relative information on future inflation and output growth contained in the term spread. Our main hypothesis is that under IT, the term spread contains little information on the changes in inflation because IT anchors the future inflation to the target rate, canceling out the target rate component embedded in the long-term bond yield and the short-term interest rate. Estrella (2005) provided a model-based account for this kind of argument. Siklos (2000) found that their results were consistent with our hypothesis in the case of New Zealand.

To build up some intuition, we consider a strict form of IT in which the actual inflation is closely tied to the target inflation rate, possibly time-varying but foreseeable. If the target rate does not change, then any change in the term spread, either the expectations hypothesis component or term premium, would fully reflect the expected changes in other factors, including future real activity, because a slight deviation would exist for future inflation rates from the target.

To this end, we mainly focus on testing the relative information contents of the term spread. A perceived difficulty is that both the concept of IT and its practical implementation vary, as succinctly stated by Bernanke (2003): "*in both theory and practice, today all inflation targeting is of the flexible variety*." Thus, testing our hypothesis for just one country may be subject to both country- and period-specific shocks. Fortunately, the history of monetary policy in developed countries for over four decades provides a natural experimental framework for testing our hypothesis across countries and over time based on IT adoption. Specifically, we include countries that have sufficiently developed financial markets and sufficiently long data series that started in the 1980s. We classify these countries into two groups, as follows: the IT countries that adopted IT around the 1990s and the countries that have not adopted IT (Non-IT countries). Hence, we can compare the predictability of inflation using the term spread between the two groups and between the two periods before and after the adoption of IT in the IT countries. In this way, we can average out the country-specific and time-specific shocks to isolate the effect of the adoption of IT on predictability.

Our empirical analysis confirms the hypothesis. Within the group of IT countries, the predictive power of the yield spread for inflation is lower after the adoption of IT, whereas no systematic tendency of predictability exists for output growth before or after the adoption of IT. We also show that the change in predictability for inflation from period 1 to period 2 exhibits random variations among the countries in the Non-IT group. However, our result is weakened when the forecasting equation of the term spread includes the short-term interest rate as an independent forecasting variable. Hence, a significant amount of the information content embedded in the term spread is shared with the monetary policy instrument. This result is consistent with the finding of Kozicki (1997), who argued that short-term interest rates are better predictors of future inflation for medium and long horizons.

The remainder of this paper is organized as follows. In Section II, we summarize the related literature on the relationship between the predictive power of yield curve and the changes in the preference of monetary policy. In Section III, we select and classify the sample countries. In Section IV, we introduce the methodology, and in Section V, we present the empirical results. In Section VI, we present our conclusions.

II. Related Literature

In this Section, we briefly review the different studies pertaining to the link between the predictive power of term spread and IT. The predictive power of the yield spread for output growth is rather robust over time and across countries, particularly in earlier studies however, Dotsey (1998) and Estrella, Rodrigues, and Schich (2003) report that the marginal predictability has been less significant in the United States in recent years. In contrast, the findings for inflation are more drastic. Mishkin (1990a), Mishkin (1991), Jorion and Mishkin (1991), Estrella and Mishkin

(1997), Schich (1996), and Gerlach (1997) observed the forecasting power of the term spread for inflation in the United States and some of members of the Organization for Economic Cooperation and Development (OECD), particularly for longer horizons. Many subsequent studies, as highlighted by Stock and Watson (2003), found little forecasting power for inflation in many industrialized countries when the inflation persistence is considered. However, even after controlling for inflation persistence, the predictive power of the spread for inflation still exists in some countries prior to adopting IT, most notably in New Zealand and in the United Kingdom, as shown in Section V. Hence, inflation persistence is not a sufficient explanation for diminishing predictive contents of the yield spread for inflation.

Several studies have attempted to identify the causes of time-variation of predictability and the decrease in forecasting power for inflation relative to output. Mishkin (1990a) estimated a forecasting equation for future inflation using the term spread in the United States from 1953 to 1987 and found that the coefficient of determination (R^2) and the coefficient of the yield spread declined for the post-1979 period. Schich (1999) also found that the predictability has changed over time in the United States and the United Kingdom, among the G-7 countries. Using a breakpoint test, he argued that the United States monetary policy might be closer to IT in the 1980s than in the late 1970s. The United Kingdom adopted exchange rate targeting in 1987 and IT in 1992. Using a simple analytical model, Estrella (2005) demonstrated that if the monetary authority implements strict IT, then the optimal parameter values of both the current inflation gap and the current output gap in the monetary policy reaction function increase, thereby reducing the predictive power of the yield spread. He reported that the forecasting power for inflation has significantly decreased in the United States since 1987.[1] For output growth, Benati and Goodhart (2008) found a significant change in the predictive power of the yield spread for several countries, but this change cannot be due to a single economic factor.

The reductions in the predictive contents of the yield spread for inflation relative to output growth are more pronounced in the United Kingdom, New Zealand, and the United States, particularly in recent

[1] In contrast to these results, Gamber (1996) employed the Granger test and the vector autoregressive (VAR) analysis to show that the predictive content of the yield spread for inflation actually increased in the United States after 1979, whereas that for real activity decreased during the same period.

years, coinciding with the IT era. Hence, it is natural question whether IT is responsible for the dissipating predictive power of the yield spread for inflation in a global context. To build up some intuition, we consider a standard Fisher equation, as follows:

$$i_t = E_t\,\pi_{t+1} + r_t, \tag{1}$$

where i_t, π_t, and r_t are the short-term nominal interest rate, inflation, and the real interest rate, respectively. $E_t\,(\cdot)$ is the mathematical expectation operator conditional on the information at time t. The no-arbitrage term structure theory implies that the long term bond yield $i_{n,t}$ with maturity n at time t can be decomposed into the expectationshypothesis component and the term premium $tp_{t,n}$ in the following way:

$$\begin{aligned} i_{t,n} &= \frac{1}{n}\sum_{j=o}^{n-1} i_{t+j} + tp_{t,n}, \\ &= \frac{1}{n}\sum_{j=o}^{n-1} E_t\pi_{t+j+1} + \frac{1}{n}\sum_{j=o}^{n-1} E_t r_{t+j} + tp_{t,n}. \end{aligned} \tag{2}$$

The second equality comes from the Fisher equation. If the central bank sets an inflation target that would prevail at time $t+j$ as π^*_{t+j} for $j=0,\ 1,\ 2,\ \cdots$, and if the policy is credible, then the expected inflation $E_t\,\pi_{t+j}$ would be anchored at π^*_{t+j}. Therefore, the term spread $i_{t,n}-i_t$ can be written as the following:

$$i_{t,n} - i_t = \left(\frac{1}{n}\sum_{j=o}^{n-1}\pi^*_{t+j+1} - \pi^*_t\right) + \left(\frac{1}{n}\sum_{j=o}^{n-1} E_t r_{t+j} - r_t\right) + tp_{t,n}. \tag{3}$$

This equation implies that a change in the term spread would reflect a change in the average future real interest rates net of the current rate, term premium, or both as long as the target inflation rates π^*_{t+j} are not altered for $j=0,\ 1,\ 2,\ \cdots$. If the target inflation rate is constant at π^*, for instance, then the term in the first parenthesis in Equation (3) disappears. The term in the second parenthesis in this equation captures variations in future output growth. Therefore, the predictability of inflation would be smaller than that of output growth under IT.

Some additional evidence has been reported for other IT countries. Siklos (2000) found a low and insignificant forecasting power of the term spread for future inflation over most of the forecasting horizons in New Zealand, but also found a significant forecasting power in Australia and the United States He argued that a strong commitment to IT accounts for the difference between New Zealand and the other two countries.

The aforementioned studies are likely to support the hypothesis that the adoption of IT is a major cause of diminishing predictability of inflation when tested within a selected group of IT countries, but a more rigorous and systematic test would require a comparison of the predictive contents of the term spread for inflation in IT countries with those of the countries before IT adoption or with those of the countries that have not adopted IT. Additionally, we examine the predictive power of the term spread for inflation relative to that for output growth. We use this examination to determine the general relationship between the predictive power of the term spread and the IT regime.

III. Classification of Sample Countries

We consider two groups of countries: IT countries that have adopted IT during the sample period, and Non-IT countries that have not adopted IT. Our sample countries are selected according to the following criteria. First, for the long-term bond yield to actually represent the market-determined prices embodying rational expectations of the market participants, the sample countries must have well-developed financial markets. The proxy for this criterion we employ in this paper is the ratio of the added value of the financial industry to that of the total industry in 2006, which is the year in which data became available for all the countries.[2] We select both IT and Non-IT countries with a ratio greater than 20%. Second, for the IT countries, the sample period encompassing the times before and after the adoption of IT must be sufficiently long to enable the assessment of the predictive power of the term spread. According to Roger (2009) and Hammond (2012), close to 30 countries have officially adopted IT.[3] However, most of these countries officially

[2] We obtain the data from Structural Analysis (STAN) Databases of OECD. The financial industry includes finance, insurance, real estate, and business services.

[3] The classification of IT countries and Non-IT countries is difficult and is incomplete. For instance, Germany and Switzerland were categorized as IT countries by Bernanke, Laubach, Mishkin, and Posen (1999), whereas they were not considered as IT countries by Ball and Sheridan (2004).

TABLE 1
CLASSIFICATION OF THE IT AND NON-IT COUNTRIES

Panel A: IT countries

Country	Period 1	Period 2 (IT Regime)
Australia	1969:Q4–1993:Q1	1993:Q2–2007:Q4
Canada	1975:Q2–1990:Q4	1991:Q1–2007:Q4
New Zealand	1974:Q2–1989:Q4	1990:Q1–2007:Q4
United Kingdom	1972:Q2–1992:Q3	1992:Q4–2007:Q4
United States	1960:Q2–1987:Q2	1987:Q3–2007:Q4
Sweden	1980:Q2–1992:Q4	1993:Q1–2007:Q4

Panel B: Non-IT countries

Country	Period 1	Period 2
Austria	1970:Q2–1992:Q3	1992:Q4–2007:Q4
Belgium	1980:Q2–1992:Q3	1992:Q4–2007:Q4
Denmark	1977:Q2–1992:Q3	1992:Q4–2007:Q4
France	1970:Q2–1992:Q3	1992:Q4–2007:Q4
Germany	1960:Q2–1992:Q3	1992:Q4–2007:Q4
Italy	1980:Q2–1992:Q3	1992:Q4–2007:Q4
Netherlands	1977:Q2–1992:Q3	1992:Q4–2007:Q4
Portugal	1981:Q2–1992:Q3	1992:Q4–2007:Q4

adopted IT after 1999, thereby indicating that the statistical test of predictability for these countries is difficult because of the lack of data for the IT period.[4] The Non-IT countries must also have data series comparable with the IT countries.

Although the United States does not announce its exact inflation target range, we follow the convention that the United States monetary authority has been implementing IT implicitly since the era of the Greenspan regime [see Goodfriend (2004) or Carare and Stone (2006), for instance]. For this reason, we include the United States as an IT country. The sample period and the adoption date of IT are reported in Panel A of Table 1.

According to our second selection criterion, the IT regime for most countries started in the early 1990s, except for the United States. To compare the forecasting power of the yield spread with the periods before and after IT across the groups, we divide the sample periods of the Non-IT countries in the fourth quarter of 1992 to make the two periods comparable to the IT countries.[5] We use this date because the first

[4] We also exclude Finland and Spain because they adopted IT for a short period in the 1990s, but gave up the IT policy prior to the launch of the Euro.

sample periods are relatively short for some of the Non-IT countries, although we may also use the average of the IT adoption dates of the IT countries. The Non-IT countries and their sample periods are reported in Panel B of Table 1.

In the sample period, we truncate the most recent data points for all countries starting from 2008 to buffer our results against the global financial turmoil triggered by the United States financial crisis. Meanwhile, we omit Japan because the information contents of the term spread would be marginal, *i.e.*, the short-term interest rate has been essentially zero since the 1990s. This fact led to virtually constant rates of long-term bond yields, and inflation has also been stable around zero.

IV. Methodology and Data

Various estimation strategies have been used in previous studies to measure the predictability of output growth and inflation using the term spread. In recent years, advanced techniques, such as the time-varying parameter approach of Stock and Watson (1998), Bayesian time-varying (VAR) of Benati and Goodhart (2008), a VAR framework restricted by the affine term structure model of Ang, Piazzesi, and Wei (2006), and a nonlinear threshold model of Duarte, Venetis, and Paya (2005), have also been proposed. These methodologies are alternatives to our analysis, but the main focus of our paper is to identify the differences in the predictability between the groups of countries and over time on the same ground, rather than measuring the time-variation in the predictability for a particular country within a sample period. Thus, we use two standard metrics to gauge the forecastability of the term spread; one standard metric is based on a simple linear forecasting equation, whereas the other is based on a VAR framework.

A. Two measures of Forecasting Power

We consider the following baseline linear single forecasting equation:

$$x_{t+h}=\beta spread_t+\gamma' z_t+u_{t+h}, \tag{4}$$

where x_{t+h} is either inflation (π_{t+h}) or real output growth (g_{t+h}) at time

[5] We also choose different starting points for the second period from the first quarter of 1991 through the second quarter of 1993, and we confirm that our results are not very different across different selection of the two periods.

$t+h$ for a forecasting horizon, $h=1, 2, \ldots, 20$. $spread_t$ is the difference between long-term government bond yield and the short-term interest rate at time t. z_t represents the other explanatory variables measurable at time t or earlier. u_{t+h} is the shock, which is assumed to be uncorrelated with the variables at time t.

The first measure of the predictive power of the term spread is the coefficient β of the term spread—size and significance—in Equation (4). The t-statistics of the coefficients β and γ are computed using the Newey-West heteroskedasticity and autocorrelation consistent (HAC) standard errors because the data are overlapping for $h>1$, and the shocks may be heteroskedastic and serially correlated.

A vast majority of papers, including recent ones by Aretz and Peel (2010), D'Agostino, Giannone and Surico (2006), Chinn and Kucko (2010), Nakaota (2005), and Poke and Wells (2009), followed a variant of this equation, although this in-sample predictability test may be misleading for out-of-sample forecasts if the estimated coefficients are statistically unstable, as pointed out by Stock and Watson (2003). While some earlier works used a form of Equation (4) without z_t, most papers used additional variables to control the past values of inflation and other potential predictors. Different choices of the control variables obviously lead to varying results. This problem may be particularly severe for an individual country and for a particular time span. Hence, we use the same set of independent variables for both prediction equations for inflation and output growth in all countries. We choose π_t and π_{t-1} based on the related literature and additionally, use g_t and g_{t-1}. The current and past inflation rates are included because they have a strong forecasting power for future inflation. Inflation exhibits high persistence for most countries, even if Benati (2008) argues against this common understanding of inflation persistence. Controlling for inflation persistence significantly reduces the predictive power of the spread, as shown by Estrella and Mishkin (1997) and Kozicki (1997) among others. We conduct our analysis using various numbers of lags in our control variables, and the results are not drastically different from our main findings, which are presented in the following Section.

Several studies, such as those of Kozicki (1997) and Benati and Goodhart (2008), showed that the short-term interest rate is an important control variable in the forecasting equation of the term spread. Indeed, we find that our results are weakened with the inclusion of the short-term interest rate. Nevertheless, no consensus exists in theory about whether the short-term interest rate is a required regressor in study of the predictive power of the term spread. Moreover, the majority of empirical studies have not included the short-term interest rate as a regressor. Thus, we present the results without the short-term interest rate, but remark on the difference when the short-term interest rate is included in the prediction equation.

The second measure of the predictability that is considered in this paper is a metric based on the forecast errors in a multivariate context. We consider a VAR model of the following:

$$y_{t+1}=A(L)y_t+v_{t+1}, \tag{5}$$

where y_{t+1} is a vector of inflation, real output growth, and the term spread at time $t+1$, $A(L)y_t=A_1 y_t+\ldots+A_4 y_{t-3}$, and v_{t+1} is the vector of innovations to y_{t+1} such that $\mathrm{Var}(v_{t+1})=\Sigma=PP'$, where P is a lower triangular matrix. Analogous to the first metric, the same set of control variables are used by fixing the same lag length for each country over the same sample periods.[6] Let $MSE_x(h)$ be the h-step mean-squared forecast error of the variable x either inflation or output growth. Similarly, $MSE_{x,sp}(h)$ denotes the h-step mean-squared forecast error of the variable x accounted for by the innovation to the term spread. Subsequently, we use the following ratio to measure the amount of the h-step mean-squared forecast error in the variable x, which is explained by the term spread shock relative to the total variance.

$$w_{x,sp}(h)=\frac{MSE_{x,sp}(h)}{MSE_x(h)}. \tag{6}$$

This statistic has an advantage over the economic significance of β because the iterated forecasts of the VAR achieve more efficiency asymptotically, provided that the VAR is correctly specified. However, this statistic may be more vulnerable to specification errors compared with the single forecasting equation approach. For instance, our order of the VAR system implies that inflation and output growth have contemporaneous effects on the term spread, but not vice versa. This is consistent with the assessment of the spread in the macro-finance literature, in which the term spreads are considered as affine functions of the macroeconomic variables under the no-arbitrage term structure theory. In

[6] We also estimated the model with different numbers of lags and found that the results are similar, except for those of Australia.

contrast, Canova and De Nicolo (2000) assumed a different ordering in their VAR analysis.[7] We believe that these advantages and disadvantages of the two measures of the predictability by the term spread are complementary to each other.

B. Data

Most of the quarterly data were obtained from the International Financial Statistics (IFS) database of the International Monetary Fund. Inflation, π_t (Output growth, g_t), is 400 times the log difference of the GDP deflator (Real GDP) between time t and $t-1$. Seasonally unadjusted series are adjusted using X-12 ARIMA. Unlike the macro data, the short-term interest rate and the long-term bond yields differ significantly across countries and over time. From the available data, we construct the spread based on the difference between the 10 year government bond yield and the overnight interbank rate for most countries. Some countries do not have exact ten-year bond rates, but have long rates comparable with a ten-year bond yield. The real problem lies in the construction of the short-term interest rate. Some European countries do not have an independent interbank overnight rate for a number of years because of country-specific matters or because of the launch of the common currency Euro. The short-term interest rates of Austria, France, and the Netherlands for the period from 1999:Q1 to 2007:Q4 are replaced with the interbank overnight rates in the Euro area. The short-term interest rate of Sweden (from 2004:Q4 to 2007:Q4) is replaced with the Stockholm interbank offered rate (STIBOR) available at the Riksbank of Sweden. The Portuguese short-term interest rate (from 2000:Q2 to 2007:Q4) is the interbank money market rate (overnight) obtained from the Banco de Portugal. For Belgium, New Zealand, Denmark, and Italy, we use the three-month interest rate instead of the overnight rate because the overnight rate is not publicly available. Detailed descriptions for the interest rate series are presented in the Appendix.

V. Empirical Results

In this Section, we present the estimates of the two explained metrics in the previous Section and assess the hypothesis that the forecasting

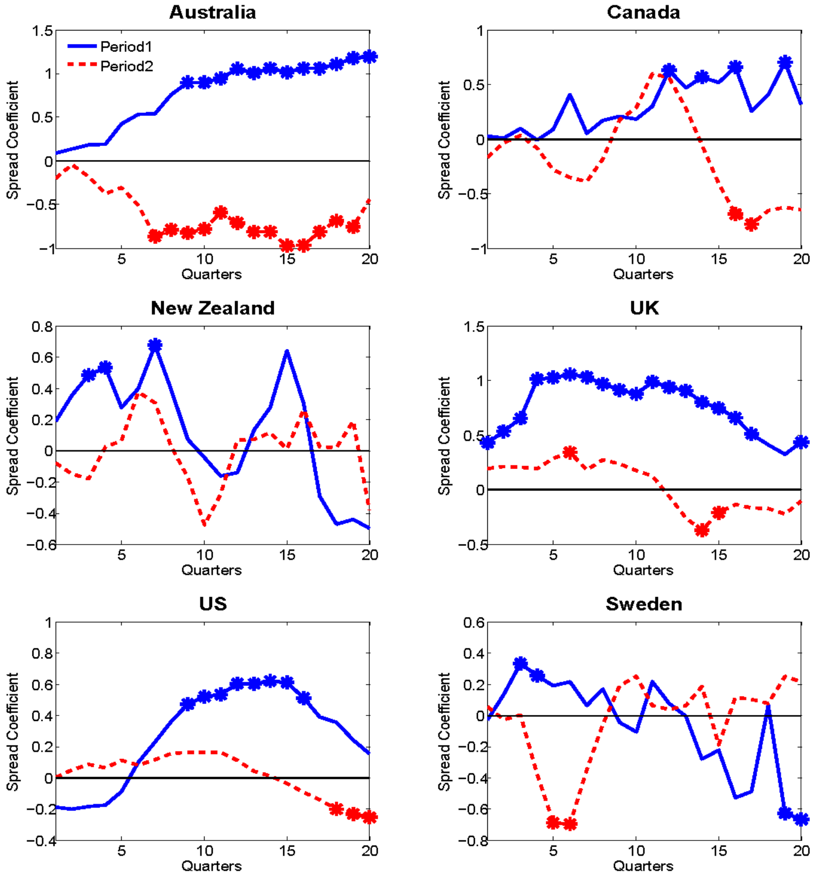
[7] Fortunately, the results under the VAR ordering of Canova and De Nicolo (2000) are not qualitatively different from ours.

power of the term spread for inflation in the IT countries would decrease after IT adoption. For the hypothesis to become valid, the forecasting power of the term spread for future inflation, measured by the estimated metrics in the second period (IT regime), should be lower than that in the first period. Such a decrease in the forecasting power for future inflation would support the hypothesis more strongly if no significant difference exists between periods 1 and 2 in terms of the predictive contents for inflation in the Non-IT countries or the predictive contents for output growth relative to inflation in the IT countries.

A. Predictability Based on Single Forecasting Equation

Figure 1 shows the estimates of the coefficient of yield spread in Equation (4) for inflation in the IT countries. The estimates with an asterisk indicate a significance at the 5% level, computed with Newey-West heteroskedasticity and autocorrelation consistent standard errors. Figure 1 shows that except for Sweden, the estimated β is mostly positive during the first period prior to IT adoption and it is significant for some forecasting horizons. In particular, the forecasting power of the term spread in the United Kingdom is noticeable because β is positive and significant for virtually all forecasting horizons. However, after adopting IT during the second period, β is not uniformly positive or negative, and it is not statistically significant over most of the forecasting horizons except for Australia. Predictability is significant in the seventh quarter and later in Australia, but it is rather counterintuitive as an increase in the term spread predicts a decrease in future inflation. The reduction in the forecastability of the term spreads for the United Kingdom, the United States, and New Zealand in the IT regime is rather strong and consistent with the empirical results of previous studies in the literature, but this is not very clear in the other IT countries. Therefore, only our first measure of the forecasting power for inflation provides marginal support for the hypothesis.

The estimated β of the IT countries is not impressive by itself, but it is strongly in contrast with the estimated β for the Non-IT countries. If IT is a major factor that differentiates the forecasting power across periods 1 and 2 in the IT countries, then the forecasting power should not be different across the periods in the Non-IT countries. Figure 2 illustrates the following point: no clear difference exists in the size, direction, or significance of the predictability for future inflation between periods 1 and 2 in the Non-IT countries. We recall that period 2 cor-

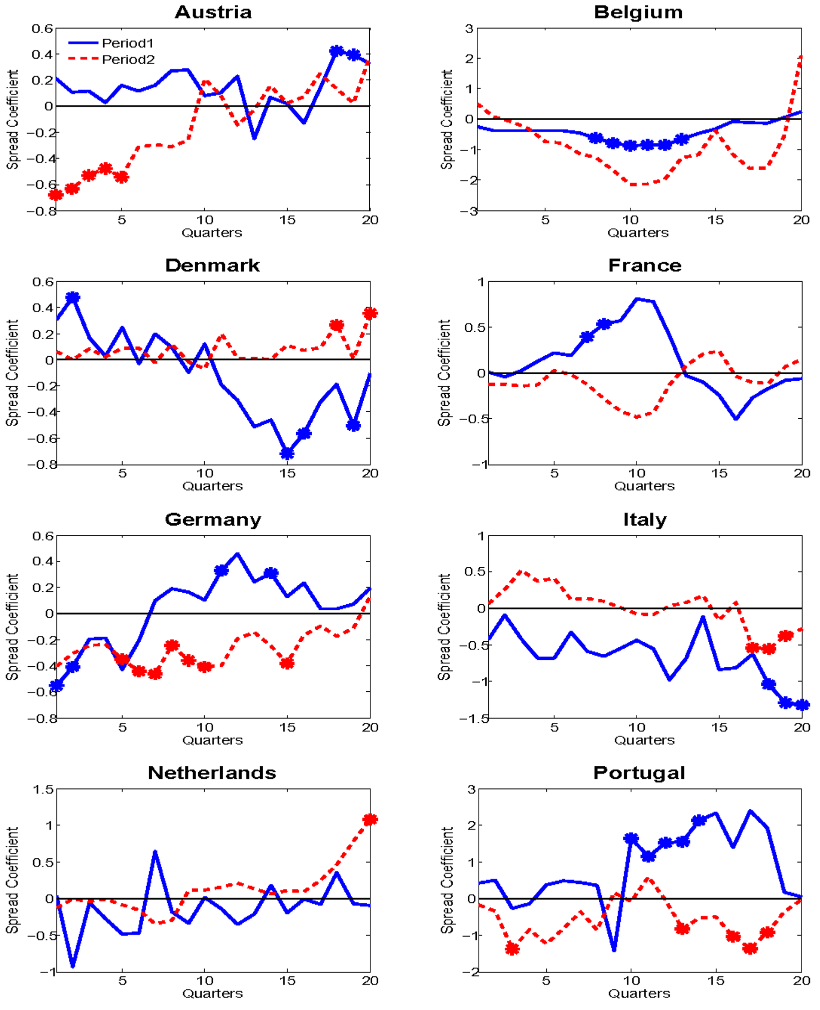


Note: This figure plots the estimated coefficient β in the forecasting Equation (4) for inflation in the IT countries during periods 1 and 2 (IT regime).

FIGURE 1

PREDICTIVE POWER OF FUTURE INFLATION IN THE IT COUNTRIES

responds to the IT regime of the IT countries. In Germany, the estimated β is negative in both periods with a similar magnitude and marginal significance in shorter forecasting horizons. In Belgium, the estimated β is even larger in period 2, although it is not statistically significant. In Austria, the estimated β is negative, but is large and significant through five quarters during the second period. The term spread in Portugal shows a certain degree of predictive power over 10 to 20 quarters in both periods. The estimated β essentially contains no informational content



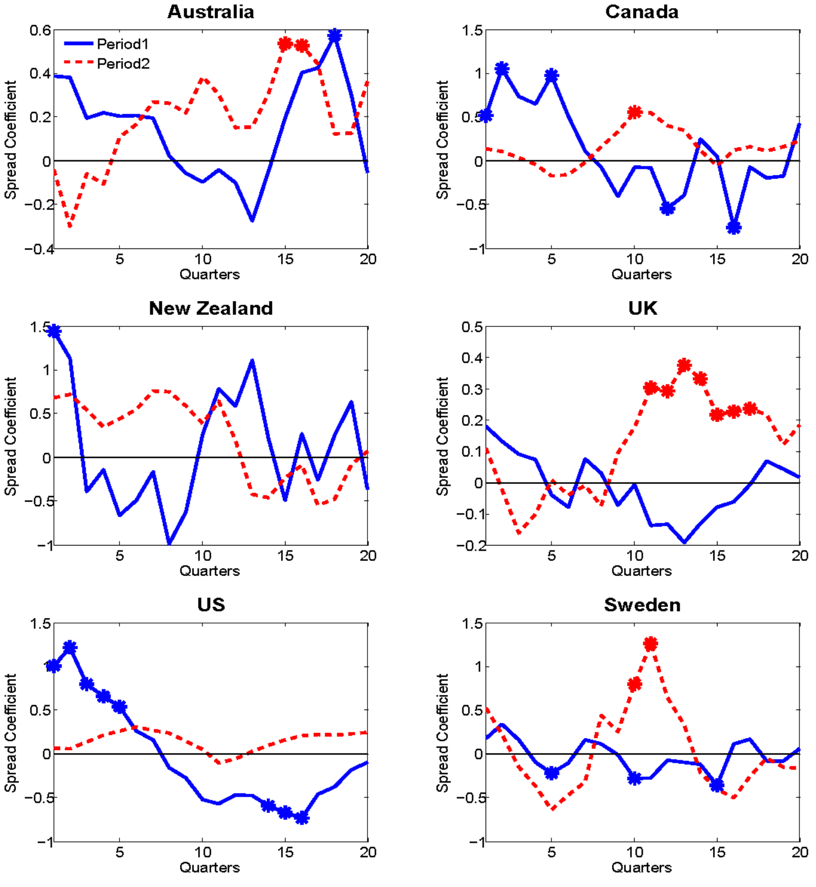
Note: This figure plots the estimated coefficient β in the forecasting Equation (4) for inflation in the Non-IT countries during periods 1 and 2 (corresponding to the IT regime).

FIGURE 2

PREDICTIVE POWER OF FUTURE INFLATION IN THE NON-IT COUNTRIES

for predictability of future inflation in other Non-IT countries.

Now, we compare the predictive power of the term spread in another dimension. Basically, the main function of IT is to anchor the level of



Note: This figure plots the estimated coefficient β in the forecasting Equation (4) for output growth in the IT countries during periods 1 and 2 (IT regime).

Figure 3

Predictive Power of Future Output Growth in the IT Countries

future inflation around the target level of the central bank, but not to (attempt to) affect future real activity, particularly in the long run. If these informational contents are fully reflected in the term structure of the interest rates, then we expect the term spreads to differentiate the informational contents for future inflation in the IT countries across the two periods, but not for other contents, such as future output growth. Thus, the forecasting power of the yield spread for output growth should be "random" across the two periods in the IT countries. Figure 3 plots the estimates of the coefficient of the yield spread in the prediction equation (4) for output growth. As in Figure 2, no clear tendency of predictability exists for future output growth in the IT countries across the two periods. Whereas the United Kingdom shows the most drastic change in forecasting power for inflation, the term spread has no predictive power for output growth before adopting IT, but it does have some predictive power starting from the 11^{th} quarter in the IT period. The predictive power for future output growth in the United States disappears in the IT regime. Before adopting IT, the yield spread in the United States positively predicted future output growth at short forecasting horizons, but it negatively predicted future output growth at long horizons. The estimated β of the remaining countries contains essentially no informational content for the predictability of future output growth.[8] Based on Equation (3), these results imply that the term spread mostly contains information on the term premium, but not information on the real interest rate or the output variations.

B. Variance Decomposition

As a second metric for measuring the predictive power of the term spread, we compute the h-step error variance of inflation accounted for by the term spread shock relative to the total variance. Table 2 shows this variance ratio for the IT countries for up to 20 quarters before and after adopting IT. In the IT countries, the forecast variances of inflation accounted for by innovations to the term spread are lower in the IT regime than those in period 1, except for the first year in Australia and the first three years in Canada. Such decrease in term structure forecastability is drastic in the United Kingdom and New Zealand, which are arguably the most aggressive IT countries in the world. As shown by Stock and Watson (2003) and by many other researchers, inflation persistence should be considered when testing the forecastability of the term spread for future inflation. Indeed, inflation has been very persistent in all the countries, and it is not surprising that much of the forecast variances of inflation in our VAR analysis are explained by the shocks to inflation. However, after controlling for inflation persistence, our vari-

[8] We also note that no clear difference should exist in the forecasting power of the term spread for future output growth across the two periods in the Non-IT countries. We find that this observation is indeed true, but we do not show this figure corresponding to Figure 3 to save space.

TABLE 2
INFLATION VARIANCE (%) ACCOUNTED FOR BY TERM SPREAD IN THE IT COUNTRIES

Country	Period	4	8	12	16	20
Australia	1	2.30	4.74	6.36	7.19	7.60
	2	3.42	4.12	5.08	5.25	5.35
Canada	1	0.70	1.12	2.35	3.18	3.56
	2	1.83	2.32	2.49	2.49	2.49
New Zealand	1	11.93	23.93	23.55	24.38	24.44
	2	2.70	2.96	2.99	3.04	3.04
United Kingdom	1	3.63	17.30	27.07	31.10	34.21
	2	0.04)	1.59	1.60	1.63	1.63
United States	1	8.92	8.71	8.12	7.74	7.53
	2	3.07	3.16	3.98	4.67	4.89
Sweden	1	11.62	11.44	11.79	11.87	11.84
	2	3.18	4.62	5.05	5.25	5.38

ance decomposition analysis clearly shows that IT is likely to be responsible for the reduction of the predictive content of the term spread for inflation.

We compare the results of the IT countries with those of the Non-IT countries as we did in the previous Subsection. Table 3 shows the variance ratio for the Non-IT countries. We expect the changes in the predictability for inflation to be random in the Non-IT countries across the two periods. The error variance of inflation accounted for by the term spread shock actually increases in four (Austria, Italy, Germany, and Portugal) of the eight countries during period 2.

This observation is in contrast with the variance ratio for inflation in the IT countries, even if the statistical determination of whether or not this result exhibits the randomness of the changes in the predictability is not possible because of the small sample size.

Lastly, we show the predictive contents of the term spread for inflation relative to those for output growth in the IT countries. Table 4 shows the h-step error variance of output growth accounted for by the term spread shock in comparison with the total variance. The variance ratio for output growth decreases in 4 out of 6 IT countries over the entire forecasting horizon, thereby indicating that the overall result does not strongly support the hypothesis. However, a comparison of Tables 2 and 4 shows that the variance ratio in the United Kingdom actually

TABLE 3
INFLATION VARIANCE (%) ACCOUNTED FOR BY TERM SPREAD IN THE NON-IT COUNTRIES

Country	Period	4	8	12	16	20
Austria	1	0.15	0.30	0.35	0.35	0.35
	2	3.70	6.49	6.49	6.51	6.51
Belgium	1	4.82	7.64	8.13	8.01	8.01
	2	1.02	1.40	1.60	1.67	1.68
Denmark	1	9.87	12.23	13.07	13.56	13.81
	2	0.28	0.34	0.46	0.46	0.47
France	1	3.24	3.31	5.52	5.82	5.62
	2	1.33	1.86	2.04	2.07	2.07
Germany	1	1.66	2.81	2.92	2.96	3.01
	2	13.14	14.21	14.73	14.80	14.78
Italy	1	6.65	4.67	6.17	7.00	7.96
	2	1.69	8.10	8.24	8.28	8.29
Netherlands	1	16.86	19.60	19.96	20.10	20.12
	2	2.90	3.08	2.99	2.96	2.95
Portugal	1	5.91	6.32	6.34	6.35	6.35
	2	10.09	12.48	12.91	12.93	12.93

TABLE 4
OUTPUT GROWTH VARIANCE (%) ACCOUNTED FOR BY TERM SPREAD IN THE IT COUNTRIES

Country	Period	4	8	12	16	20
Austria	1	3.80	3.44	3.48	3.51	3.52
	2	0.55	1.39	1.71	1.76	1.76
Canada	1	21.73	34.12	34.00	33.93	33.92
	2	2.82	2.86	2.85	2.86	2.86
New Zealand	1	7.80	8.27	8.37	8.37	8.37
	2	5.97	7.54	8.46	8.46	8.50
United Kingdom	1	1.59	1.91	2.42	2.67	2.80
	2	9.11	9.83	10.22	10.23	10.23
United States	1	17.32	20.41	20.55	20.52	20.51
	2	0.32	0.54	0.84	0.87	1.05
Sweden	1	4.76	7.13	7.86	7.96	7.95
	2	0.47	0.83	0.92	0.95	0.97

increases from approximately 2% prior to the IT regime to 10% during the IT regime, whereas variance ratio is similar across the two sample periods in New Zealand. This observation implies that the variance ratio for inflation relative to that for output growth decreases drastically in the United Kingdom and in New Zealand. The predictive contents of the spread for inflation drop significantly compared with those for output growth in the two countries with the strictest IT.

C. Discussion

Overall, the empirical results based on the two measures of predictability are consistent with each other, and they support the hypothesis that the adoption of IT is responsible for reducing the predictive contents of the term spread for future inflation, even if the empirical evidence for the hypothesis is weak in some IT countries, such as Australia and Canada. Our results indicate that the credibility in the actual implementation of IT matters for a reduction of the forecasting contents of the term spread for inflation. Based on papers by Bernanke and Mishkin (1997) and Svensson (1999), the characteristics and implementation of IT are not homogeneous among the IT countries. Assessing the consequences of the different forms of IT in theory and practice is beyond the scope of this paper, but a reduction in the forecasting power of the term spread for inflation is clearly pronounced in the two strictest IT countries, namely, the United Kingdom and New Zealand.

We follow the majority of the literature in testing the forecasting power of the term spread by excluding the short-term interest rate in the forecasting equation. For instance, the short-term interest rate is not included in the forecasting equations in the work of Mishkin (1990b), who used the Fisher equation to deduce a forecasting equation, and Estrella (2005), who combined the Expectations hypothesis with a set of simple New Keynesian models to derive a forecasting equation. These studies are theoretically sound, but some challenges against the omission of the short-term interest rate have been made on various grounds. Kozicki (1997), for example, argued that the short-term interest rate is a better measure of monetary policy than the term spread, which is subject to the fluctuation of a time-varying term premium, and shows that the marginal predictive contents of the term spread dissipate after controlling the short-term interest rate. The results for output growth are mixed. Estrella and Mishkin (1997) found that the predictability is still significant when the interest rate is included, whereas Ang *et al.*

TABLE 5

INFLATION VARIANCE (%) ACCOUNTED FOR BY TERM SPREAD IN THE IT COUNTRIES WHEN INCLUDING THE SHORT TERM INTEREST RATE IN PREDICTION EQUATIONS

Country	Period	4	8	12	16	20
Austria	1	3.79	4.17	6.85	9.67	11.56
	2	6.67	8.61	15.87	20.27	22.43
Canada	1	2.72	2.48	3.05	4.36	5.42
	2	2.82	3.64	3.91	3.97	4.05
New Zealand	1	1.72	3.48	3.50	3.52	3.50
	2	1.12	1.18	1.29	1.29	1.29
United Kingdom	1	5.40	11.38	12.70	13.40	14.25
	2	0.75	1.80	2.03	2.05	2.06
United States	1	4.04	5.56	6.97	8.61	10.07
	2	3.77	4.90	6.38	7.22	7.87
Sweden	1	7.16	7.03	6.79	6.78	6.69
	2	5.58	6.80	6.77	6.81	6.91

(2006) and Benati and Goodhart (2008) reported the opposite result.

Both approaches are appealing, but we provided our results based on the forecasting equation in the absence of the short-term interest rate. When the short-term interest rate is included in our forecasting equations, the results are weaker with regard to supporting the hypothesis. Instead of replicating all the results with the interest rate, we present the variance ratio statistics for the IT countries based on VAR analysis with inflation, output growth, short-term interest rate, and term spread.[9] Table 5 shows the h-step error variance of inflation accounted for by the term spread shock relative to the total variance for the IT countries over 5 years before and after adopting IT.

Reduction in forecasting power of the term spread for inflation is weaker when the short-term interest rate is included in the prediction equations, but comparing Tables 5 and 2 reveals conclusions that are qualitatively similar for most of the IT countries. Canada shows no difference in the predictive power of the term spread for inflation before and after IT, whereas New Zealand, the United Kingdom, and the United States show reduction in predictive power. One exception is Sweden;

[9] All results that consider the interest rate are available from the authors upon request.

when the short-term interest rate is included, the difference between the predictive powers before and after IT disappears. This observation might imply that the dynamics of the short-term rate in Sweden is much larger than in other country. Our results indicate that some of the predictive contents of the term spread are also embodied in the short-term interest rate, particularly in the first period.[10] We also find that the predictive contents of the term spread for inflation for the Non-IT countries and those for output growth in the IT countries, corresponding to Tables 3 and 4, respectively, are still random.

Including the short-term interest rate in the forecasting equations weakens the support of the hypothesis that IT is responsible for the reduction in forecasting power of the term spread for inflation, but the dissipating predictive power in the IT period is still observed in the strictest IT countries, namely, the United Kingdom and New Zealand.

VI. Conclusion

Numerous empirical studies investigating the forecasting power of the term spread for inflation exist in the literature. Overall, our results for individual countries agree with these studies. Nevertheless, no study systematically analyzes the relationship between IT and the predictive power of the term spread. Our main contribution is to bridge this gap in the literature and to provide empirical evidence in favor of the hypothesis that IT is responsible for a reduction of the predictive contents of the term spread for inflation. Specifically, we carefully select a group of IT countries, and a comparison was made between this IT group and a group of Non-IT countries. Moreover, we divide the sample period into the pre-IT regime and the IT regime in the IT countries, and we partition the sample period in the Non-IT countries into the two periods comparable to those in the IT countries. Subsequently, we directly test the predictability across the two periods in the IT countries, followed by a comparison of this predictability with that of the Non-IT countries. We also assess the predictive contents for inflation relative to those for output growth.

The main empirical findings of this paper can be summarized as fol-

[10] In finance, it is standard to extract the slope factor from the term structure as a second principal component orthogonal to the level and curvature factors [see Dai and Singleton (2000) for instance], and our results show that the term spread is closely related but not equal to the slope factor.

lows. First, in the group of IT countries, we find that the predictive power of the yield spread for inflation is generally low after the adoption of IT. Second, little or no systematic tendency of predictability for output growth is found before or after the adoption of IT. Third, we also find that the predictability of the term spread for inflation from period 1 to period 2 exhibits no systematic changes in the Non-IT countries. We are unable to conduct a robust statistical test on the differences in the predictive power over the two periods and across countries due to the small sample problem, but all of the abovementioned findings weakly support our hypothesis.

A number of avenues for future research may be motivated by our study, which also reveals some caveats of this paper. First, our paper does not directly test the causality of the hypothesis. For such a test, a sound theoretical background for the hypothesis should be developed. Second, we do not make a distinction between the expectations hypothesis component and the term premium embedded in the term spread. Decoupling these components of the term spread would have different implications in its relationship with IT. Third, our results appear to indicate that the form of IT does matter for the predictive contents of the term spread. Disentangling the degree of IT is by itself difficult, and it would be even more difficult to test a general relationship between the form of IT and the predictability for inflation and output. However, this difficulty is a worthy challenge for future research.

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Appendix: Description of the Long-Term Bond Yield and Short-Term Interest Rate

Country	Long-Term Bond Yield	Short-Term Interest Rate
Australia	Beginning July 1969, assessed secondary market yield on ten-year non-rebate bonds. Yield is calculated before brokerage and on the last business day of the month.	Weighted average short-term rate of outstanding loans. Beginning in January 1995, rate paid on unsecured overnight loans of cash as calculated by the Australian Financial Markets Association and published on Reuters page at 11 a.m. Beginning in January 1999, weighted average rate of the interest rates at which banks have borrowed and lent exchange settlement funds during the day. The rate is weighted by loan amounts.
Canada	Issues with original maturity of 10 years and over.	The overnight money market financing rate.
New Zealand	The yield of 10-year government bonds on the secondary market.	3 month or 90 day rates and yields: the average of market rates at 11 a.m. each day for bank bills with approximately 90 days to maturity.
United Kingdom	Issue at par with five years to maturity: theoretical gross redemption bond yields. Beginning June 1976, the calculations are based on a method described by Bank of England. Beginning January 1984, refers to the average daily secondary market yield on 10-year, fixed-rate government bonds.	Interbank offer rate for overnight deposits.
United States	Ten-year constant maturities.	Federal Funds Rates: weighted average rate at which banks borrow funds through New York brokers. The daily rate is the average of the rate on a given day weighted by the volume of transactions.
Sweden	Yields on government bonds maturing in 15 years. Beginning	The monthly average of daily rates for day-to-day interbank

Country	Long-Term Bond Yield	Short-Term Interest Rate
	January 1987, data refer to secondary market yields on bonds maturing in 10 years.	loans. STIBOR (Stockholm interbank offered rate) for 2004:Q4-2007:Q4.
Austria	All government bonds issued and not yet redeemed and are weighted with the share of each bond in the total value of government bonds in circulation. The data include bonds benefiting from tax privileges under the tax reduction scheme. Beginning January 1985, refers to secondary market yields of government bonds with a 10-year maturity.	Rate on one-day interbank loans among banks in Vienna. EONIA (Euro Overnight Index Average) since 1999: Q1.
Belgium	Beginning January 1980, rate refers to secondary market yields of government bonds with a ten-year maturity.	The 3-month interbank offer rate attaching to loans given and taken amongst banks for any excess or shortage of liquidity over several months. The 3 month "European Interbank Offered Rate" is used from the date the country joined the Euro (1999: Q1).
Denmark	Yield on five-year government bonds. Beginning June 1983, rate refers to secondary market yields of government bonds with a ten-year maturity.	Arithmetic average of offered interbank rates. Prior to January 1993, weighted average of three-month interbank rates.
France	Average yield to maturity on public sector bonds with original maturities of more than five years. Beginning January 1980, refers to secondary market yields of government bonds with a ten-year maturity.	Prior to January 1999, data refer to the monthly average of rates for overnight loans against private bills, based on opening quotations. EONIA (Euro Overnight Index Average) since 1999: Q1.
Germany	Bonds issued by the Federal government, the railways, the postal system, the Länder governments, municipalities, specific purpose public associations, and other public associations established under special legislation. Average yields on all bonds with remaining maturity of more than three years	Period averages of ten daily average quotations for overnight credit.

Country	Long-Term Bond Yield	Short-Term Interest Rate
	weighted by amount of individual bonds in circulation. Beginning January 1980, rate refers to yields on listed federal securities which can be delivered on the German Financial Futures and Options Exchange (DTB) with a remaining maturity of nine-to-ten years.	
Italy	Beginning January 1980, average yields to maturity on bonds with residual maturities between 9 and 10 years. From January 1999 onward, monthly data are arithmetic averages of daily gross yields to maturity of the fixed-coupon, ten-year treasury benchmark bond, based on prices in the official wholesale market.	Three-month interbank rate. Beginning in February 1990, data represent arithmetic averages of daily rates, which are weighted averages of rates based on the volume of transactions for the day.
Netherlands	Secondary market yields of the most recent 10-year government bond.	Average market rate paid on bankers' call loans. EONIA (Euro Overnight Index Average) since 1999: Q1.
Portugal	Weighted monthly average of daily yields on floating rate ten-year government bonds. Beginning in July 1993, simple monthly average of daily yields on ten-year floating rate government bonds in the secondary market.	Prior to 1986, weighted average rate for interbank deposits up to three days. From 1986 to 1991, the weighted average rate for interbank deposits up to five days. Beginning in 1992, weighted monthly average rate for interbank overnight transactions. Beginning of 2000:Q2, weighted average rate of the non-collateralised same-day-value operations traded in the SITEME Interbank Money Market, with maturity of 1 working day.

All data are obtained from International Financial Statistics except for the following. The data of New Zealand (long- and short-term rates) and Belgium (short-term rates) are from OECD. The short-term interest rates of Austria, France, and the Netherlands since the first quarter of 1999 are from ECB. The short-term rates of Portugal since the second quarter of 2000 are from Banco de Portugal. The short-term rates of Sweden since the fourth quarter of 2004 are from Riksbank. Most of the series descriptions are also obtained from the IFS country notes, 2010.

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