Direct tests of the expectations theory of the term structure: Survey expectations, the term premium and coefficient biases

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Abstract
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JEL: E43, G10, G12
Keywords: Expectations theory, term structure of interest rates, survey expectations, term premium

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1 INTRODUCTION

A large literature has reported on various empirical tests of the expectations theory of the term structure of interest rates (ET). Common tests include the forward rate and excess holding return tests, roll-over spread tests, cointegration tests, VAR restrictions, and variance bound test. It appears to be the view of many economists that the ET is generally rejected in empirical tests. They point out that estimated coefficients do not conform to their hypothesized theoretical value, particularly when using data from the U.S., and auxiliary studies tend to find problems with the assumption of rational expectations. Without reviewing the empirical literature in great detail, a comparison of the various and frequently contradictory results shows that the empirical evidence is in fact far from conclusive, particularly when viewed across countries, across markets, across sample periods, and across various testing methodologies.[1] The United States Treasury bill market consistently provides results that reject the usual ET hypotheses, whereas interest rates from many other markets and other countries tend to support the ET. The ET is sometimes rejected for some bond or for some money market maturity ranges, but supported when using the opposite maturity range. Certain statistical tests seem to result in more frequent rejections than other tests. The essential question that follows from the various empirical results should be why the evidence is in fact so mixed. We know that as a result of the very nature of (economic) theories - being simplified and abstract representations of reality -, it is always possible to empirically reject a theoretical model (Fama, 1991).[2]

There are surprisingly few studies that test the ET directly using survey expectations.[3] There may be several reasons for this. First, most studies using survey data focus on the quality of the forecasts, presumably partly on the assumption that 'rational' forecasts are required before they can be used. Second, the survey data are frequently not immediately suitable for direct tests of the ET due to the use of period averages and forecast horizons that do not match the available term structure data. Finally, survey data are viewed with some suspicion, because the survey responses do not necessarily correspond to the true expectations and may not represent the expectations of the relevant investor(s).

As far as I have been able to determine, the earliest investigation of the ET using survey expectations was reported by Kane and Malkiel (1967). Friedman (1979) uses quarterly data from the U.S. Goldsmith-Nagan Bond and Money Market Letter on one-quarter-ahead and two-quarters-ahead expectations for the 3-month Treasury bill. His results show that the term premium is not zero and in fact time-varying. Froot (1989) uses the same source on survey expectations for several short and long interest rates and finds that the forward premium is a biased estimate of expected future interest rate changes. For short-maturity interest rates the results suggest a time-varying term premium. For short-term changes in long-maturity interest rates a time-varying term premium appears to be relatively unimportant, but the survey expectations exhibit systematic forecast errors (i.e. underreacting, most likely related to a similar phenomenon in inflation expectations during the same sample period). Cook and Hahn (1990) also use the Goldsmith-Nagan survey data and their results show that the survey data improve the performance of the forward rate equations, although the R^2 is still relatively low and rejection of the EH restriction persists in the Treasury bill market (but not in the Eurodollar and Commercial Paper market). Batchelor (1995) employs the Blue Chip Financial Forecasts which provides monthly observations on one to three-quarter-ahead expectations of 3-month U.S. Treasury bills. His conclusion is that the time-varying term premium is as important as the time-variation in expected

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[1] Shiller (1990), Cook and Hahn (1990), Campbell (1995) and Rudebusch (1995) provide most of the typical results and associated discussions. Key empirical studies using a multi-country framework and various types of tests are Jorion and Mishkin (1991), Hardouvelis (1994), Siklos and Wohar (1996), Gerlach and Smets (1997). Recent studies include Jondeau and Ricart (1999), Dominguez and Novales (2000), Drakos (2002). Empirical results have been shown to depend on the choice of sample period (Mankiw and Miron, 1986; Hardouvelis, 1988; Simon, 1990; Hsu and Kugler, 1997), country (Kugler, 1988; Gerlach and Smets, 1997; Jondeau and Ricart, 1999), market segment (Cook and Hahn, 1990; Longstaff, 2000; Downing and Oliner, 2007), maturity horizon (Cook and Hahn, 1990; Jorion and Mishkin, 1991), data frequency (Choi and Wohar, 1991; Drakos, 2002), and estimation method (Driffill, Psaradakis and Sola, 1997, 1998).

[2] Dotsey and Otrok (1995, p.65) even go so far as to argue that "the rejections are so striking that the large amount of irrationality implied by the data is too implausible".

[3] MacDonald (2000) provides a recent survey of the literature using survey data for foreign exchange, interest rates and stock market prices. A broader review of the use of survey data in economics is Pesaran and Weale (2006).

interest rate changes in explaining movements in the forward spread. MacDonald and Macmillan (1994) examine the Consensus Forecasts data on one-quarter ahead UK 3-month interbank rates. They find that 60% of changes in the forward spread can be explained by a time-varying term premium, although this result depends crucially on the inclusion of observations related to the UK's ERM crisis in the early 1990s. Jongen, Verschoor and Wolff (2005) examine an international dataset for 20 countries. They report that the null-hypothesis for the ET coefficient is rejected for 16 of the 20 countries. Important to note for future reference is that all these studies, except Friedman (1979), regress the survey expectation on the forward rate rather than the reverse.

As mentioned before, there are many more studies interested in examining the quality of survey forecasts of interest rates and testing the rational expectations hypothesis. Spiwoks, Bedke and Hein (2008, Table 1) provide an extensive list of studies on the accuracy of interest rate forecasts, but these studies are not directly relevant to this paper (see the discussion below). Most of these studies are for U.S. interest rates, using one of several surveys available for that country. More recently, Jongen and Verschoor (2008) report a large set of international results on forecasts of 3-month rates. For forecast horizons of 3 and 12 months, unbiasedness of survey forecasts is rejected for 7 and 15 of the 20 countries examined. The empirical results suggest a strong tendency for forecasts to follow adaptive or extrapolative mechanisms.

Before moving on to the empirical tests and results of this paper, I need to discuss two important issues and common confusions in the literature on respectively rational expectations and term premiums. First, most empirical studies have historically used the perfect-foresight-with-error version of the rational expectations hypothesis (REH) to substitute actual future interest rates for the expected interest rates of the model. Much of the empirical literature on the rational expectations hypothesis shows that the perfect-foresight model is problematic. Leaving aside certain crucial empirical problems with respect to data (e.g. real time data) and method used (e.g. accounting for common macro forecast errors in panel studies), the fundamental reason for the weak performance of the perfect-foresight model is that this basic model assumes that the economic environment is stochastic stationary, i.e. all economic agents have come to know the true economic model and have sufficient information to interpret the results of economic shocks. In contrast, real economies are more accurately described as stochastic non-stationary, i.e. experiencing unobserved regime shifts, structural breaks, etc., and subject to uncertainty rather than risk.[4] Consequently, economic agents do not have perfect foresight, but they must learn – rationally – in an uncertain environment and with only limited and costly time and information. In this economic environment, empirical results of bias and inefficiency of forecasts, particularly in small samples, do not necessarily signal a failure of rational expectations, but may simply reflect the need for a more complicated rational expectations model. The restrictive assumptions of the perfect-foresight-with-error model were already pointed out by the original developers of the rational expectations approach (see Muth, 1961, p.316-7 and Lucas and Sargent, 1979, p.13). For example, Lucas and Sargent state "it has been only a matter of analytical convenience and not of necessity that equilibrium models have used the assumption of stochastically stationary shocks and the assumption that agents have already learned the probability distributions they face. Both of these assumptions can be abandoned, albeit at a cost in terms of the simplicity of the model." [5] The perfect-foresight model remains extremely useful for theoretical analyses, but its assumptions simply do not fit the real world very well.

Second, many empirical studies have defined the ET as a theory that supposedly presumes that risk, liquidity or term premiums in interest rates are zero or constant. However, this is an unnecessarily narrow view of the theory. The constant term premium should be regarded as an auxiliary assumption that suited easy exposition of the theory, as well as facilitating empirical tests using a fixed intercept in regression analysis. Historically, the original authors were well aware of the risk or term premium. Fisher (1896, p.91) notes that the interest rate relationships he discusses are subject to variations due to uncertainties of various kinds. Lutz (1940, p.36), frequently credited for the pure ET model, states as one of his initial assumptions that everybody concerned knows what the future short-term rates will be; and with perfect foresight there is no risk. He discusses the effect of risk and liquidity premiums later, and actually seems to prefer a preferred habitat

[4] The difference between uncertainty and risk refers to the discussion by Knight (1921, Chapter 7) and Keynes (1936, Chapter 12). See Meltzer (1982) for a comprehensive review of the issues.
[5] For a detailed critique of the common empirical rational expectations tests see Webb (1987).

model (Lutz, p.48). Lutz even discusses the empirical bounds on arbitrage due to trading costs. In essence, the ET is a fundamental no-arbitrage condition for financial markets - a parity condition. In economic theory, adequate compensation for risk and liquidity are natural components of a no-arbitrage condition (as are arbitrage bounds due to trading costs), and there is nothing in economic theory that suggests that risk and liquidity premiums should be constant over time. Although tests of a zero or constant term premium might be called tests of the hypothetical pure form of the ET, a time-varying term premium is not a failure of the ET, but simply an unfortunate complication for empirical research and at the same time a call for a better term premium model. As noted by Fama (1984, p.509), "Variation through time in these premiums can obscure the power of forward rates as predictors of future spot prices." Different premium models (i.e. liquidity: Hicks (1939), Lutz (1940), preferred habitat: Culbertson (1957), Modigliani and Sutch (1966), risk: Benninga and Protopapadakis (1983)) are not alternatives to the ET perse, but specific elaborations on a neglected but natural component of the general ET.

The structure of the remainder of this paper is as follows. Section 2 presents the empirical model for the direct tests of the ET and discusses the problem of coefficient biases. Section 3 presents the data and empirical results. Section 4 concludes the paper. This paper finds that the ET is not rejected in an empirical test that 1) uses survey data to correct for the failing perfect-foresight-with-error rational expectations assumption, and that 2) estimates the version of the test equation that minimizes the bias from the unobserved stochastic term premium or a measurement error.

2 SPECIFICATION OF THE EMPIRICAL TESTS

2.1 Forward rate tests

There are many versions of empirical tests of the ET. However, studies using survey expectations of future interest rates generally focus on the equation

$$(1) \quad E_t r_{t+k}^{n-k} - r_t^{n-k} = \alpha_1 + \beta_1 (f_t^{(n,k)} - r_t^{n-k}) + \nu_t^{n-k}$$

According to the ET the forward rate at time t calculated from a long maturity interest rate of n periods and a short maturity interest rate of k periods ($f_t^{(n,k)}$), should be equal to the expected future interest rate at time t+k for an interest rate of n-k maturity ($E_t r_{t+k}^{n-k}$), corrected for a term premium (θ_t^{n-k}).

$$(2) \quad f_t^{(n,k)} = E_t r_{t+k}^{n-k} + \theta_t^{n-k}$$

Under the null hypothesis of the ET, coefficient β is expected to equal one and the intercept α represents the unobserved term premium. The correction to the level of variables introduced by subtracting r_{t+k}^{n-k} left and right is used to solve econometric problems associated with non-stationary variables (i.e. spurious regression).[6]

It is important to note that the use of equation (1) is a result of historical studies that replaced $E_t r_{t+k}^{n-k}$ with r_{t+k}^{n-k} , invoking the rational expectations hypothesis. Equation (1) allowed the presumably random forecast error to be relegated to the equation residual. In principle, switching left hand side and right hand side variables does not change the tested hypothesis in any material way. We can therefore also write the equation as

$$(3) \quad f_t^{(n,k)} - r_t^{n-k} = \alpha_2 + \beta_2 (E_t r_{t+k}^{n-k} - r_t^{n-k}) + \nu_t^{n-k}$$

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[6] Equation (1) is generally supplemented with similar equations that allow examination into contributions of expectations errors and predictable changes in the term premium or forward premium (see Froot, 1989).

Equations (1) and (3) differ in their sensitivity to alternative sources of an errors-in-variables problem. Imperfect measurement of interest rate expectations and a stochastic but unobserved term premium result in biased regression coefficients. This coefficient bias argument relating to ET regressions was introduced by Fama (1984) and Mankiw and Summers (1984).[7] Attempts to solve the bias problem include estimation with instrumental variables (for example, Driffill, Psaradakis and Sola, 1997) and modeling the dynamics of the term premium (for example, Tzavalis and Wickens, 1997). Only a few studies have attempted to solve the problems involving the rational expectations hypothesis by using interest rate expectations collected in various surveys of market participants and forecasting institutions.

Ignoring the complications of non-zero correlations and serial correlations, and using a simplified notation, it is easy to show that the Ordinary Least Squares estimate of equation (1) results in

$$(4) \quad \beta_1^{OLS} = \frac{\text{var}(E_t \Delta r)}{\text{var}(E_t \Delta r) + \text{var}(\theta_t)} = \frac{1}{1 + \text{var}(\theta_t) / \text{var}(E_t \Delta r)}$$

The estimated coefficient β_1 equals one when the variance of the term premium θ is zero. The bias towards zero increases when the variability of the predictable change in interest rates declines <u>relative</u> to the variance of the term premium. Of course, the predictable change in short-term interest rates is heavily influenced by the type of monetary policy that exists in a particular country and time period and is in practice frequently subjected to regime shifts. This insight provides a very natural interpretation of the many different results reported for various countries and sample periods. Mankiw and Miron (1986) and Hardouvelis (1988) emphasized the importance of the <u>relative</u> volatility of the term premium compared to the predictable changes in interest rates during alternative monetary policy regimes. Gerlach and Smets (1997) provide supporting empirical evidence in a multi-country perspective by showing how the predictability of future short-rates is related to the estimated values of β. The simulation studies of Rudebusch (1995) and Dotsey and Otrok (1995) show that results with the rational expectations assumption are very sensitive to the time series model of the monetary policy rate. McCallum (1994) has shown that tests of the ET result in inconsistent estimates when the short-term monetary policy rate responds to changes in the long-short interest rate spread and uses it as an information variable.

Similarly, we find that the OLS estimate of equation (3) results in

$$(5) \quad \beta_2^{OLS} = \frac{\text{var}(E_t \Delta \bar{r})}{\text{var}(E_t \Delta \bar{r}) + \text{var}(\varepsilon_t)} = \frac{1}{1 + \text{var}(\varepsilon_t) / \text{var}(E_t \Delta \bar{r})}$$

, where $\bar{r}$ and ε denote the true market expectation of the future interest rate and the measurement error in survey expectations, i.e. $E_t r_{t+k}^{n-k} = E_t \bar{r}_{t+k}^{n-k} + \varepsilon_t^{n-k}$ and $f_t^{(n,k)} = E_t \bar{r}_{t+k}^{n-k} + \theta_t^{n-k}$. The estimated coefficient β_2 equals one when the variance of the measurement error in the surveyed expected rate change is zero. The bias towards zero increases when the variability of the predictable change in interest rates declines <u>relative</u> to the variance of the measurement error.

Note that the errors-in-variables problem in equation (3) is probably reduced the most when we use the more direct and more accurate measurement of interest rate expectations from surveys.[8] The basic assumption underlying equation (3) is that the stochastic term premium that affects the forward rate is actually the most important econometric problem to solve, and the stochastic term premium component is in equation (3) relegated to the equation residual.

2.2 Roll-over spread tests

[7] Mankiw (1986) pointed out that measurement error, for example in long-term bond rates derived from estimated yield curves, also causes a bias to equation coefficients. Random market mistakes that represent deviations from the ET would have the same effect.

[8] Of course, survey expectations remain imperfect measurements. Generally we do not directly observe the expectations of market participants but only of (analysts of) forecasting institutions, and even more fundamentally, we do not observe the relevant marginal buyer and seller on the market but only the average of forecasts. In addition, there are complications with the available information sets and precise timing when various survey participants prepare their responses.

The 3-month forward rate test has become more or less the standard test in studies using survey data. Undoubtedly, this has been the result of availability of survey data with only one point forecast. Another test of the ET is the so-called roll-over spread test. In this test we compare the average of a series of expected future interest rates with the currently observed long-term interest rate. In previous studies this test has only been used with the auxiliary assumption of perfect-foresight rational expectations or an econometric forecasting model (e.g. a VAR model and corresponding restrictions).

According to the ET we expect to find β_3=1 in a regression equation

$$(6) \quad (1/n)\sum_{k=0}^{n-1} E_t r_{t+k}^1 - r_t^1 = \alpha_3 + \beta_3 (R_t^n - r_t^1) + \nu_t^n$$

, where R_t^n , r_t^1 are the n-period and 1-period interest rates at time t.

Reversing the two dependent and independent variables as before we can also estimate an equation (7) with the ET hypothesis β_4=1. In a similar way as before, it is easy to show that the two equations differ in their sensitivity to a term premium and a measurement error bias. It is also important to note that equation (6) for the roll-over spread and equation (1) for the forward spread differ in their sensitivity to a stochastic term premium. The aggregate term premium in the long-term rate is an average of a series of individual short-term forward rate term premiums. If the stochastic component in the forward term premiums averages to zero, the coefficient bias in equation (6) may be less than the bias in equation (1).

3 EMPIRICAL RESULTS

3.1 Data sources and issues

The main source of interest rate expectations used in this paper is the monthly survey by Consensus Economics for the G-7 countries and Western Europe. Each month a number of private sector forecasting institutions, normally from each of the selected countries, are surveyed and the individual forecasts and the arithmetic average, mean or 'consensus' forecast are reported. The interest rate forecasts are part of a range of macroeconomic forecasts, including inflation, real GDP growth and foreign exchange rates. The official survey date is the second Monday of every calendar month, although most survey participants send their responses on the Friday before the publication day. For the empirical analysis, Jongen et al. (2005) use the Friday before the official survey date, whereas MacDonald and Macmillan (1994) decided to use the 2nd Monday date. I follow the latter, assuming that this is the day that forecasts will have been worked into market prices.

The forecast horizon for the monthly forecasts is the end of the month 3-months and 12-months ahead (i.e. the January survey forecasts are for the end of April and the end of January next year). Given the survey date, the true forecast horizon is thus actually slightly longer than 3 and 12 months. In this study I use the monthly survey data for the 3-month interest rate for eight countries: the United States, the United Kingdom, Canada, Germany, Japan, Sweden, Norway and Switzerland.[9] The sample period is determined by the constraints of a library subscription to the survey and covers January 1996 to December 2007. The sample ends with 2007 in order to avoid complications from the recent turmoil in financial markets. Data for Norway and Switzerland were added to the survey in June 1998. For Canada a longer data set is available that starts in October 1989.

The money market term structure data are in most cases obtained from Thompson Reuters Datastream. Selection of the appropriate time series variables involved some careful consideration of available sources and definitions, as well as interpreting the most likely moment of some changes in the forecasted rate (see the data appendix). Use of the money market rates is relatively straightforward, taking into account money market conventions of simple interest calculations. The only adjustment made to the data is the conversion of U.S. Treasury bill discount rates into investment yield interest rates using the formula $r_y = r_d\,[100 / (100 - r_d\, m/360)]$ where r_d and m are the discount rate and maturity of the T-bill (m=91 and 182). Canadian T-bills are already reported on an investment yield basis, although they are annualized using 365 days (as are U.K.

[9] Monthly survey data on 10-year government bond yields is also available. Semi-annual surveys in April and October include long-term forecasts for the 10-year government bond yield for 2 to 10 years ahead.

rates). In the case of Japan, data availability necessitates that we change the rate definition from the CD rate indicated in the survey to the Euro-yen and interbank rate, but these rates match the survey data very well. The 3-month forward rate 3-months ahead is calculated using the formula $f^{6,3} = 400*((1+r^6/200)/(1+r^3/400)-1)$. There is a slight mismatch between the forecast horizon (3+ months) and the available term structure data (generally 1, 3, 6 and 12 months), and further refinements in terms of compounding and day counting will unfortunately always remain within the bounds of approximation and measurement error.

In addition to the monthly forecasts, the Consensus Economics Forecasts survey provides quarterly (March, June, September, December) forecasts for 3-month interest rates with quarterly intervals up to seven quarters ahead. As far as I know, these data have not been used before to test the ET. I use the current 3-month rate and the expected 3-month rates for Q+1 to Q+3 to match survey expectations with the actual 12-month interest rate from the money market term structure. Taking into account money market conventions, the 12-month rate implied by the survey forecasts is $(1+R^{12}/100) = (1+r^3/400)\ (1+s^3_{+3}/400)\ (1+s^3_{+6}/400)\ (1+s^3_{+9}/400)$, where R, r, and s refer to the current long rate and short rate and the survey forecasts. Calculations for the U.S. Treasury bill data are slightly different due to their discount rate notation and the fact that the series for the 12-month Treasury bill secondary market rate has been discontinued. The term structure data are in this case obtained from the U.S. Treasury constant maturity rates. The constant maturity data however refer to bond yields with semi-annual compounding. After the conversion from discount rate to investment yield (as before), the 3-month T-bill rates imply a 12-month constant maturity bond yield (y^{12}) of $(1+y^{12}/200)^2 = (1+r^3/400)\ (1+s^3_{+3}/400)\ (1+s^3_{+6}/400)\ (1+s^3_{+9}/400)$.

To examine the robustness of the results to changes in sample period and survey, additional forecasts for 3-month U.S. Treasury bill rate are taken from the Survey of Professional Forecasters. Quarterly interest forecasts in the SPF start with the survey of the third quarter of 1982. At least two assumptions must be made when using these survey data. First, there are no explicit survey dates mentioned in the source for before 1992Q3 when the Federal Reserve Bank of Philadelphia took over responsibility for the survey. I maintain the assumption that the survey date for 1982-1992 has been the 20th of the middle month of every quarter. If the 20th falls on Saturday or Sunday the survey date is moved forward to Monday in order to obtain the relevant term structure data. The second problem is that the forecasts refer to the quarterly average rate, rather than the rate on a specific date. One solution used in previous studies is to assume that the quarterly average can be used for the middle of the month (i.e. 15th). In matching the 3-month forward rate 3-months ahead and the survey expectation the assumption is therefore that the one-quarter ahead quarterly forecast can be treated as the expected rate exactly 3-months ahead from the survey date.

Recent studies have argued that consensus forecasts may be subject to an aggregation bias and that it is worthwhile to exploit cross-sectional information from surveys, particularly when time series data is limited. Although forecasts from individual forecast institutions are available from the survey, I only use the average (= mean) consensus forecast. Using the median of forecasts may be preferable in order to eliminate sensational outlier forecasts, but this measure is not available without substantial data collection effort and outliers are much more likely to be present in longer horizon forecasts. The main reason for not using a pooled estimation strategy is that it incorrectly assumes that market efficiency requires all individual forecasts to be rational and efficient. Market efficiency, however, relates to average market behavior or more specifically the influence of the important marginal investor. Observing individual irrationality cannot disprove market efficiency and/or the ET.

3.2 Results on the forward rate test

Equations (1) and (3) are estimated using the ordinary least squares method with Newey-West HAC standard errors. A monthly data frequency and multi-month forecast horizon introduces an overlapping observations problem, in which case serial correlation of the residuals is expected. At the same time the HAC standard errors also make a correction for the likely presence of heteroskedasticity.

Table 1 provides simple descriptive statistics on the three variables of importance to the empirical analysis: the forward spread $f_t^{6,3} - r_t^3$ obtained from the term structure data, the expected rate change $E_t r_{t+3}^3 - r_t^3$

obtained from the survey data, and the implied term premium $f_t^{6,3} - E_t r_{t+3}^3$.[10] The average term premium is significant and positive for the U.S., Germany and Canada. For the U.K. the average term premium is negative but not significant. More important for this study are the measures of variability, because the discussion above suggests a very important role for the relative variability of expected rate changes and the term premium in the bias of estimated coefficients. The normal range of ratios between variances of the term premium and the expected rate change seems to be between 0.6 (Norway) and 0.9 (UK, Canada and Germany). Japan (2.2) and Switzerland (1.4) are outliers in this group of countries. These ratios indicate a high potential for substantial coefficient bias in estimates of equation (1). Equation (3) depends on the variability of the measurement error in the survey expectations, but the measurement error remains unobserved. In fact, the measurement error is a part of the estimated term premium. The maintained hypothesis in this paper, however, is that the measurement error is the smaller problem. Finally, the Jarque-Bera test statistic suggests that regression estimation and tests may suffer from deviations from the normal distribution. The underlying statistics suggest that excess kurtosis is the main problem.

Results for the estimation of equations (1) and (3) are presented in Table 2. Consistent with the previous literature we find that in equation (1) the hypothesis $\beta_1=1$ is strongly rejected in all eight countries. The forward rate in the money market term structure is found to be a biased indicator of market expectations. However, the results on the hypothesis $\beta_2=1$ in equation (3) provide a very different message. The ET hypothesis $\beta_2=1$ is not rejected, except in the case of Switzerland. On a secondary level, the weakest results for the ET are found for the U.S. Treasury bill market (p-value 5.3%) and Japan (p-value 9.1%). The overall results in Table 2 suggest a strong reversal in the performance of the ET by taking into account the econometric problem of coefficient bias.

The somewhat weak performance of the U.S. Treasury bill market is not entirely surprising given the results available from cross-country and cross-market analyses in previous studies. Empirical results in the literature also show that using Commercial Paper or Eurodollar market rates tends to be more favorable to the ET. Unfortunately, the survey data for these rates are not available. Why the U.S. Treasury bill market is such a special case remains a question to be answered, but many have suggested an effect of the importance of T-bills in U.S. central bank operations and banks' liquidity requirements.

Closer examination of the regression results and data suggests that several countries experienced sizable shocks to the term premium that could affect the regression estimates. The U.K., Japan, Germany, Sweden, Norway and Switzerland show a large increase in the observed term premium in three months centered on September or August 1999. Japan had a similar experience around October 1998. Perhaps this can be related to the year 2K problem that affected financial markets at the end of 1999. For Japan, October 1998 may relate to discussions of a bank bailout plan in Japan. This issue may require further discussion and analysis. The clear statistical rejection of the ET using the Swiss data disappears when the sample period is limited to 2000-2007 (the Swiss data consist of a small sample period and start in 1998M06), but this is of course an inadequate ad hoc solution.

For the longer sample available for Canada, descriptive statistics can be found in Panel B of Table 1. Regression results are presented in Panel B of Table 2. The results are similar to the results based on the shorter sample used in Table 1.

Descriptive statistics for the U.S. Survey of Professional Forecasters sample can be found in Panel C of Table 1. Regression results are presented in Table 2. The results are very similar to the results of the shorter sample used in Table 1. However, the probability value for the t-test on $\beta_2=1$ is now only 3.3%, and this results in a rejection of the ET on a conventional significance level of 5%. Further examination of the data and regression results shows that over longer time periods, in particular before 1995, the calculated term premium for the Treasury bill market is not on average constant, but the U.S. T-bill term premium has

[10] Each of the variables was dutifully examined for unit roots and stationarity using Ng-Perron and KPSS test statistics (results available as appendix). Not uncommon, the results of the tests are not always in agreement and require some judgment. The combined results suggest that the three variables can be considered stationary, when at least one of the two tests rejects the unit root or does not reject stationarity.

gradually decreased over time from at least 1981. This (broken) trend in the term premium may be an explanation for the coefficient bias that we find for the U.S. in the long sample. To capture this trending behaviour of the term premium I re-estimated equations (1) and (3) with an intercept dummy and linear trend. The estimated beta coefficients move towards one, no longer rejecting the hypothesis β_1=1 in equation (1) but still rejecting β_2=1 in equation (3). These results suggest that in these regressions the measurement error associated with the SPF data dominates the stochastic component of the term premium.

3.3 Results on the roll-over spread test

Results for equations (6) and (7) are presented in Table 3. Again, as in Table 2 we find that in equation (6) the hypothesis β_3=1 is strongly rejected in all eight countries. However, the results on the hypothesis β_4=1 in equation (7) again provide the opposite message. The ET hypothesis β_4=1 is not rejected for any of the eight countries. Compared to the forward rate test in Table 2 the roll-over spread test also eliminates or avoids the troublesome result for Switzerland, emphasizing the importance of selecting a specific test type. The weakest result in Table 3, as usual, is for the U.S. Treasury bill rates (β_4 p-value equals 5.9%).

Panel B of Table 3 presents additional results for the roll-over spread test using the longer time series for the U.S. SPF survey. The results are similar to Table 2. The two hypotheses β_3=1 and β_4=1 are both rejected using the SPF data. Taking again into account the long-term broken trend in the T-bill term premium the hypothesis β_3=1 is not rejected on a much larger p-value than β_1=1 in Table 2. Still, the alternative test β_4=1 remains strongly rejected, and again the suggestion based on our discussion of the theoretical model is that the measurement error for market expectations introduced by using the SPF data is important.

4 SUMMARY AND CONCLUSIONS

The expectations theory of the term structure of interest rates has a tarnished reputation in the empirical literature. Although the results of empirical tests are actually mixed when viewed across sample periods, markets and countries, the strong focus on studies using U.S. data causes that many economists regard the ET as empirically rejected.

This paper has highlighted three major issues with respect to the existing empirical literature. First, the rational expectations hypothesis (REH), as implemented in its perfect-foresight-with-error variant, is empirically weak, frequently rejected by the data and needs to be replaced by a more complicated rational expectations model that fits a stochastic non-stationary economy - as was already suggested by several of its original contributors a long time ago. Empirical tests of the ET based on the rational expectations hypothesis must be discounted because it is the secondary joint hypothesis (i.e. perfect foresight) that most likely causes the empirical rejection. Second, a time-varying term premium may be an empirical nuisance and may represent a rejection of the simplified textbook pure ET, but it does not present a rejection of the basic foundation of the general ET. The general ET is to be seen as a no-arbitrage condition or parity relationship that naturally includes appropriate compensation for risk, which in turn does not in any way need to be constant over time. Third, various tests have been developed for the ET, but some are clearly more sensitive to econometric problems than others. A careful examination must include the sensitivity of tests to the stochastic term premium bias and stochastic measurement error bias.

The empirical results in this paper show that by at the same time using survey data on interest rate expectations and taking into account the various sensitivities to coefficient bias, the expectations theory fits the term structure data very well in the eight countries examined in this paper.

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TABLE 1. Simple descriptive statistics

		Forward spread $f_t^{6,3} - r_t^3$	Expected change $E_t r_{t+3}^3 - r_t^3$	Term premium $f_t^{6,3} - E_t r_{t+3}^3$	Forecast error $r_{t+3}^3 - E_t r_{t+3}^3$
Panel A. Sample period 1996M01-2007M12, 144 monthly obs.					
US	Mean	0.252	0.225	0.027	-0.291
	St.dev.	0.237	0.192	0.172	0.547
	JB	[0.480]	[0.095]	[0.000]	[0.000]
UK	Mean	0.028	0.018	0.010	-0.010
	St.dev.	0.250	0.190	0.179	0.403
	JB	[0.001]	[0.000]	[0.000]	[0.020]
CN	Mean	0.260	0.151	0.109	-0.190
	St.dev.	0.266	0.189	0.175	0.529
	JB	[0.000]	[0.110]	[0.007]	[0.000]
JP	Mean	0.077	0.052	0.025	-0.026
	St.dev.	0.165	0.105	0.157	0.160
	JB	[0.000]	[0.001]	[0.000]	[0.000]
GE	Mean	0.070	0.010	0.061	0.027
	St.dev.	0.204	0.149	0.142	0.304
	JB	[0.124]	[0.005]	[0.000]	[0.723]
SWE	Mean	0.119	0.070	0.048	-0.147
	St.dev.	0.253	0.201	0.166	0.410
	JB	[0.000]	[0.018]	[0.000]	[0.001]
NO*	Mean	-0.153	-0.202	0.049	0.217
	St.dev.	0.414	0.327	0.250	0.715
	JB	[0.000]	[0.011]	[0.046]	[0.000]
SWI*	Mean	0.163	0.115	0.049	-0.089
	St.dev.	0.214	0.164	0.191	0.395
	JB	[0.000]	[0.000]	[0.000]	[0.001]
Panel B. Sample period 1989M10-2007M12, 219 monthly obs.					
CN	Mean	0.183	0.018	0.165	-0.153
	St.dev.	0.467	0.357	0.360	0.838
	JB	[0.000]	[0.000]	[0.000]	[0.000]
Panel C. Sample period 1981Q3 – 2007Q4, 106 quarterly obs.					
US	Mean	0.363	0.102	0.261	-0.174
	St.dev.	0.428	0.386	0.375	0.799
	JB	[0.000]	[0.000]	[0.000]	[0.000]

Notes: * Sample for Norway and Switzerland starts in 1998M06 with 115 obs. Panel A uses the monthly Consensus Economics survey data. Panel B for Canada uses an extended sample from the same survey. Panel C for the U.S. uses the quarterly Survey of Professional Forecasters.
JB is the probability value of the Jarque-Bera test of normality.

TABLE 2. Regression estimates of the forward rate test

(1) $E_t r_{t+k}^{n-k} - r_t^{n-k} = \alpha_1 + \beta_1 (f_t^{(n,k)} - r_t^{n-k}) + \nu_t^{n-k}$

(3) $f_t^{(n,k)} - r_t^{n-k} = \alpha_2 + \beta_2 (E_t r_{t+k}^{n-k} - r_t^{n-k}) + \nu_t^{n-k}$

					Probability values of t-tests		
		α	β	R^2	α=0 p-value	β=0 p-value	β=1 p-value
Panel A. Sample period 1996M01-2007M12, 144 monthly obs.							
US	Eq1	0.082	0.566	0.486			
		(0.020)	(0.073)		0.000	0.000	0.000
	Eq3	0.059	0.859	0.486			
		(0.030)	(0.072)		0.053	0.000	0.053
UK	Eq1	0.003	0.534	0.491			
		(0.020)	(0.095)		0.894	0.000	0.000
	Eq3	0.012	0.918	0.491			
		(0.025)	(0.104)		0.637	0.000	0.432
CN	Eq1	0.011	0.537	0.569			
		(0.023)	(0.047)		0.625	0.000	0.000
	Eq3	0.100	1.060	0.569			
		(0.021)	(0.141)		0.000	0.000	0.671
JP	Eq1	0.033	0.251	0.155			
		(0.016)	(0.059)		0.037	0.000	0.000
	Eq3	0.045	0.617	0.155			
		(0.013)	(0.225)		0.001	0.007	0.091
GE	Eq1	-0.027	0.523	0.514			
		(0.014)	(0.073)		0.063	0.000	0.000
	Eq3	0.061	0.983	0.514			
		(0.019)	(0.126)		0.002	0.000	0.891
SWE	Eq1	-0.001	0.599	0.573			
		(0.021)	(0.107)		0.964	0.000	0.000
	Eq3	0.052	0.956	0.573			
		(0.022)	(0.081)		0.022	0.000	0.591
NO*	Eq1	-0.106	0.628	0.634			
		(0.035)	(0.049)		0.003	0.000	0.000
	Eq3	0.051	1.009	0.634			
		(0.028)	(0.181)		0.075	0.000	0.960
SWI*	Eq1	0.050	0.397	0.269			
		(0.024)	(0.108)		0.038	0.000	0.000
	Eq3	0.086	0.677	0.269			
		(0.039)	(0.129)		0.030	0.000	0.014
Panel B. Sample period 1989M10-2007M12, 219 monthly obs.							
CN	Eq1	-0.073	0.495	0.419			
		(0.034)	(0.069)		0.033	0.000	0.000
	Eq3	0.168	0.847	0.419			
		(0.043)	(0.191)		0.000	0.000	0.425
Panel C. Sample period 1981Q3 – 2007Q4, 106 quarterly obs.							
US	Eq1	-0.088	0.523	0.337			
		(0.065)	(0.169)		0.179	0.003	0.006
	Eq3	0.297	0.644	0.337			
		(0.059)	(0.165)		0.000	0.000	0.033
US	Eq1 (lt)	0.003	0.697	0.477			
		(0.047)	(0.179)		0.946	0.000	0.093
	Eq3 (lt)	0.113	0.675	0.588			
		(0.038)	(0.108)		0.004	0.000	0.003

Notes: * Sample for Norway and Switzerland starts 1998M06. Newey-West HAC standard errors in parentheses (lag truncation=4).

Panel A and B use the Consensus Economics survey. Panel C uses the quarterly U.S. Survey of Professional Forecasters. Equations 1 (lt) and 3 (lt) include a linear trend and intercept dummy for the period 1981Q3-1997Q4 to capture the decline in the U.S. T-bill term premium.

TABLE 3. Roll-over spread regressions

$$(6)\quad (1/n)\sum_{k=0}^{n-1} E_t r_{t+k}^1 - r_t^1 = \alpha_3 + \beta_3 (R_t^n - r_t^1) + \nu_t^n$$

$$(7)\quad R_t^n - r_t^1 = \alpha_4 + \beta_4 ((1/n)\sum_{k=0}^{n-1} E_t r_{t+k}^1 - r_t^1) + \nu_t^n$$

		α	β	R^2	Probability values of t-tests α=0 p-value	β=0 p-value	β=1 p-value
Panel A. Quarterly sample period 1996Q1-2007Q4							
US	Eq6	0.102	0.403	0.254			
		(0.028)	(0.096)		0.001	0.000	0.000
	Eq7	0.145	0.629	0.254			
		(0.074)	(0.192)		0.056	0.002	0.059
UK	Eq6	0.040	0.632	0.568			
		(0.045)	(0.121)		0.384	0.000	0.004
	Eq7	0.036	0.899	0.568			
		(0.034)	(0.102)		0.297	0.000	0.326
CN	Eq6	0.113	0.431	0.496			
		(0.037)	(0.050)		0.003	0.000	0.000
	Eq7	0.067	1.150	0.496			
		(0.054)	(0.166)		0.206	0.000	0.371
JP	Eq6	0.032	0.449	0.364			
		(0.020)	(0.151)		0.115	0.005	0.001
	Eq7	0.035	0.810	0.364			
		(0.011)	(0.144)		0.002	0.000	0.194
GE	Eq6	0.014	0.557	0.636			
		(0.022)	(0.087)		0.535	0.000	0.000
	Eq7	0.039	1.141	0.636			
		(0.041)	(0.251)		0.353	0.000	0.576
SWE	Eq6	0.079	0.555	0.581			
		(0.032)	(0.076)		0.016	0.000	0.000
	Eq7	0.030	1.047	0.581			
		(0.032)	(0.121)		0.346	0.000	0.698
NO*	Eq6	0.002	0.710	0.796			
		(0.040)	(0.060)		0.956	0.000	0.000
	Eq7	-0.014	1.120	0.796			
		(0.044)	(0.115)		0.758	0.000	0.303
SWI*	Eq6	0.147	0.286	0.265			
		(0.029)	(0.103)		0.000	0.009	0.000
	Eq7	0.046	0.926	0.265			
		(0.106)	(0.354)		0.667	0.013	0.836
Panel B. Quarterly sample period 1981Q3 – 2007Q4, 106 quarterly obs.							
US	Eq6	-0.117	0.533	0.333			
		(0.076)	(0.158)		0.128	0.001	0.004
	Eq7	0.347	0.624	0.333			
		(0.060)	(0.139)		0.000	0.000	0.008
US	Eq6(lt)	0.000	0.796	0.553			
		(0.051)	(0.183)		0.944	0.000	0.267
	Eq7(lt)	0.093	0.685	0.671			
		(0.034)	(0.081)		0.007	0.000	0.000

Notes: * Sample for Norway and Switzerland starts 1998Q2. Newey-West HAC standard errors in parentheses (lag truncation=3).

Panel A uses Consensus Economics survey data. The September 2006 data were not available and are treated as a missing obs. Panel B uses U.S. Survey of Professional Forecasters. Equations 6 (lt) and 7 (lt) include a linear trend and intercept dummy for the period 1981Q3-1997Q4 to capture the decline in the US T-bill term premium.

APPENDIX. Data sources and definitions

Consensus Economics Forecasts
Although the Consensus Economics forecast survey (CF) states the specific interest rate that is forecasted, creating the term structure dataset has at least three complications. First, sometimes alternative sources or definitions exist. Second, term structure data may not be available. Third, the survey date data sometimes suggest that a shift in source or definition has occurred at a date different from the one indicated in the publication. The following series have been selected by matching the published survey date observation to the available data series.
United States: 3-month Treasury bill rate (secondary market, discount rate)
Data: Although CF data seem to be sourced from the Financial Times, US forecasting institutions are more likely to relate to the Federal Reserve H.15 time series. Datastream FRTBS3M, FRTBS6M
U.S. Treasury bill discount rates are converted into coupon equivalent or investment yield interest rates using the formula $r_y = r_d\,[100 / (100 - r_d\,m/360)]$ where r_d and m are the discount rate and maturity of the T-bill (m=91 for 3 months and 182 for 6 months)
For the quarterly analysis using the 12-month roll-over approach the Treasury constant maturity data are used because the FRTBS1Y is unavailable after August 2001. The constant maturity data are semi-annual compounded bond yields. Datastream FRTCM3M, FRTCM1Y.
United Kingdom: 3-month Interbank rate
Source Tradition. Data: Datastream LDNIB3M, LDNIB6M, LDNIB1Y. This series fits the CF data slightly better than the Libid/Libor rate available from the Bank of England.
Canada: 3-month Treasury bill rate (yield basis)
Data: Before 31Dec1993 only the weekly auction rate is available, but two series exist: one for the rate measured on Wednesdays, the other for the most recent Thursday auction. The Wednesday rate is used as the representative series. Source Cansim/Bank of Canada using Datastream CN13884, CN13885, CN13886. From 31Dec1993 the secondary market series. Source Bank of Canada using Datastream CNTBB3M, CNTBB6M, CNTBB1Y.
Japan: 3-month CD rate
Data: There is no term structure data available for the CD rate. Best match with the published CF data are: until Nov1998 Euro-Yen rate London. Source: FT/ICAP/TR using Datastream ECJAP3M, ECJAP6M, ECJAP1Y. From Dec1998 Tokyo Interbank Offered Rate (TIBOR). Source Japan Bankers Association through Datastream JPIBK3M, JPIBK6M, JPIBK1Y.
Germany: 3-month Euro-DM rate, from Jan1999 3-month Euribor
Data: Until Dec1998 Euro-Mark rate London. Source: FT/ICAP/TR using Datastream ECWGM3M, ECWGM6M, ECWGM1Y. From Jan1999 Euribor. Datastream EIBOR3M, EIBOR6M, EIBOR1Y.
Sweden: 3-month Euro-Krona, from Mar2004 3-month Deposit rate, from Aug2005 3-month Interbank rate
Data: Euro-Krona - until Mar1997 Source Goldman-Sachs Datastream GSSEK3M, GSSEK6M, GSSEK1Y and from Apr1997 source FT/ICAP/TR Datastream ECSWE3M, ECSWE6M, ECSWE1Y. The GSSEK series do not match during Nov1998-Dec1999. Deposit/Interbank rate: from Mar2004 Stockholm Interbank Offer Rate (STIBOR). Data: Source Bank of Sweden using Datastream SIBOR3M, SIBOR6M, SIBOR1Y. The Deposit rate data seems to suffer from infrequent trading or updating from approx. 2001.
Norway: 3-month Euro-Krone, from Mar2004 3-month Interbank rate
Data: Euro-Krone, until Jun1999. Source FT/ICAP/TR using Datastream ECNOR3M, ECNOR6M, ECNOR1Y. Interbank: Interbank (effective) rate fits the CF data best from Jul1999. Source Norges Bank using Datastream NWIBE3M, NWIBE1Y; corresponding 6-month (effective) rate obtained from the Norges Bank website.
Switzerland: 3-month Euro-SwissFranc
Data: Euro-SwissFranc rate London. Source FT/ICAP/TR through Datastream ECSWF3M, ECSWF6M, ECSWF1Y. It remains uncertain if Swiss forecasting institutions are more likely to relate to the Zurich Euromarket rate.

Survey of Professional Forecasters
The quarterly SPF asks participants to forecast the quarterly average 3-month Treasury bill rate (secondary market, discount rate). Source: Federal Reserve H.15 time series using Datastream FRTBS3M, FRTBS6M.
U.S. Treasury bill discount rates are converted into coupon equivalent or investment yield interest rates using the formula $r_y = r_d\,[100 / (100 - r_d\,m/360)]$ where r_d and m are the discount rate and maturity of the T-bill (m=91 for 3 months and 182 for 6 months).

APPENDIX

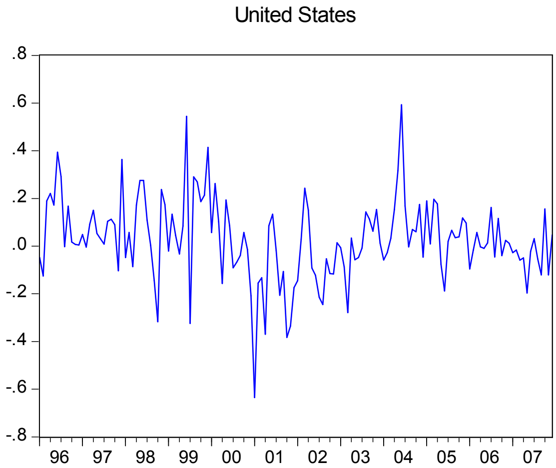
Unit root and stationarity tests

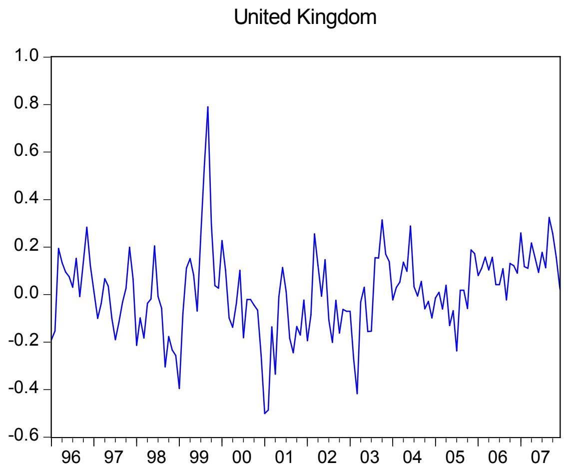
		Forward spread $f_t^{6,3} - r_t^3$		Expected change $E_t r_{t+3}^3 - r_t^3$		Term premium $f_t^{6,3} - E_t r_{t+3}^3$	
A. Sample period 1996M01-2007M12							
US	MZa	-10.21	**	-7.80	*	-60.35	***
	KPSS	0.14		0.31		0.25	
UK	MZa	-6.91	*	-3.41		-29.15	***
	KPSS	0.04		0.18		0.25	
CN	MZa	-11.32	**	-13.82	***	-29.79	***
	KPSS	0.45	*	0.08		0.90	***
JP	MZa	-77.68	***	-27.74	***	-44.57	***
	KPSS	0.31		0.43	*	0.13	
GE	MZa	-9.69	**	-24.23	***	-10.32	**
	KPSS	0.12		0.11		0.14	
SWE	MZa	-4.56		-3.28		-32.51	***
	KPSS	0.22		0.47		0.25	
NO*	MZa	-9.35	**	-10.31	**	-22.81	***
	KPSS	0.69	**	0.84	***	0.13	
SWI*	MZa	-22.88	***	-14.30	***	-26.69	***
	KPSS	0.14		0.49	**	0.25	
B. Sample period 1989M10-2006M05							
CN	MZa	-15.21	***	-7.69	*	-37.67	***
	KPSS	0.35	*	0.96	***	0.41	*

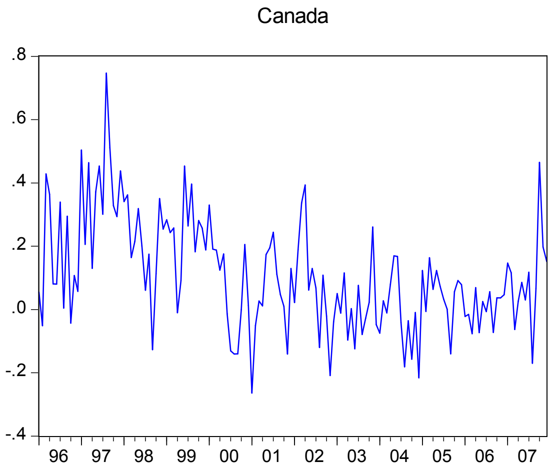
Notes: * Sample for Norway and Switzerland starts 1998M06.
MZa refers to the Ng-Perron modified unit root test with 1%, 5% and 10% critical values of -13.8, -8.1 and -5.7. KPSS test for stationarity, with critical values 0.739, 0.463, 0.347. ***, **, * symbols indicate significance at 1, 5 and 10 percent levels.

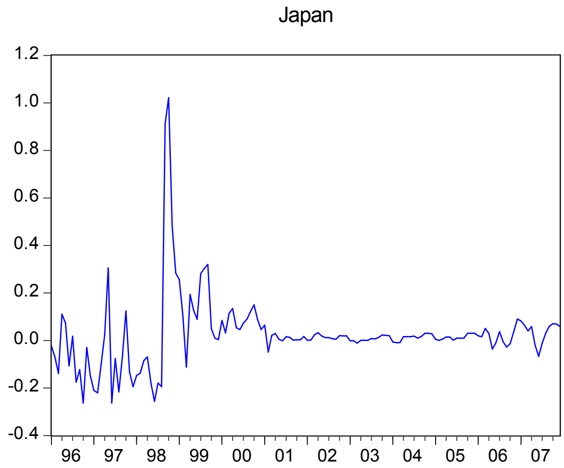
APPENDIX

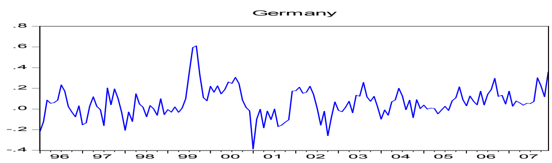
Term premiums in the 3-month forward rate: $f_t^{6,3} - E_t r_{t+3}^3$

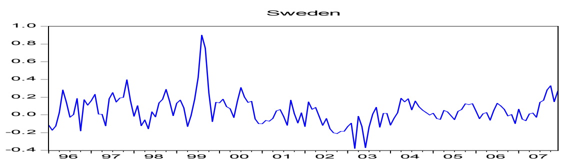




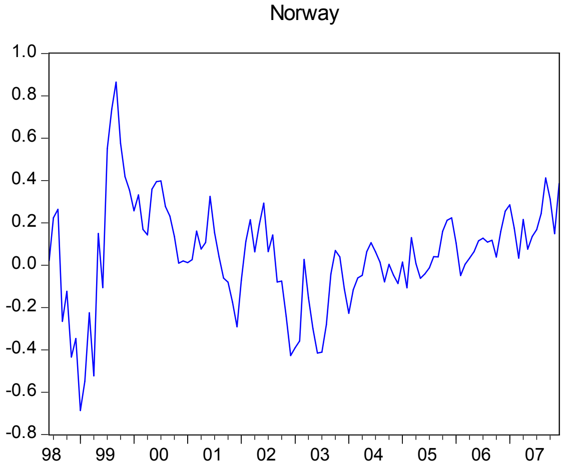


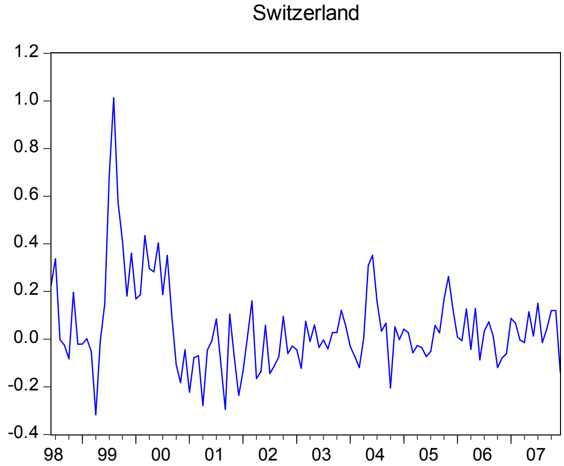


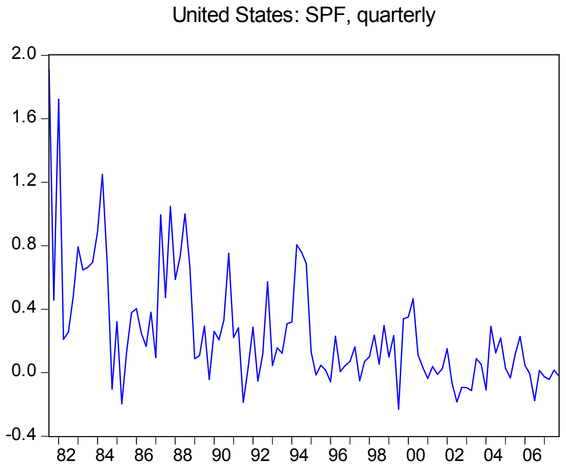




Term premiums in the 3-month forward rate (cont)

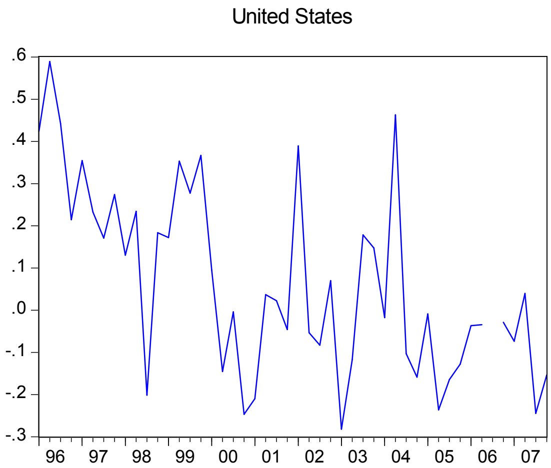


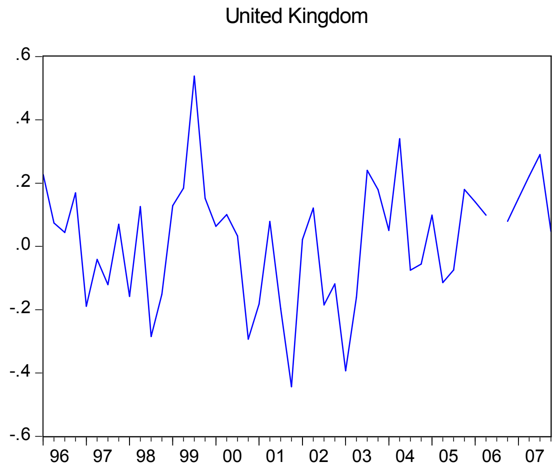


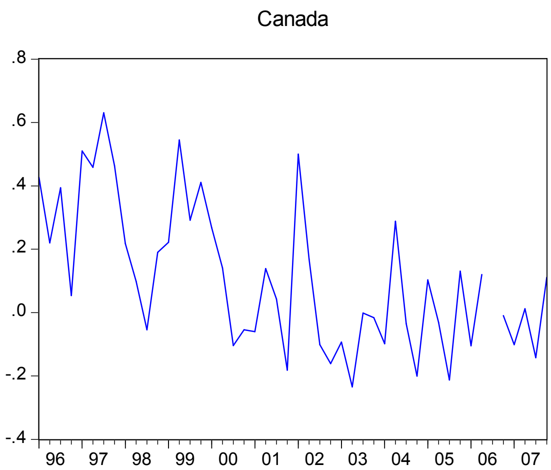


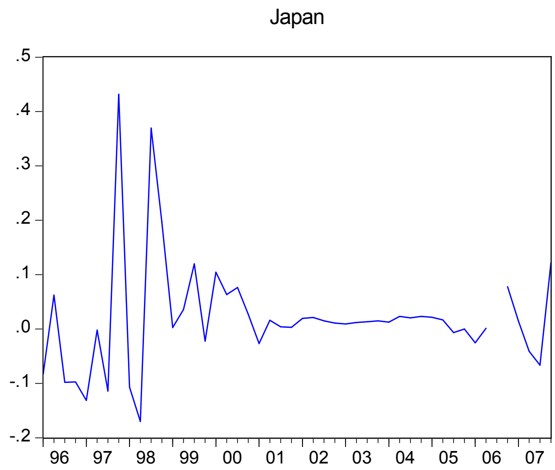
APPENDIX

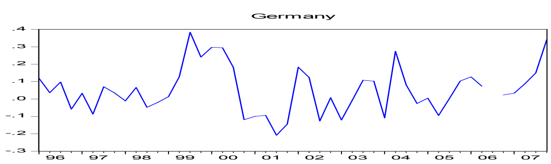
Term premiums in the roll-over spread: $R_t^{12} - (1/4)\sum_{k=0}^{3} E_t r_{t+3*k}^{3}$

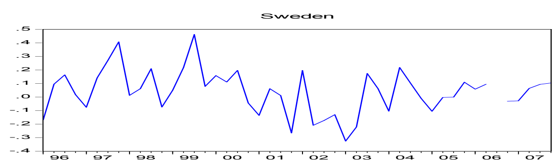












Term premiums in the roll-over spread (Cont)