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What Does the Yield Curve Tell Us about Exchange Rate Predictability?*

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Abstract

This paper uses information contained in the cross-country yield curves to test the asset-pricing approach to exchange rate determination, which models the nominal exchange rate as the discounted present value of its expected future fundamentals. Since the term structure of interest rates embodies information about future economic activity such as GDP growth and inflation, we extract the Nelson-Siegel (1987) factors of *relative* level, slope, and curvature from cross-country yield differences to proxy expected movements in future exchange rate fundamentals. Using monthly data between 1985-2005 for the United Kingdom, Canada, Japan and the US, we show that the yield curve factors predict bilateral exchange rate movements and excess currency returns one month to two years ahead. They also outperform the random walk in forecasting short-term exchange rate returns out of sample. Our findings have intuitive economic interpretations and offer an explanation to the uncovered interest parity puzzle.

Keywords: Exchange Rate Forecasting, Term Structure of Interest Rates, Uncovered Interest Parity
JEL Classification: E43, F31, G12, G15

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1. Introduction

Do the term structures of interest rates contain information about a country's exchange rate dynamics? This paper shows that the Nelson-Siegel factors extracted from two countries' relative yield curves can predict future exchange rate changes and excess currency returns one to twenty-four months ahead. When the home yield curve becomes steeper relative to the foreign one, over the subsequent months the home currency tends to depreciate and its excess return – currency returns net of interest differentials – declines. When the domestic yield curve shifts up or its curvature increases relative to the foreign one, home currency will appreciate subsequently, though the curvature response is not as robust. We also find that the relative factors together can forecast exchange rate out-of-sample one to two months ahead better than a random walk. Since the shape of the yield curve is known to reflect expected dynamics of future economic activity, our findings provide support for the asset pricing approach of exchange rate determination.

Decades of exchange rate studies have uncovered many well-known empirical puzzles, in essence failing to connect floating exchange rates to their theoretical macroeconomic determinants, or “fundamentals”.[1] From a theoretical standpoint, the nominal exchange rate should be viewed as an asset price; however, the empirical validation of this view remains elusive. This asset approach is consistent with a range of structural models and relates the nominal exchange rate with the discounted present value of its expected future fundamentals, which include money supply, output, inflation and others. As measuring market expectations is difficult, additional assumptions, such as a linear driving process for the fundamentals, are typically imposed in order to relate the exchange rate to its currently observable fundamentals.[2] The performance of the resulting exchange rate equations is infamously dismal, especially at short horizons such as less than a year or two.

This paper contends that market expectations may be more complicated than what econometricians can capture with the simple processes commonly assumed. As such, previous empirical failure may be the result of using inappropriate proxies for the market expectations of future fundamentals, rather than the failure of the models themselves. We propose an alternative method to test the asset approach by exploiting information contained in the shapes of the yield curves to capture market expectations. Research on the term structure of interest rates have long maintained that the yield curve contains information about expected future economic dynamics, such as monetary policy, output, and inflation,

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[1] The handbook chapter by Frankel and Rose (1995) offers a comprehensive summary of the various difficulties confronting the empirical exchange rate literature. Sarno (2005) and Rogoff and Stavrakeva (2008) present more recent surveys. Several recent studies examine the role of monetary policy rules such as the Taylor rule in exchange rate determination. By removing theoretical parameter restrictions, the Taylor rule fundamentals tend to deliver better performance in forecasting exchange rates (see, Molodtsova and Papell 2008; Wang and Wu 2009, for example).

[2] Engel and West (2005) and Mark (1995) are recent examples, among many others, that assume the fundamentals are driven by linear autoregressive processes.

which are all relevant exchange rate fundamentals.[3] Extending this lesson to the international context, we extract three Nelson-Siegel (1987) factors – *relative* level, slope, and curvature – from the cross-country yield curve differences to summarize the expectation information contained in the term structures of their interest rates.[4]

We look at three currency pairs over the period August 1985 to July 2005: the Canadian dollar, the British pound, and the Japan yen relative to the US dollar.[5] Using monthly yield data, we extract the three Nelson-Siegel relative factors from the zero-coupon yield differences between the three countries and the US at maturities from one month to ten years. Our in-sample predictive regressions show that all three relative yield curve factors can help explain and predict bilateral exchange rate movements and excess currency returns one month to two years ahead, with the slope factor being the most robust across currencies. We find that a one-percent increase in the relative slope or level factors of a country is associated with a 3-4% appreciation of its currency subsequently, with the magnitude of the effect declining over the horizon. The curvature factor has a much smaller effect of roughly one-to-one, and it is also the least robust. In our analysis, we pay special attention to the inference bias inevitable in our small sample long-horizon regressions, which we discuss in more detail in Section 3. In addition to in-sample predictive analysis, we conduct rolling out-of-sample forecasts to see how our model compares to the random walk forecasts, the gold standard in the Meese and Rogoff (1983) forecast literature.[6] Using the Clark and West (2006) test, we find that the relative factors model outperforms a driftless random walk forecast for horizons one to two months ahead.[7]

Tying floating exchange rates to macroeconomic fundamentals has been a long standing struggle in international finance. Our results suggest that to the extent that the yield curve is shaped by market expectations about future macro fundamentals, exchange rate movements are not "disconnected" from fundamentals but relate to them via a present value asset pricing relation. Moreover, our results have straight-forward economic interpretations, and offer some insight into the uncovered interest parity (UIP) puzzle.[8] In particular, we find that deviations from the UIP − the currency risk premium − systematically

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[3] See Sections 2.2 and 5.2 for details and empirical evidence that yield curve factors capture market expectations.

[4] The Nelson-Siegel factors are well-known for their empirical success over the past 20 years in providing a parsimonious summary for the price information for a large number of nominal bonds. See, for example Diebold, Piazzesi and Rudebusch (2005). Some papers proxy the yield curve by using only the term-spreads – the difference between the 10-year T-notes and the three-month T-bills. We use the Nelson-Siegel framework as it is more comprehensive.

[5] We note that our results hold also for the other currency pair combinations in our sample that do not involve the US dollar. For ease of presentation, we only provide results relative to the US dollar in this paper. Other results are available upon request.

[6] Since Meese and Rogoff (1983), the exchange rate forecast literature has repeatedly found the random walk model difficult to beat, especially at short horizons. See Frankel and Rose (1995) and Engel and West (2005).

[7] Due to our small sample size, we cannot obtain meaningful comparisons for long-horizon forecasts.

[8] UIP puzzle refers to the empirical regularity that when regressing exchange rate changes on the forward premium or interest differentials across countries, the slope coefficient tends to be negative instead of the theoretical prediction of unity. See Sec. 2 below for further details.

respond to the shape of the yield curves, or how the market perceives future inflation, output, and other macro indicators. Take, for example, our results that a flatter relative yield curve or an upward shift in its overall level predict subsequent home currency appreciation and a rising home risk premium. Since the flattening of the yield curve is typically considered as a signal for an economic slow-down or a forthcoming recession, a flat domestic yield curve relative to the foreign one suggests that the expected future growth at home is relatively low. In accordance with the present value relation, home currency faces depreciation pressure as investors pull out, and ceteris paribus, appreciates back up over time towards its long-term equilibrium value.[9] A similar explanation can also be applied to an increase in the level factor, which reflects rising expected future inflation.[10] Both of these scenarios can induce higher perceived risk about domestic currency holdings, leading to a significant rise in excess home currency returns, i.e. the risk premium associated with the domestic currency. Noting that a rise in the short-term interest rate can either flatten the slope of the yield curve or raise its overall level, it is then easy to see, through the above mechanism, that the home currency may subsequently appreciate instead of depreciate according to the UIP, if the risk premium adjustment is large enough. Even though we do not explicitly model expectations and perceived risks, our results are in accordance with simple economic intuition.

Using data from the Survey of Professional Forecasters, we provide empirical support that the yield curve factors are highly correlated, in the directions discussed above, with investors' reported expectations about future GDP growth and inflation in the US, as well as with their reported levels of "anxiety" about an impending economic downturn. In the appendix, we further show that the relative factors can explain exchange rate movements better than the typical UIP setup, and their explanatory power is beyond the information contained in the time series of the exchange rates themselves. As for their ability to capture market expectations, we believe the success of the yield curve factors in predicting exchange rates may also be partially attributable to their "real-time" nature. Molodtsova *et al*. (2008), for instance, estimate Taylor rules for Germany and the United States, and find strong evidence that higher inflation predicts exchange rate appreciation, using *real-time data* but not revised data. Finally, we note that our approach is consistent with previous research efforts using the term structure of the exchange rate forward premia to predict future spot exchange rate, such as Clarida and Taylor (1997) and Clarida *et al*. (2003).[11] Yield differences relate to exchange rate forwards via the covered interest parity condition. However, given that the exchange rate forwards are only available up to a year or so, our yield curve approach can

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[9] We note that this finding is contrary to the classic Dornbusch (1976) overshooting result but consistent with observations made in more recent papers, e.g. Eichenbaum and Evans (1995), that a rise in the US federal funds rate can lead to persistent appreciation of the dollar for two years or longer. Gourinchas and Tornell (2004) also demonstrate that when investors systematically underestimate the persistence in the interest rate process, a high interest rate in a country may lead to the subsequent appreciation of its currency. See also Clarida and Waldman (2008). The Dornbusch (1976) model predicts the opposite pattern: an immediate appreciation and subsequent depreciation in response to a higher interest rate.

[10] We present more detailed discussions and empirical evidence in Sections 2.2, 5.2, and 5.3.

[11] Clarida *et al*. (2003) find the term structure of forward premia contains useful information for forecasting future spot rates and proposes a regime-switching vector equilibrium correction model that out-performs a random walk.

potentially capture a much a wider range of relevant market information by looking at yields all the way up to ten years.

The rest of the paper is organized as follows. Section 2 discusses the relevant model and literature on the yield curve and nominal exchange rate modeling. Section 3 presents our data and empirical strategies. Our main results are shown in Section 4. Section 5 covers additional robustness checks and discussions. Finally, Section 6 concludes.

2. The Exchange Rates and the Yield Curves

Both the exchange rate and the yield curve have decades of research behind them. This paper makes no attempt to propose a comprehensive framework to jointly model the two (though we certainly believe it to be worthwhile endeavor).[12] Our conjecture here is that market expectations are extremely difficult to capture appropriately in simple models, contributing to previous difficulties in fitting the exchange rate models empirically. We thus propose to sidestep it all together, and instead extract expectation information directly from the data. In this section, we first present the standard workhorse approach to modeling the nominal exchange rate as an asset price. We then propose that progress in the yield curve literature, namely the empirical evidence that the yield curves embody information about expected future dynamics of key macroeconomic variables, can help improve upon the approach used in previous exchange rate estimations. Next, we offer a brief presentation on the Nelson-Siegel yield curve factors as a parsimonious way to capture the information in the entire yield curve at each point in time, and present a short discussion on excess returns and the risk premium.

2.1 The Present Value Model of Exchange Rate

The asset approach to exchange rate determination models the nominal exchange rate as the discounted present value of its expected future fundamentals, such as cross-country differences in monetary policy, output, and inflation. This present value relation can be derived from various exchange rate models that linearly relate log exchange rate, s_t, to its log fundamental determinants, f_t, and its expected future value $E_t s_{t+1}$. A classical example is the workhorse monetary model first developed by Mussa (1976) and explored extensively in subsequent papers. Based on money market equilibrium, uncovered interest parity and purchasing power parity, the monetary model can be expressed as:

$$s_t = \gamma f_t + \psi E_t s_{t+1} \tag{1}$$

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[12] Bekaert, Wei and Xing (2007) and Wu (2007) are recent examples that attempt to jointly analyze the uncovered interest parity and the Expectation Hypothesis of the term structure of interest rates.

where $f_t = (m_t - m_t^*) - \phi(y_t - y_t^*)$, m is money stock, y is output, "*" denotes foreign variables, and ϕ, γ, ψ (as well as λ below) are parameters related to the income and interest elasticities of money demand. Variations of the monetary model that capture price rigidities and short-term liquidity effects expand the set of fundamentals to: $f_t^M = (m_t - m_t^*) - \beta_y(y_t - y_t^*) - \beta_i(i_t - i_t^*) + \beta_\pi(\pi_t - \pi_t^*)$, as in Frankel (1979). Solving equation (1) forward and imposing the appropriate transversality condition, nominal exchange rate has the standard asset price expression, based on information at time t, I_t:

$$s_t = \lambda \sum_{j=0}^{\infty} \psi^j E_t(f_{t+j} | I_t) \tag{2}$$

This present-value expression, with alternative sets of model-dependent fundamentals, serves as the starting point for standard textbook treatments (Mark 2001; Obstfeld and Rogoff 1996) and many major contributions in the empirical exchange rate literature, such as Mark (1995) and Engel and West (2005).

Several recent papers emphasize the importance of monetary policy rules, and in particular, the Taylor rule, in modeling exchange rates (see Engel and West 2005; Molodtsova and Papell 2008; and Wang and Wu 2009 as examples). This approach assumes that central banks adjust short-term interest rates in response to target variables such as the output gap and inflation, and together with the uncovered interest rate parity condition, it can also deliver a set of fundamentals relevant to our discussion. We assume the monetary policy instruments, the home interest rate i_t and the foreign rate i_t^*, are set as follows:

$$\begin{aligned} i_t &= \mu_t + \beta_y y_t^{gap} + \beta_\pi \pi_t^e \\ i_t^* &= \mu_t{}^* + \beta_y y_t^{*,gap} + \beta_\pi \pi_t^{*,e} - \delta q_t \end{aligned} \tag{3}$$

where y_t^{gap} is the output gap, π_t^e is the expected inflation, $\beta_y, \beta_\pi, \delta > 0$, and μ_t contains the inflation and output targets, the equilibrium real interest rate, and other omitted terms. The foreign corresponding variables are denoted with a "*", and following the literature, we assume that the foreign central bank explicitly targets the real exchange rate or purchasing power parity $q_t = s_t - p_t + p_t^*$ in addition, with p denoting the overall price level. For notation simplicity, we assume the home and foreign central banks to have the same weights β_y and β_π. The efficient market condition for the foreign exchange markets, under rational expectations, equates cross border interest differentials $i_t - i_t^*$ with the expected rate of home currency depreciation, adjusted for the risk premium associated with home currency holdings:

$$i_t - i_t^* = E_t \Delta s_{t+1} + \rho_t^H \tag{4}$$

Plugging equation (3) into (4) and letting $\nu_t = \mu_t - {\mu_t}^*$, we have:

$$\beta_y (y_t^{gap} - y_t^{*,gap}) + \beta_\pi (\pi_t^e - \pi_t^{*,e}) + \delta (s_t - p_t + p_t^*) + \nu_t = E_t \Delta s_{t+1} + \rho_t^H \tag{5}$$

Solving for s_t and re-arranging terms, we arrive at an expression equivalent to equation (1) above, with a different set of fundamentals f_t^{TR1}:

$$s_t = \frac{\delta}{1+\delta}(p_t - p_t^*) - \frac{1}{1+\delta}\{\beta_y (y_t^{gap} - y_t^{*,gap}) + \beta_\pi (\pi_t^e - \pi_t^{*,e}) - \rho_t^H + \nu_t\} + \frac{1}{1+\delta} E_t s_{t+1} \tag{6}$$

and $f_t^{TR1} = \{(p_t - p_t^*), (y_t^{gap} - y_t^{*,gap}), (\pi_t^e - \pi_t^{*,e}), \rho_t^H\}$. As pointed out in Engel and West (2005), equation (6) can also be expressed differently as the following, again in the same general form as equation (1) but with yet a different set of fundamentals f_t^{TR2}:

$$s_t = \delta(i_t - i_t^*) + \delta(p_t - p_t^*) - \beta_y (y_t^{gap} - y_t^{*,gap}) - \beta_\pi (\pi_t^e - \pi_t^{*,e}) + (1-\delta)\rho_t^H - \nu_t + (1-\delta) E_t s_{t+1} \tag{7}$$

with $f_t^{TR2} = \{(i_t - i_t^*), (p_t - p_t^*), (y_t^{gap} - y_t^{*,gap}), (\pi_t^e - \pi_t^{*,e}), \rho_t^H\}$.

Both equations (6) and (7) can be solved forward, leading to the asset pricing equation (2) above, but with a different set of fundamentals f_t^{TR1} or f_t^{TR2}.

The above shows that various structural exchange rate models, classical or Taylor rule-based, can deliver the net present value equation where the exchange rate is determined by expected future values of cross country output, inflation, and interest rates. As shown in the next section, these are exactly the macroeconomic indicators for which the yield curves appear to embody information.

Empirically, the nominal exchange rate is best approximated by a unit root process, so we express equation (2) in a first-differenced form (ε is expectation error):

$$\Delta s_{t+1} = \lambda \sum_{j=1}^{\infty} \psi^j E_t\left(\Delta f_{t+j} | I_t\right) + \varepsilon_{t+1} \tag{8}$$

From here, rather than following the common approach in the literature and imposing additional assumptions about the statistical processes driving the fundamentals, we discuss in the next section how to use the information in the yield curves to proxy the expected discounted sum on the right-hand side of equation (8).[13]

2.2 The Yield Curve and the Nelson-Siegel Factors

The yield curve or the term structure of interest rates describes the relationship between yields and their time to maturity.[14] Traditional models of the yield curve posit that the shape of the yield curve is determined by expected future paths of interest rates and perceived future uncertainty (the risk premia). While the classic expectations hypothesis performs badly in empirical studies, research on the term structure of interest rates has convincingly demonstrated that the yield curve contains information about expected future economic conditions, such as output growth and inflation.[15] Below we give a brief presentation on the Nelson-Siegel (1987) framework for characterizing the shape of the yield curve, and then summarize findings in the macro-finance literature about its predictive content.

The Nelson-Siegel (1987) factors offer a succinct approach to characterize the shape of the yield curve. To derive the factors, they first approximate the forward rate curve at a given time t with a Laguerre function that is the product between a polynomial and an exponential decay term. This forward rate is the (equal-root) solution to the second order differential equation for the spot rates. A parsimonious approximation of the yield curve can then be obtained by averaging over the forward rates, with the resulting function capable of capturing the relevant shapes of the empirically observed yield curves: monotonic, humped, or S-shaped. It takes the following form:

$$i_t^m = L_t + S_t\left(\frac{1 - e^{-\lambda m}}{\lambda m}\right) + C_t\left(\frac{1 - e^{-\lambda m}}{\lambda m} - e^{-\lambda m}\right) \tag{9}$$

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[13] Previous literature has attempted to use surveyed market expectations as an alternative, with limited success. See Frankel and Rose's (1995) Handbook chapter, Sarno (2005), and Chen and Tsang (2009) for more discussions.

[14] In our discussion as well as analysis, we consider only zero-coupon bonds to avoid the coupon effect. We use the Treasuries to abstract away from default risks and liquidity concerns.

[15] Briefly, the expectations hypothesis says that a long yield of maturity m can be written as the average of the current one-period yield and the expected one-period yields for the coming $m - 1$ periods, plus a term premium. See Thornton (2006) for a recent example on the empirical failure of the expectations hypothesis.

where i_t^m is the continuously-compounded zero-coupon nominal yield on an m-month bond. The parameter λ controls the speed of exponential decay, and the three factors, L_t, S_t, and C_t, have simple intuitive interpretations. The level factor L_t , with its loading of 1, has the same impact on the whole yield curve. The loading on the slope factor S_t starts at 1 when m = 0 and decreases down to zero as maturity m increases. This factor captures short-term movements that mainly affect yields on the short end of the curve. An increase in the slope factor means the yield curve becomes flatter, holding the long end of the yield curves fixed. The curvature factor C_t is a “medium” term factor, as its loading is zero at the short end, increases in the middle maturity range, and finally decays back to zero. It captures how curvy the yield curve is at the medium maturities. These three factors typically capture most of the information in a yield curve (the R^2 is usually close to 0.99).

There is long history of using the term structure to predict output and inflation.[16] Mishkin (1990a and 1990b) shows that the yield curve predicts inflation, and that movements in the longer end of the yield curve are mainly explained by changes in expected inflation. Barr and Campbell (1997) use data from the UK index-linked bonds market and show that long-term expected inflation explains almost 80% of the movements in the long yields. Estrella and Mishkin (1996) show that the term spread is correlated with the probability of a recession, and Hamilton and Kim (2002) find that it can forecast GDP growth.[17]

The more recent macro-finance literature connects the observation that the short rate is a monetary policy instrument with the idea that yields of all maturities are risk-adjusted averages of expected short rates. This more structural approach offers deeper insight into the relationship between the yield curve factors and macroeconomic dynamics.[18] Ang, Piazzesi and Wei (2006) estimate a VAR model for the US yield curve and GDP growth. By imposing the non-arbitrage condition on the yields, they show that the yield curve predicts GDP growth better than a simple unconstrained OLS of GDP growth on the term spread. More specifically, they find that the term spread (the slope factor) and the short rate (the sum of level and slope factor) outperform a simple AR(1) model in forecasting GDP growth four to twelve quarters ahead. Using a New Keynesian model, Bekaert, Cho and Moreno (2006) demonstrate that the level factor is mainly moved by changes in the central bank’s inflation target, and monetary policy shocks dominate the movements in the slope and curvature factors. Dewachter and Lyrio (2006) estimate an affine model for the yield curve with macroeconomic variables. They find that the level factor reflects agents’ long-run

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[16] A non-exhaustive list of papers that show the predictive power of the yield curve include Estrella and Hardouvelis (1991), Plosser and Rouwenhorst (1994), Haubrich and Dombrosky (1996), Dueker (1997), and Dotsey (1998). Stock and Watson (2003) provides a comprehensive survey on output and inflation forecasts.

[17] Estrella and Mishkin estimated the probability of a recession a year later to be 90% when the yield spread averages -2.4 percentage points. Hamilton and Kim (2002) decompose the term spread into expected future short rate changes and the term premium, and found both components to have forecasting power for GDP. Estrella (2005) provides a survey and an explanation on why the yield curve predicts output and inflation.

[18] See Diebold, Piazzesi and Rudebusch (2005) for a short survey. There is also ample evidence that shocks to macroeconomic fundamentals have strong effect on the yield curve, but that is unrelated to our purpose here.

inflation expectation, the slope factor captures the business cycle, and the curvature represents the monetary stance of the central bank. Last but not least, Rudebusch and Wu (2007, 2008) contend that the level factor incorporates long-term inflation expectations, and the slope factor captures the central bank's dual mandate of stabilizing the real economy and keeping inflation close to its target. They provide macroeconomic underpinnings for the factors, and show that when agents perceive an increase in the long-run inflation target, the level factor will rise and the whole yield curve will shift up.[19] They model the slope factor behaving like a Taylor-rule, reacting to the output gap y_t^{gap} and inflation π_t. They show that when the central bank tightens monetary policy, the slope factor rises, forecasting lower growth in the future.[20]

As concisely stated in Rudebusch and Wu (2008), "the term structure factors summarize expectations about future short rates, which in turn reflect expectations about the future dynamics of the economy. With forward-looking economic agents, these expectations should be important determinants of current and future macroeconomic variables." We apply this insight to the exchange rate. Noting that the exchange rate fundamentals discussed in Section 2.1 are in cross country *differences*, we propose to measure the discounted present value on the right-hand side of equation (8) with the cross country *differences* in their yield curves. Assuming symmetry and exploiting the linearity in the factor-loadings in equation (9), we fit three Nelson-Siegel factors of the *relative* level (L_t^R), the relative slope (S_t^R), and the relative curvature (C_t^R), as follows:

$$i_t^m - i_t^{m*} = L_t^R + S_t^R \left(\frac{1 - e^{-\lambda m}}{\lambda m} \right) + C_t^R \left(\frac{1 - e^{-\lambda m}}{\lambda m} - e^{-\lambda m} \right) \qquad (10)$$

The relative factors, L_t^R, S_t^R, and C_t^R, serve as a proxy for expected future fundamentals in our exchange rate regressions.

2.3 Excess Currency Returns and the Risk Premium

In addition to exchange rate changes, we also look at how excess returns respond to expectations about future macroeconomic dynamics. Excess return, defined here for the foreign currency, is the difference in the cross-country yields adjusting for the relative currency movements:

$$rx_{t+m} = i_t^{m*} - i_t^m + \Delta s_{t+m} \qquad (11)$$

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[19] Kozicki and Tinsley (2001) also argue that the endpoint of the term structure, which is the same as our level factor, is closely related to long-run inflation expectation.

[20] The literature does not provide a convincing interpretation on the curvature factor, and we do not emphasize its role here.

where the last term represents the percent appreciation of foreign currency.

As discussed earlier, under the assumptions that on aggregate, foreign exchange market participants are risk neutral and have rational expectations, the efficient market condition for the foreign exchange market equates expected exchange rate changes to cross-country interest rate differences over the same horizon. This is the uncovered interest parity (UIP) condition. In *ex post* data, however, the UIP condition is systematically violated over a wide range of currency-interest rate pairs as well as frequencies. The leading explanations for this UIP puzzle point to either the presence of time-varying risk premia or systematic expectation errors.[21] We note that under the assumption of rational expectations, excess returns in equation (11) represents the risk premium associated with foreign currency holdings, ρ^F, in the risk-adjusted UIP relationship (ε_{t+m} is the rational expectation error):

$$\text{UIP:} \quad \Delta s_{t+m} = i_t^m - i_t^{m*} + \rho_{t+m}^F + \varepsilon_{t+m} \tag{12}$$

We will examine how the risk premium adjusts to market expectations about future relative macroeconomic dynamics, as captured by the relative factors discussed above.

3. Empirical Methods

In this section, we describe the data we use, our regression specifications, as well as how we address the overlapping data problem in our regressions.

3.1 Data Description

Our sample consists of monthly data from August 1985 to July 2005 for the US, Canada, Japan, and the United Kingdom. We look at zero-coupon bond yields for maturities 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 48, 60 72, 84, 96, 108 and 120 months, where the yields are computed using the Fama-Bliss (1987) methodology.[22] For the rest of the paper, we treat the US as the home country, and we measure exchange rate S as the US dollar price per unit of the foreign currency.[23] A lower number means an appreciation of the home currency, the USD. For all horizons, we define the exchange rate change as the annualized change of the log exchange rate s.

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[21] The peso problem of Rogoff (1980), among others, is also a common explanation. See Engel (1996) and Sarno (2005) for a survey and detailed discussion.

[22] For details on the data, please see Diebold, Li and Yue (2007).

[23] The yields are reported for the second day of each month. We match the yield data at time t with the exchange rate of the last day of the previous month (two days earlier).

We fit the Nelson-Siegel (1987) yield curve as equation (10) above, which we put here again:

$$i_t^m - i_t^{m*} = L_t^R + S_t^R\left(\frac{1-e^{-\lambda m}}{\lambda m}\right) + C_t^R\left(\frac{1-e^{-\lambda m}}{\lambda m} - e^{-\lambda m}\right)$$

where i_t^m is the home nominal zero-coupon yield of maturity m, and i_t^{m*} is corresponding foreign yield.[24] We call the three factors L_t^R, S_t^R and C_t^R the *relative factors* for the two countries, and they summarize the differences in level, slope and curvature for the two yield curves. The parameter λ is fixed at 0.0609, as suggested by Nelson and Siegel. We use OLS to estimate the above equation for each period t, and as usual, the Nelson-Siegel curve gives a really good fit and the R-square is almost always above 0.99. The relative factors for each country versus the US are plotted with the log exchange rate in Figures 1-3, and their summary statistics are reported in the first half of Table 1. We note, in addition, that the augmented Dickey-Fuller test of Elliott *et al.* (1996) reject the presence of a unit root in all of the relative factors, exchange rate changes, and excess return series.

The relative factors behave differently from the typical single-country Nelson-Siegel factors. The relative level factor has low persistence and small volatility. Unlike the single-country Nelson-Siegel slope factor which is relatively noisy, it is difficult to visually distinguish the relative slope factor from the relative level factor. The relative curvature factor is the most volatile, as with the single-country curvature. Correlation coefficients among the nine relative factors in the second half of Table 1 show us the following. First, factors across countries are positively correlated, especially for the level and slope factors. This is likely due to the presence of the US yield curve in each of these country pairs.[25] Within each country the three factors are also correlated, but there is no consistent pattern.

Finally, excess currency return is computed as:

$$rx_{t+m} = i_t^{m*} - i_t^m + \frac{1200(s_{t+m} - s_t)}{m} \tag{13}$$

where m is the horizon measured in months. As discussed above, it measures the annualized percent return from both interest differentials and currency appreciation, and represents the risk premium associated with holding foreign currency.

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[24] Unlike the typical application of the Nelson-Siegel yield curve, we fit the term structure of interest *differentials* for each country-pair on a *relative* level, a slope and a curvature factors in each period t. Alternatively, we can fit the Nelson-Siegel yield curve for each country first and then compute the difference of the three factors. We obtain slightly different results as there are missing yields for some maturities for one country but not the other, but the differences are very small and negligible.

[25] Here we emphasize again that while we only present results based on the dollar-cross rates, our conclusions extend to non-dollar country pairs as well.

3.2 Estimation Specifications

To see if the relative factors predict exchange rate changes and excess currency returns in sample, we run the following two main regressions, each for horizons $m =$ 3, 6, 12, 18, and 24, and also m =1 for equation (14):[26]

$$\frac{1200(s_{t+m} - s_t)}{m} = \beta_{m,0} + \beta_{m,1} L_t^R + \beta_{m,2} S_t^R + \beta_{m,3} C_t^R + u_{t+m} \tag{14}$$

$$rx_{t+m} = \gamma_{m,0} + \gamma_{m,1} L_t^R + \gamma_{m,2} S_t^R + \gamma_{m,3} C_t^R + v_{t+m} \tag{15}$$

We note that for the UK, the relationship between the two dependent variables and the relative factors during the Exchange Rate Mechanism (ERM) crisis differs significantly from the rest of the sample.[27] So in our analysis we drop the period October 1990 - September 1992, which is when the crisis was in effect, from the regressions for the UK.

3.3 Overlapping Data Problem

It is well known that in longer horizon predictive analyses, one needs to address inference bias due to overlapping data. When the horizon for exchange rate change or excess currency return is more than one month, our LHS variable overlaps across observations, and u_{t+m} or v_{t+m} in equations (14) and (15) above will be a moving average process of order $m-1$. Statistics such as the standard errors will be biased. The typical solution to the problem is to use Newey-West standard errors. However, as shown in Ang and Bekaert (2006), the Newey-West adjustment suffers from serious size distortion (i.e. rejecting too often) when the sample size is small and the regressors are persistent. We address the problem with two alternative methods.

Following Parker and Julliard (2005), we set up a Monte Carlo experiment under the null hypothesis that the exchange rate follows a random walk. First, we sample with replacement from the one-month exchange rate returns and create a series of size equal to our sample of "white noise" under the null. Second, using this re-sampled one-month exchange rate change series, we generate the 1, 3, 6, 12, 18, and 24 month-ahead exchange rate changes as our LHS variables. Third, we regress these variables on the relative factors and keep the t-statistics. We repeat the three steps 2,000 times and use the critical values from the distributions of the t-statistics to do our inference. The setup for the excess currency

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[26] Since one-month yield data is not available, we do not have excess returns data to run equation (15). For both regressions, we use the Bayesian Information Criterion to select the optimal lag lengths.

[27] We run equations (14) and (15) with the relative factors and their interaction with an "ERM dummy", and find significant results on the interaction terms. Figure 3 also shows the large fluctuation in the UK exchange rate during that period.

return regression is similar except we use the actual yields in the second step to create the re-sampled excess returns. The rationale behind the experiment is that, if the exchange rate is truly unpredictable as a random walk, the Monte Carlo results will tell us the probability that the predictability we find is spurious.

An alternative method for correcting the long-horizon bias is to use the re-scaled t statistic suggested by Moon, Rubia and Valkanov (2004) and Valkanov (2003). Consider the standard returns regression setup proposed in Campbell and Shiller (1988) and Nelson and Kim (1993):

$$\begin{aligned} r_{t,t+1} &= \alpha + \beta x_t + u_{t+1} \\ x_t &= \rho x_{t-1} + \epsilon_t \end{aligned} \tag{16}$$

where $r_{t,t+1}$ is the one-period return between time t and $t+1$, ρ is close to unity, and u_t , ϵ_t are independent and identically distributed over time with a possibly non-zero covariance.[28] The null hypothesis is that $r_{t,t+1}$ is not predictable by x_t, i.e. $H_0\colon \beta = 0$. The long-horizon predictive regression for horizon m ahead is as follows:

$$R_{t,t+m} = \alpha_m + \beta_m x_t + u_{m,t+1} \tag{17}$$

where the long-horizon return between t and $t+m$ is constructed from one-period returns: $R_{t,t+m} = \sum_{j=0}^{m-1} r_{t+j,t+j+1}$, and overlaps across observations. Given a fixed sample size T, we see that the larger the m, the more serious is the degree of data overlap, which can significantly influence the properties and the limiting distributions of the inference statistics. Specifically, Moon, Rubia and Valkanov show that the OLS t-statistic for $\hat{\beta}_m$ diverges as horizon m increases, even under the null hypothesis of no predictability. Put differently, we tend to observe a larger bias towards predictability for a higher m. The authors demonstrate that the re-scaled t-statistic $t/\sqrt{m}$ has a well-defined limiting distribution. Based on Monte Carlo experiments, they show that the re-scaled t statistic is approximately standard normal, provided that the regressor x_t is highly persistent and the correlation between the two shocks u_t and ϵ_t is not too high. When the regressor is not a near-integrated process, the adjusted t-statistic tends to under-reject the null. Since the unit root null is rejected for most of our factors, the predictive power of the factors may actually be stronger than implied by the results we present below in Tables 2-4.

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[28] The analysis can be extended to a multivariate framework. For notation simplicity, we let x_t be a scalar.

Comparing our two approaches, we find the rescaled t-statistics deliver more conservative inferences than the Monte Carlo experiment results. We therefore report results using this more conservative method only in the next section.

4. Main Results

Our main exchange rate predictive results based on equation (14) are presented in panel (a) in Tables 2-4, and the corresponding ones for excess returns, equation (15), are in panel (b). As a robustness check, we use the first month of each quarter and each half-year to construct a three-month and a six-month sample with no data overlap. We report the findings using the non-overlapping data in Tables 5 and 6. Below we discuss the results for each currency pairs.

Canada: the Canadian-USD results appear to be the weakest among the currency pairs we looked at, and our conjecture is that it is mainly due to the Canadian dollar's "commodity currency" status.[29] The relative factors do not seem to predict exchange rate movements beyond a quarter (panel (a) in Table 2), but they work better for excess returns (panel (b) in Table 2). The level and slope factors are statistically important in predicting excess returns up to a year, with quantitatively significant effect. For example, a 1% increase in the relative level factor predicts a more than 3% annualized drop in the excess return of Canadian dollar over the subsequent three months. Our results based on non-overlapping data reveal the same pattern: the three-month and six-month adjusted R^2 statistics for exchange rate change are only 0.029 and 0.02, while for excess returns they are 0.064 and 0.161, with all three factors contributing at times.

Japan: The relative slope factor plays both a statistically and an economically strong role in predicting the yen-dollar movements. As shown in Table 3 panel (a), a 1% increase in the relative slope factor (i.e. the Japanese yield curve becomes steeper relative to the US one) predicts a 4% annualized depreciation of the yen over the next three months. In panel (b), the same 1% increase in the relative slope factor predicts a 6% drop in excess yen returns over the US dollar in the three-month horizon. We do not find large and statistically significant results for the other two relative factors. In Table 5, results based on non-overlapping data again tell us that the relative slope factor is a strong predictor for both exchange rate changes over the three-month and six-month horizons Table 6 shows that the relative slope explains a substantial part of the future variations of the excess return as well, as evident by their R^2 statistics. We also note that while we only report results up to two years, the predictive power of the relative slope factor remains beyond two years for both exchange rate changes and excess returns.

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[29] The Canadian dollar, along with Australian and New Zealand dollars, South African rand and so forth, are known to respond mainly to the world price of their primary commodity exports, of which their economies have a large dependency. See Chen and Rogoff (2003) for more discussion about the "commodity currencies".

United Kingdom: All the three factors predict exchange rate changes and excess returns, and all are both quantitatively and statistically significant. For example, a 1% increase in the relative level factor (i.e. the whole yield curve of the US shifts up by 1% relative to that of the UK) predicts almost 4% depreciation of the UK pound against the US dollar over the coming three months. The same increase in the relative level factor predicts an almost 5% drop in the excess sterling return over the next three months. The predictive power of the relative factors for excess return remains beyond the 24-month horizon (not shown). The non-overlapping results in Tables 5 and 6 confirm the relative factors' importance and the three-month and six-month adjusted R-squares for exchange rate change are 0.092 and 0.194, and for excess return are 0.131 and 0.274.

Overall, we see that for all three currency pairs, the relative yield curve factors can play a quantitatively and statistically significant role in explaining future exchange rate movements, from one month ahead to sometimes beyond two years. Another interesting pattern that is consistent across the currency pairs is that the effect of the factors, as captured by the size of the regression coefficients, tends to approach zero as forecast horizon increases. We take this as an indication that current information and expectations have a declining effect on the actual exchange rate realization farther into the future, but the imprecision in the estimates and the likely bias from the noise in longer-horizon data prevent any conclusive statement.

5. Robustness Tests and Discussions

5.1 Out-Sample Forecasting Results

We next look at the out-of-sample forecasting performance of the relative yield curve factors, compared to that of a random walk. We use a rolling window with a size of five years and construct out-of-sample forecasts for one, two, and three months ahead and for each forecast we calculate the squared prediction error. The first regression uses the first 60+m observations (as our LHS variable is the m-period ahead return), and then make a forecast for the exchange rate change from 60+m to 60+$2m$. The second regression moves forward over time by one period and make another forecast, and so on. At the end of the rolling process, we calculate the mean squared forecast error (MSFE) for our model, and compare it with MSFE produced by a drift-less random walk. Table 7 reports the t-statistics for the comparison based on the Clark-West (2006) predictability test, which accounts for the upward shift of MSFE in our model.[30]

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[30] Under the null of equal predictability, the sample MSFE of the factor model is expected to be greater than that of the random walk model. The Clark and West (2006) test statistic adjusts for this upward shift in the sample MSFE. Their simulations show that the inference made using asymptotically normal critical values gives properly-sized tests for rolling regressions.

For all three currency pairs, the null of equal predictability (i.e. our model) is rejected at the one-month horizon, and some also at the two-month horizon. Due to the small sample size, we do not learn much from forecasts of longer horizons, as the sampling variance is too large for us to reject the random walk model.

5.2 Yield Curve Factors and Surveyed Forecasts

We discussed in Section 2 various prior research that shows the term structure factors as a robust and power predictor for future exchange rate fundamentals. In this section, we provide some simple empirical evidence as additional support. The Survey of Professional Forecasters (SPF), compiled by the Federal Reserve Bank of Philadelphia, collects forecasts on a wide range of economic indicators from a large group of private-sector and institutional economists. We take its mean forecasts for real GDP growth and CPI inflation for horizons from one to four quarters ahead, and correlate them to the current yield curve factors. We also analyze how the Anxious Index – a measure of the market's perceived probability for a decline in real GDP k quarters later – corresponds to the current slope factor. Our sample period is 1985Q3 to 2005Q2, and to match SPF's quarterly data for the US, we create quarterly average from our monthly US factors (not relative).[31] Below we focus on the level L_t and slope S_t factors individually; additional results using all three factors are in the appendix.

Our regression setup is as follows. Denote $E\Delta y_{t+m}$ as the real GDP growth forecast, $E\pi_{t+m}$ as the CPI inflation forecast, and A_{t+m} as the Anxious Index for monthly horizon m = 3, 6, 9, and 12 ahead. We run the following three sets of regression, corresponding to our discussion in Section 2.2 regarding the information embodied in the slope and level factors. Since our main argument is that the factors can capture market expectations about the dynamics of future fundamentals beyond the currently observed fundamentals, we also include them as additional regressors.

$$E_t\Delta y_{t+m} = \alpha_{Sm} + \beta_{Sm} S_t + \beta_{ym}\Delta y_t + u_{Smt} \qquad (18)$$

$$A_{t+m} = \gamma_{Sm} + \delta_{Sm} S_t + \delta_{ym}\Delta y_t + v_{Smt} \qquad (19)$$

$$E_t\pi_{t+m} = \alpha_{Lm} + \beta_{Lm} L_t + \beta_{\pi m}\pi_t + u_{Lmt} \quad \text{for m= 3, 6, 9, and 12} \qquad (20)$$

The first two regressions check if the slope factor in the current quarter is correlated with expected real GDP growth, and the third regression checks if the level factor is correlated with expected future inflation. The results in Table 8 show that indeed, a larger slope factor (flatter slope) corresponds to lower expected output three quarters to a year ahead, as well as higher perceived probability of an economic

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[31] Using factors from the first month of each quarter does not change the results much.

downturn in six months to a year horizon. A larger level factor consistently maps to higher expected inflation across all future horizons.[32]

5.3 Interpretation and Discussion

This section provides an intuitive interpretation of our findings. We emphasize once more that since the goal of this paper is to sidestep explicit modeling of market expectations, including perceived risks, our results do not constitute an explicit test for any specific model. Nevertheless, our positive results have simple and intuitive economic interpretations, as follows. As discussed in Section 2.2, the yield curve literature tells us is that when a country's yield curve is flatter or its level higher, the market expects forthcoming economic downturn or rising inflation. Our results show that under these scenarios, everything else equal, its currency will be less desirable and it faces depreciation pressure according to the present value relation. Subsequently, it appreciates back towards it longer-run equilibrium level. The declining effect of the yield curve information on exchange rate changes further into the horizon suggests that movements in market expectations tend to be transitory.

Under rational expectations, excess foreign currency return is the risk premium associated with holding foreign currency. Our result show that this risk premium, ρ^F, responds strongly to the relative yield curve factors. When market expectation points to more output decline (flat relative slope) or higher future inflation (high relative level) in the foreign country, we see a corresponding rise in ρ^F.[33] This finding provides an insight into the uncovered interest rate parity puzzle. Consider an increase in the foreign short-term interest rate i^*. Crudely speaking, its impact on the shape of the foreign yield curve can either be flattening (if the long rates do not respond), or raising the whole curve (if the longer maturity rates go up as well).[34] Assuming the home yield curve stays fixed, this corresponds to the scenario we just discussed, and ρ^F should rise. It is then easy to see from equation (12), that if the rise in ρ^F is large enough, the exchange rate term, Δs_{t+m}, can indeed turn positive, i.e. foreign currency appreciates in response to a rise in the foreign interest rate.

Our results are also consistent with Meredith and Chinn's (1998) finding that the UIP holds better at a longer horizon (five and ten years). As noted in Section 4, the relative factors, embodying time t expectations about future economic dynamics, have a declining impact on the risk premium at more distant horizons. This suggests that the expectation and perceived risk at time t for horizons further into

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[32] These results are robust to the exclusion of the current fundamentals as well (results available upon request).

[33] In the notation of equation (12), this means either S^R or L^R is low, and excess return, or ρ^F is high.

[34] In other words, the short rate differences and the relative factors should be positively correlated, as we observe in the data. We also find the correlation declining with yields of longer maturity.

the future tend to be smaller or more neutral. As such, the exchange rate responses are less affected by risk and are more in line with basic fundamentals such as the interest differentials. Consequently, the UIP condition holds better.

Even though we offer no rigorous proof, the above interpretation offers a potential answer to the concern raised in Sarno (2005): While defining the risk premium as excess return "would allow us to study some of the properties of the risk premium by examining its projection on available information, there is no reason to expect that this implicitly defined risk premium will behave in a manner consistent with our economic intuition."

6. Conclusion

We find that the Nelson-Siegel factors extracted from the relative yield curves between two countries are both statistically and economically significant in explaining future exchange rate movements and in addition, excess currency returns. This result supports the view that exchange rate movements are systematically related to expected future fundamentals, via a present value relationship, as in the asset approach to exchange rate determination. Our approach addresses the Meese-Rogoff (1983) forecast puzzle by outperforming the random walk in short-horizon out-of-sample forecasts. Our findings also offer an intuitive explanation for the failure of the short-horizon UIP puzzle.

One may contend that we have merely transported the exchange rate puzzles to the yield curve side, since we did not explicitly justified the behavior and shape of the yield curves. Indeed we do not propose any structural modeling of the expectation formation process or have an explanation for the empirical failing of the expectation hypothesis. Our view is that market expectations of future variables in different time horizons may be too complicated to be captured by simple models, theoretical or empirical. Given the term structure of interest rates has been found to embody such market expectations, the present value approach to exchange rate determination can thus be tested without having to impose either structural or statistical assumptions on the expectation formation process. Our findings support this approach: the difference between two countries' yield curves can predict the relative value of their currencies.

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Table 1. Summary Statistics and Correlations of the Relative Factors

(a) Summary Statistics

	Relative Level L^R			Relative Slope S^R			Relative Curvature C^R		
	Canada	Japan	UK	Canada	Japan	UK	Canada	Japan	UK
Mean	-0.567	3.168	-0.146	-0.633	-0.835	-1.765	-0.827	1.115	-1.430
Median	-0.592	3.166	-0.481	-0.516	-0.988	-2.323	-0.686	1.093	-0.855
Max	2.024	5.725	3.910	6.463	3.594	7.576	8.641	8.585	16.073
Min	-3.094	1.203	-4.620	-5.398	-5.419	-6.780	-13.889	-7.313	-24.945
SD	0.941	0.902	1.845	1.926	1.990	2.571	3.039	2.736	7.048
Skewness	0.204	0.151	0.219	0.383	0.025	0.997	-0.454	-0.139	-0.968
Kurtosis	3.029	2.538	2.592	3.323	2.119	4.294	6.437	2.596	5.304

(b) Correlations between Relative Factors

	L^R - Can	L^R - Jap	L^R - UK	S^R - Can	S^R - Jap	S^R - UK	C^R - Can	C^R - Jap	C^R - UK
L^R - Can	1.000								
L^R - Jap	0.576	1.000							
L^R - UK	0.629	0.517	1.000						
S^R - Can	-0.030	-0.044	0.265	1.000					
S^R - Jap	0.082	-0.058	0.206	0.616	1.000				
S^R - UK	-0.095	-0.047	0.168	0.654	0.658	1.000			
C^R - Can	-0.515	-0.060	-0.036	-0.131	0.000	0.142	1.000		
C^R - Jap	-0.091	-0.177	0.054	0.360	0.482	0.405	0.318	1.000	
C^R - UK	-0.316	-0.142	-0.770	-0.236	-0.205	-0.339	0.035	0.063	1.000

Table 2. Predicting the Canadian-US Exchange Rate and Excess Returns

(a) Exchange Rate $\frac{1200(s_{t+m}-s_t)}{m}=\beta_{m,0}+\beta_{m,1}L_t^R+\beta_{m,2}S_t^R+\beta_{m,3}C_t^R+u_{t+m}$

	m=1	m=3	m=6	m=12	m=18	m=24
L^R	-3.542*	-2.789*	-1.789	-1.540	-1.249	-0.720
$t/\sqrt{m}$	-1.928	-1.832	-1.184	-0.966	-0.722	-0.377
S^R	-0.731	-0.575	-0.517	-0.458	-0.367	-0.244
$t/\sqrt{m}$	-0.944	-0.898	-0.812	-0.685	-0.506	-0.306
C^R	-0.945*	-0.867*	-0.643	-0.496	-0.461	-0.349
$t/\sqrt{m}$	-1.652	-1.834	-1.360	-0.995	-0.850	-0.584
N. obs.	239	237	234	228	222	216

(b) Excess Return $i_t^{m*}-i_t^m+\frac{1200(s_{t+m}-s_t)}{m}=\gamma_{m,0}+\gamma_{m,1}L_t^R+\gamma_{m,2}S_t^R+\gamma_{m,3}C_t^R+v_{t+m}$

	m=3	m=6	m=12	m=18	m=24
L^R	-3.206*	-2.550*	-2.585	-2.305	-1.721
$t/\sqrt{m}$	-1.817	-1.660	-1.611	-1.339	-0.908
S^R	-1.437*	-1.333*	-1.174*	-0.963	-0.753
$t/\sqrt{m}$	-1.845	-2.038	-1.746	-1.335	-0.949
C^R	-0.828	-0.744	-0.739	-0.771	-0.633
$t/\sqrt{m}$	-1.448	-1.550	-1.472	-1.431	-1.068
N. obs.	172	224	228	222	216

Note: Exchange rate s is log(USD/CAD). The row $t/\sqrt{m}$ reports the re-scaled t-statistics for the estimates (see text for details). Estimates for the constant term are omitted, and * indicates a significance level of 10% or below.

Table 3. Predicting the Japanese-US Exchange Rate and Excess Returns

(a) Exchange Rate $\frac{1200\,(s_{t+m}-s_t)}{m} = \beta_{m,0} + \beta_{m,1}L_t^R + \beta_{m,2}S_t^R + \beta_{m,3}C_t^R + u_{t+m}$

	m=1	m=3	m=6	m=12	m=18	m=24
L^R	-2.606	-1.424	-0.871	-2.155	-1.504	-1.504
$t/\sqrt{m}$	-0.705	-0.467	-0.293	-0.866	-0.590	-0.617
S^R	-4.093*	-4.061*	-3.950*	-3.176*	-2.321*	-2.321*
$t/\sqrt{m}$	-2.173	-2.605	-2.607	-2.506	-1.778	-1.852
C^R	0.535	0.890	0.566	-0.096	-0.565	-0.565
$t/\sqrt{m}$	0.385	0.771	0.504	-0.102	-0.585	-0.609
N. obs.	239	237	234	228	222	216

(b) Excess Return $i_t^{m*} - i_t^m + \frac{1200\,(s_{t+m}-s_t)}{m} = \gamma_{m,0} + \gamma_{m,1}L_t^R + \gamma_{m,2}S_t^R + \gamma_{m,3}C_t^R + v_{t+m}$

	m=3	m=6	m=12	m=18	m=24
L^R	-2.187	-2.233	-3.151	-3.223	-2.521
$t/\sqrt{m}$	-0.656	-0.752	-1.265	-1.262	-1.031
S^R	-5.787*	-4.967*	-3.899*	-3.160*	-2.846*
$t/\sqrt{m}$	-3.431	-3.281	-3.076	-2.411	-2.260
C^R	1.023	0.463	-0.327	-0.762	-0.852
$t/\sqrt{m}$	0.802	0.409	-0.347	-0.788	-0.915
N. obs.	153	228	228	222	216

Note: Exchange rate s is log(USD/JPY). The row $t/\sqrt{m}$ reports the re-scaled t-statistics for the estimates (see text for details). Estimates for the constant term are omitted, and * indicates a significance level of 10% or below.

Table 4. Predicting the UK-US Exchange Rate and Excess Returns

(a) Exchange Rate $\frac{1200(s_{t+m}-s_t)}{m} = \beta_{m,0} + \beta_{m,1}L_t^R + \beta_{m,2}S_t^R + \beta_{m,3}C_t^R + u_{t+m}$

	m=1	m=3	m=6	m=12	m=18	m=24
L^R	-3.101	-3.929*	-3.104*	-2.593*	-2.028	-1.512
$t/\sqrt{m}$	-1.332	-2.293	-2.031	-1.791	-1.410	-1.094
S^R	-1.836	-2.354*	-1.965*	-1.353*	-1.097	-0.806
$t/\sqrt{m}$	-1.519	-2.629	-2.431	-1.751	-1.435	-1.097
C^R	-0.751	-1.125*	-1.006*	-0.796*	-0.607	-0.395
$t/\sqrt{m}$	-1.129	-2.296	-2.282	-1.900	-1.445	-0.983
N. obs.	215	213	210	204	198	192

(b) Excess Return $i_t^{m*} - i_t^m + \frac{1200(s_{t+m}-s_t)}{m} = \gamma_{m,0} + \gamma_{m,1}L_t^R + \gamma_{m,2}S_t^R + \gamma_{m,3}C_t^R + v_{t+m}$

	m=3	m=6	m=12	m=18	m=24
L^R	-4.858*	-4.451*	-3.718*	-3.086*	-2.534*
$t/\sqrt{m}$	-1.959	-2.446	-2.507	-2.134	-1.821
S^R	-3.772*	-2.824*	-2.138*	-1.727*	-1.397*
$t/\sqrt{m}$	-1.926	-2.377	-2.530	-2.249	-1.888
C^R	-0.939	-1.229*	-1.039*	-0.906*	-0.718*
$t/\sqrt{m}$	-0.994	-2.135	-2.363	-2.157	-1.766
N. obs.	108	159	195	198	192

Note: Exchange rate s is log(USD/GBP). The row $t/\sqrt{m}$ reports the re-scaled t-statistics for the estimates (see text for details). Estimates for the constant term are omitted, and * indicates a significance level of 10% or below.

Table 5. Exchange Rate Regressions with Non-Overlapping Data

	m=3	m=6	m=3	m=6	m=3	m=6
	Canada		Japan		UK	
L^R	-3.220*	-1.702	-2.153	0.060	-4.666*	-2.669*
	(1.357)	(1.393)	(2.982)	(2.975)	(1.890)	(1.176)
S^R	-0.550	-0.642	-3.494*	-4.226*	-2.308*	-2.080*
	(0.521)	(0.425)	(1.693)	(1.816)	(0.943)	(0.674)
C^R	-0.794*	-0.791*	0.503	1.024	-1.240*	-0.831*
	(0.443)	(0.442)	(1.258)	(1.255)	(0.563)	(0.325)
N. obs.	79	39	79	39	71	35
Adj. R^2	0.029	0.020	0.029	0.067	0.092	0.194

Table 6. Excess Currency Return Regressions with Non-Overlapping Data

	m=3	m=6	m=3	m=6	m=3	m=6
	Canada		Japan		UK	
L^R	-2.725	-2.655	-1.450	-0.932	-7.165*	-3.756*
	(1.445)	(1.393)	(3.297)	(2.971)	(3.593)	(1.505)
S^R	-1.561*	-1.503*	-6.893*	-5.049*	-3.477	-3.222*
	(0.587)	(0.430)	(1.430)	(1.808)	(2.226)	(1.029)
C^R	-0.765	-0.916*	1.613	0.867	-2.576	-0.869
	(0.472)	(0.443)	(1.567)	(1.249)	(1.552)	(0.588)
N. obs.	58	39	33	39	35	28
Adj. R^2	0.064	0.161	0.289	0.135	0.131	0.274

Note to Tables 5 and 6: Newey-West standard errors are reported in the parentheses. * indicates a significance level of 10% or below. We use the first month of a quarter and the first month of every half-year to construct non-overlapping samples. Observations during the ERM period are dropped for the UK.

Table 7. Clark-West (2006) Output-of-Sample Test Statistics

Horizon	Canada	Japan	UK
m=1	3.860*	2.517*	3.274*
m=2	2.002*	1.475	1.719*
m=3	1.367	1.240	1.128

Note: * indicates a significance level of 10% or below. See Clark and West (2006) for details of the testing procedure.

Table 8. Surveyed Forecasts and Yield Curve Factors

a) $E_t \Delta y_{t+m} = \alpha_{Sm} + \beta_{Sm} S_t + \beta_{ym} \Delta y_t + u_{Smt}$

	m=3	m=6	m=9	m=12
β_{Sm}	0.025	-0.070	-0.083*	-0.197*
	(0.062)	(0.047)	(0.034)	(0.037)
N. obs.	80	80	80	80
Adj. R^2	0.072	0.028	0.047	0.29

b) $A_{t+m} = \gamma_{Sm} + \delta_{Sm} S_t + \delta_{ym} \Delta y_t + v_{Smt}$

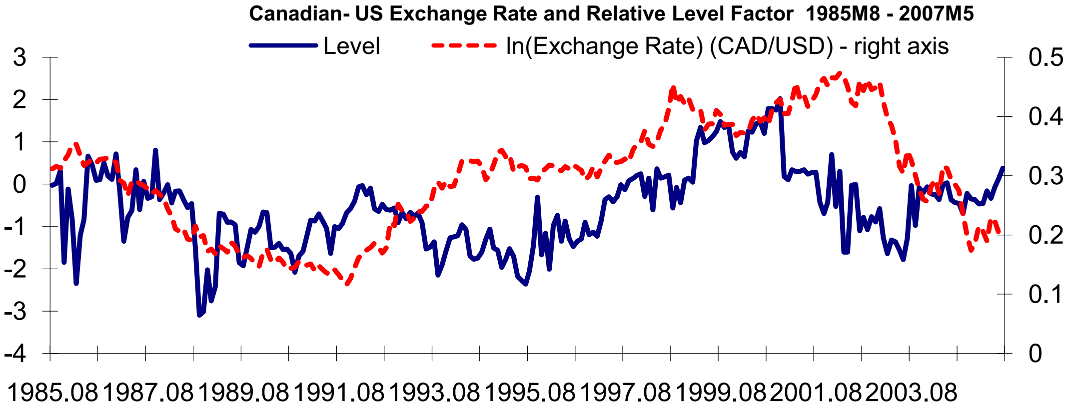
	m=3	m=6	m=9	m=12
δ_{Sm}	-0.546	0.985*	1.813*	1.989*
	(0.743)	(0.486)	(0.336)	(0.335)
N. obs.	80	80	80	80
Adj. R^2	0.243	0.182	0.267	0.321

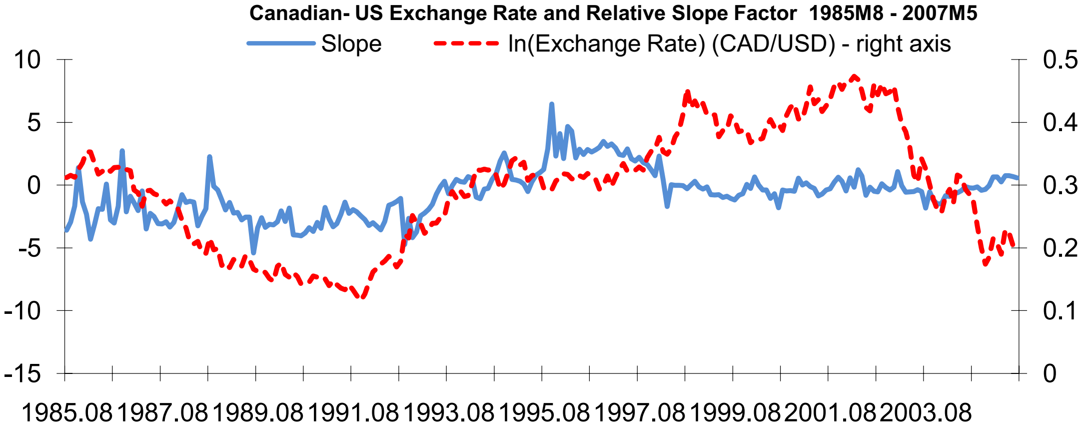
c) $E_t \pi_{t+m} = \alpha_{Lm} + \beta_{Lm} L_t + \beta_{\pi m} \pi_t + u_{Lmt}$

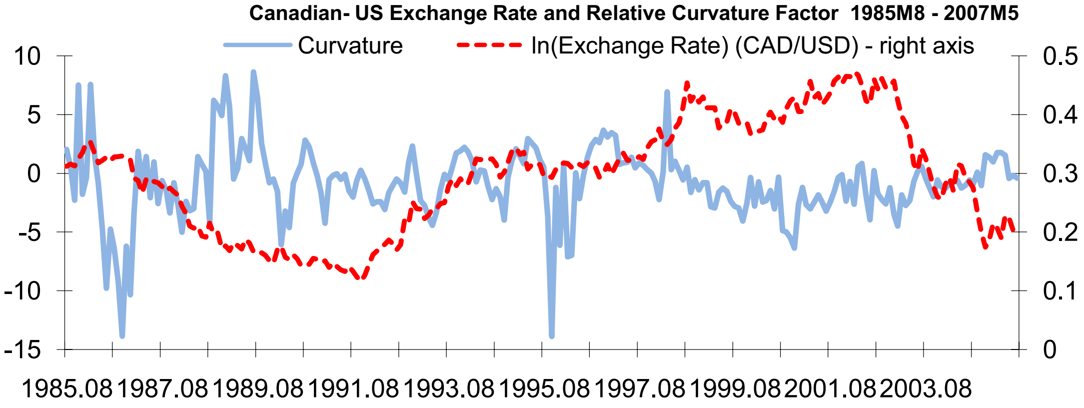
	m=3	m=6	m=9	m=12
β_{Lm}	0.373*	0.412*	0.434*	0.453*
	(0.042)	(0.042)	(0.042)	(0.042)
N. obs.	80	80	80	80
Adj. R^2	0.722	0.693	0.687	0.702

Note: * indicates a significance level of 10% or below. We use quarterly data from the Survey of Professional Forecasters maintained by the Federal Reserve Bank of Philadelphia. The factors are quarterly average of the monthly data (though we obtain similar results when we use the first month of each quarter instead).

Figure 1. The Canadian-US Exchange Rate and Relative Factors

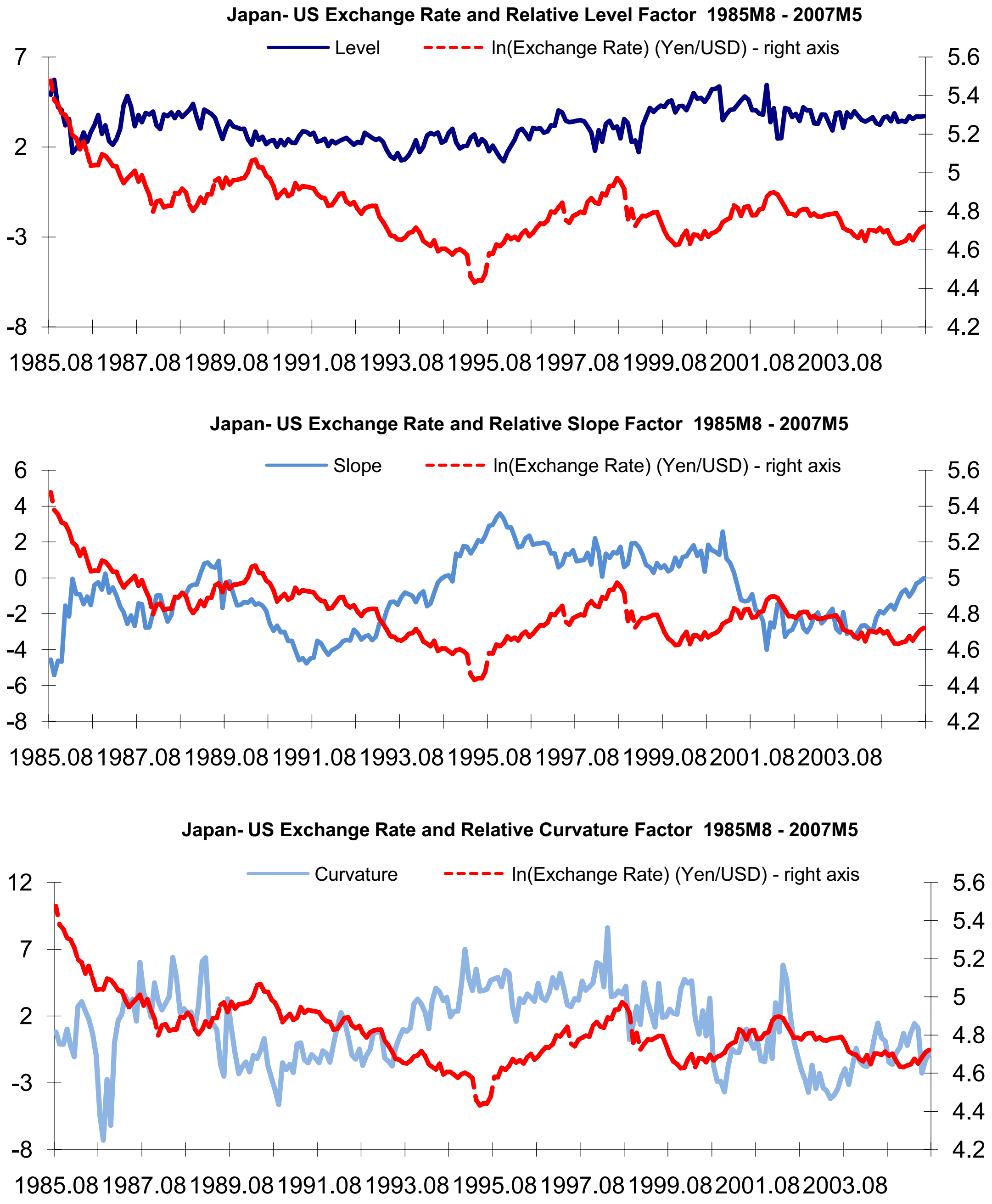






Note: The relative term structure factors are calculated by the following procedure: in each period, we subtract the yields of the country from those of the US with matching maturities. We then fit the Nelson-Siegel yield curve on the yield differences to obtain the level, slope and curvature factors for that period.

Figure 2. The Japan-US Exchange Rate and Relative Factors



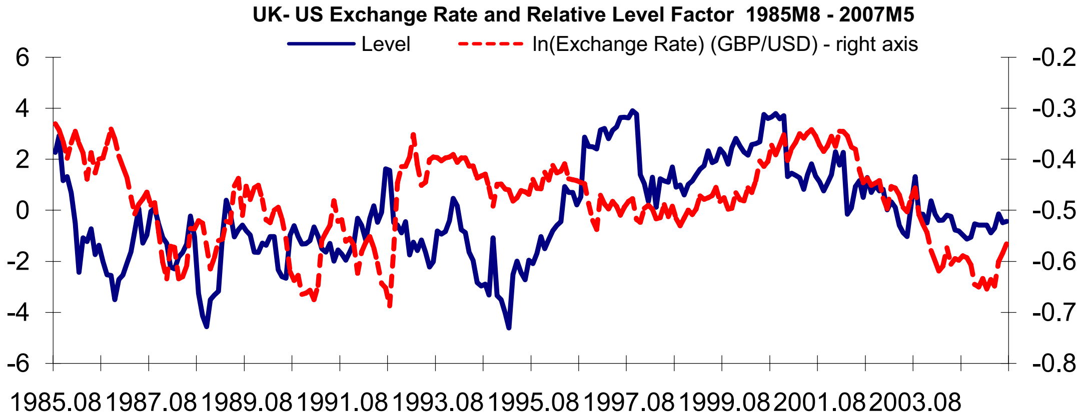
Japan- US Exchange Rate and Relative Level Factor 1985M8 - 2007M5

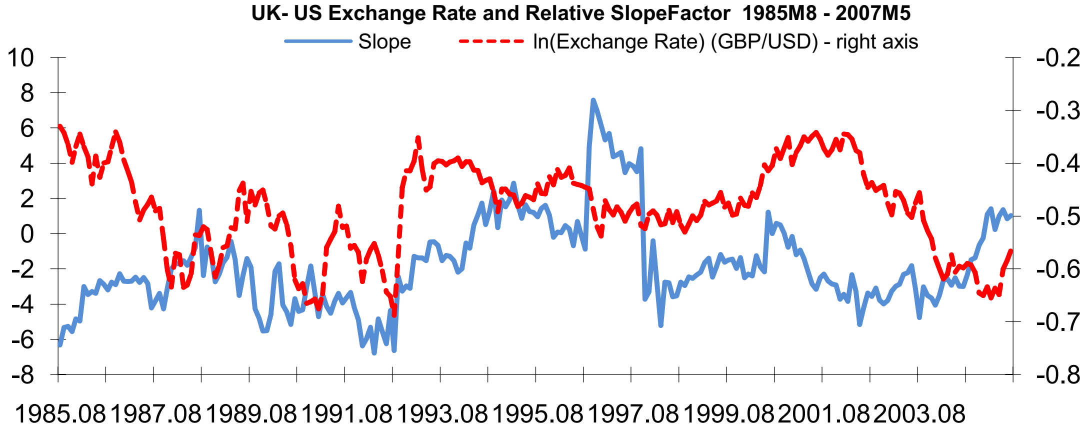
Japan- US Exchange Rate and Relative Slope Factor 1985M8 - 2007M5

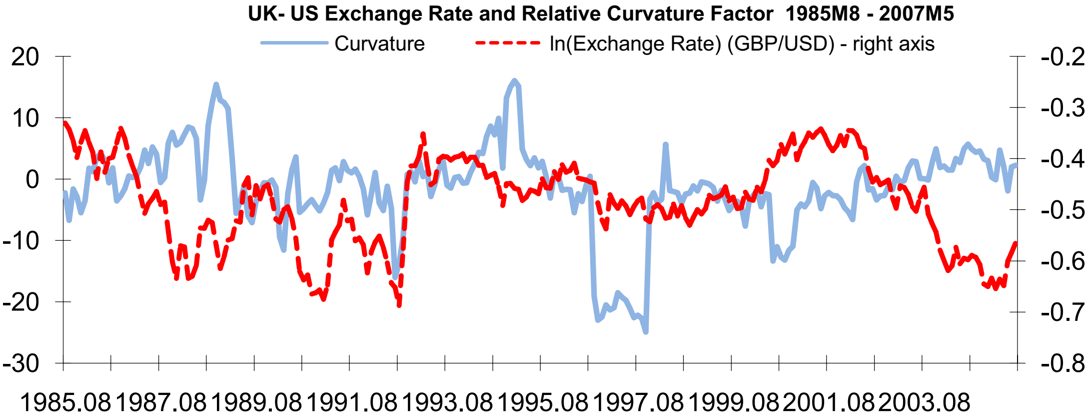
Japan- US Exchange Rate and Relative Curvature Factor 1985M8 - 2007M5

Note: The relative term structure factors are calculated by the following procedure: in each period, we subtract the yields of the country from those of the US with matching maturities. We then fit the Nelson-Siegel yield curve on the yield differences to obtain the level, slope and curvature factors for that period.

Figure 3. The UK-US Exchange Rate and Relative Factors


UK- US Exchange Rate and Relative Level Factor 1985M8 - 2007M5


UK- US Exchange Rate and Relative SlopeFactor 1985M8 - 2007M5


UK- US Exchange Rate and Relative Curvature Factor 1985M8 - 2007M5

Note: The term structure factors for each country are calculated by the following procedure: in each period, we subtract the yields of each country from those of the US, matching the maturities. We then fit the Nelson-Siegel yield curve on the yield differences and obtain the level, slope and curvature factors for that period.

Appendix

Table A1. Canadian Regressions with the Inclusion of Lagged Dependent Variable

a) Exchange Rate $\frac{1200(s_{t+m}-s_t)}{m} = \beta_{m,0} + \beta_{m,1}L_t^R + \beta_{m,2}S_t^R + \beta_{m,3}C_t^R + \beta_{m,4}\frac{1200(s_t-s_{t-m})}{m} + u_{t+m}$

	m=1	**m=3**	**m=6**	**m=12**	**m=18**	**m=24**
L^R	-3.472*	-2.724*	-1.650	-1.265	-1.057	-0.657
$t/\sqrt{m}$	-2.291	-1.770	-1.074	-0.822	-0.602	-0.336
S^R	-0.732	-0.628	-0.528	-0.255	-0.127	-0.006
$t/\sqrt{m}$	-1.149	-0.972	-0.812	-0.385	-0.164	-0.007
C^R	-0.931*	-0.865*	-0.633	-0.512	-0.347	-0.235
$t/\sqrt{m}$	-1.977	-1.813	-1.305	-1.022	-0.547	-0.334
Lagged LHS	0.026	-0.015	0.016	0.031	0.014	0.002
$t/\sqrt{m}$	0.399	-0.407	0.591	1.638	0.760	0.081
N. obs.	238	234	228	216	204	192

b) Excess Return $i_t^{m*} - i_t^m + \frac{1200(s_{t+m}-s_t)}{m} = \gamma_{m,0} + \gamma_{m,1}L_t^R + \gamma_{m,2}S_t^R + \gamma_{m,3}C_t^R + i_{t-m}^{m*} - i_{t-m}^m + \frac{1200(s_t-s_{t-m})}{m} + v_{t+m}$

	m=3	**m=6**	**m=12**	**m=18**	**m=24**
L^R	-2.247	-2.535	-2.045	-2.109	-1.845
$t/\sqrt{m}$	-1.202	-1.631	-1.261	-1.151	-0.929
S^R	-1.609*	-1.145*	-0.868	-0.775	-0.631
$t/\sqrt{m}$	-1.913	-1.669	-1.231	-0.964	-0.712
C^R	-0.467	-0.736	-0.701	-0.637	-0.509
$t/\sqrt{m}$	-0.739	-1.505	-1.354	-0.985	-0.736
Lagged LHS	-0.096	0.126	0.291	0.085	-0.134
$t/\sqrt{m}$	-0.716	0.781	1.323	0.275	-0.314
N. obs.	132	210	216	204	192

Note: Exchange rate s is log(USD/CAD). The row $t/\sqrt{m}$ reports the re-scaled t-statistics for the estimates (see text for details). Estimates for the constant term are omitted, and * indicates a significance level of 10% or below.

Table A2. Japanese Regressions with the Inclusion of Lagged Dependent Variable

a) Exchange Rate $\frac{1200(s_{t+m}-s_t)}{m} = \beta_{m,0} + \beta_{m,1}L_t^R + \beta_{m,2}S_t^R + \beta_{m,3}C_t^R + \beta_{m,4}\frac{1200(s_t-s_{t-m})}{m} + u_{t+m}$

	m=1	m=3	m=6	m=12	m=18	m=24
L^R	-3.636	-2.357	-2.362	-2.770	-2.359	-1.604
$t/\sqrt{m}$	-1.206	-0.751	-0.812	-1.118	-0.998	-0.839
S^R	-3.572*	-3.586*	-3.712*	-2.642*	-2.747*	-2.395*
$t/\sqrt{m}$	-2.298	-2.194	-2.424	-2.053	-2.134	-2.341
C^R	0.299	0.696	0.402	-0.284	-0.098	-0.267
$t/\sqrt{m}$	0.265	0.601	0.376	-0.314	-0.102	-0.342
Lagged LHS	-0.010	-0.004	-0.032	0.000	-0.014	-0.018*
$t/\sqrt{m}$	-0.150	-0.111	-1.311	-0.009	-1.177	-2.233
N. obs.	238	234	228	216	204	192

b) Excess Return $i_t^{m*} - i_t^m + \frac{1200(s_{t+m}-s_t)}{m} = \gamma_{m,0} + \gamma_{m,1}L_t^R + \gamma_{m,2}S_t^R + \gamma_{m,3}C_t^R + i_{t-m}^{m*} - i_{t-m}^m + \frac{1200(s_t-s_{t-m})}{m} + v_{t+m}$

	m=3	m=6	m=12	m=18	m=24
L^R	-6.202	-3.666	-3.779	-3.602	-3.017
$t/\sqrt{m}$	-1.330	-1.240	-1.514	-1.522	-1.555
S^R	-4.824*	-4.957*	-3.372*	-3.417*	-2.924*
$t/\sqrt{m}$	-2.197	-3.150	-2.571	-2.624	-2.827
C^R	0.747	0.289	-0.515	-0.361	-0.554
$t/\sqrt{m}$	0.522	0.269	-0.570	-0.376	-0.702
Lagged LHS	-0.067	-0.164	-0.005	-0.230	-0.373*
$t/\sqrt{m}$	-0.443	-1.143	-0.027	-1.203	-2.187
N. obs.	103	216	216	204	192

Note: Exchange rate s is log(USD/JPN). The row $t/\sqrt{m}$ reports the re-scaled t-statistics for the estimates (see text for details). Estimates for the constant term are omitted, and * indicates a significance level of 10% or below.

Table A3. UK Regressions with the Inclusion of Lagged Dependent Variable

a) Exchange Rate $\frac{1200(s_{t+m}-s_t)}{m} = \beta_{m,0} + \beta_{m,1}L_t^R + \beta_{m,2}S_t^R + \beta_{m,3}C_t^R + \beta_{m,4}\frac{1200(s_t-s_{t-m})}{m} + u_{t+m}$

	m=1	**m=3**	**m=6**	**m=12**	**m=18**	**m=24**
$\mathbf{L^R}$	-3.150*	-4.053*	-3.139*	-2.615*	-1.495	-1.173
$t/\sqrt{m}$	-1.641	-2.345	-2.005	-1.727	-0.940	-0.766
$\mathbf{S^R}$	-1.796*	-2.312*	-1.969*	-1.433*	-0.763	-0.466
$t/\sqrt{m}$	-1.797	-2.527	-2.296	-1.720	-0.934	-0.597
$\mathbf{C^R}$	-0.755	-1.131*	-1.007*	-0.820*	-0.429	-0.253
$t/\sqrt{m}$	-1.383	-2.301	-2.230	-1.862	-0.945	-0.584
Lagged LHS	0.002	-0.014	-0.007	-0.001	-0.009	-0.008
$t/\sqrt{m}$	0.029	-0.432	-0.310	-0.090	-0.657	-0.681
N. obs.	214	210	204	192	180	168

b) Excess Return $i_t^{m*} - i_t^m + \frac{1200(s_{t+m}-s_t)}{m} = \gamma_{m,0} + \gamma_{m,1}L_t^R + \gamma_{m,2}S_t^R + \gamma_{m,3}C_t^R +$
$i_{t-m}^{m*} - i_{t-m}^m + \frac{1200(s_t-s_{t-m})}{m} + v_{t+m}$

	m=3	**m=6**	**m=12**	**m=18**	**m=24**
$\mathbf{L^R}$	-2.929	-3.829*	-3.733*	-2.632*	-2.255
$t/\sqrt{m}$	-0.907	-1.720	-2.340	-1.649	-1.487
$\mathbf{S^R}$	-5.065*	-2.890*	-2.254*	-1.382*	-1.009
$t/\sqrt{m}$	-2.095	-1.803	-2.355	-1.680	-1.295
$\mathbf{C^R}$	0.803	-0.781	-1.068*	-0.727	-0.545
$t/\sqrt{m}$	0.544	-1.005	-2.192	-1.592	-1.258
Lagged LHS	-0.257	-0.087	0.002	-0.177	-0.256
$t/\sqrt{m}$	-1.297	-0.481	0.011	-0.715	-0.858
N. obs.	57	122	175	180	168

Note: Exchange rate s is log(USD/GBP). The row $t/\sqrt{m}$ reports the re-scaled t-statistics for the estimates (see text for details). Estimates for the constant term are omitted, and * indicates a significance level of 10% or below.

Table A4. Correlation between SPF Forecasts and the US Factors

Real GDP Growth: $E_t \Delta y_{t+m} = \beta_{0m} + \beta_{1m} L_t + \beta_{2m} S_t + \beta_{3m} C_t + u_{mt}$

Horizon m	$\boldsymbol{\beta_{1m}}$	$\boldsymbol{\beta_{2m}}$	$\boldsymbol{\beta_{3m}}$	**Adj. R-Sq.**
3	-0.244*	-0.061	0.063	0.102
	(0.071)	(0.076)	(0.055)	
6	-0.187*	-0.070	-0.035	0.214
	(0.049)	(0.053)	(0.038)	
9	-0.136*	-0.066*	-0.046	0.306
	(0.034)	(0.037)	(0.026)	
12	-0.165*	-0.145*	-0.091*	0.563
	(0.034)	(0.036)	(0.026)	

CPI Inflation: $E_t \pi_{t+m} = \beta_{0m} + \beta_{1m} L_t + \beta_{2m} S_t + \beta_{3m} C_t + u_{kt}$

Horizon m	$\boldsymbol{\beta_{1m}}$	$\boldsymbol{\beta_{2m}}$	$\boldsymbol{\beta_{3m}}$	**Adj. R-Sq.**
3	0.458*	0.154*	0.050	0.698
	(0.041)	(0.044)	(0.032)	
6	0.449*	0.118*	0.072*	0.756
	(0.035)	(0.038)	(0.028)	
9	0.448*	0.094*	0.080*	0.768
	(0.034)	(0.037)	(0.027)	
12	0.461*	0.086*	0.081*	0.779
	(0.034)	(0.036)	(0.026)	

Anxiety Index: $A_{t+m} = \beta_{0m} + \beta_{1m} L_t + \beta_{2m} S_t + \beta_{3m} C_t + u_{mt}$

Horizon m	$\boldsymbol{\beta_{1m}}$	$\boldsymbol{\beta_{2m}}$	$\boldsymbol{\beta_{3m}}$	**Adj. R-Sq.**
3	3.399*	1.676	-2.150*	0.148
	(0.914)	(0.981)	(0.711)	
6	2.585*	2.235*	-1.117*	0.246
	(0.541)	(0.581)	(0.421)	
9	2.004*	2.212*	-0.175	0.530
	(0.312)	(0.335)	(0.243)	
12	1.731*	1.754*	0.555*	0.585
	(0.304)	(0.326)	(0.236)	

Table A5. In-Sample Fit Comparison between UIP and Factors Regressions

	m=3		m=6		m=9	
	Factors	**UIP**	**Factors**	**UIP**	**Factors**	**UIP**
Canada	0.025	0.003	0.042	0.016	0.060	0.033
N. obs.	172		224		229	
Japan	0.133	0.111	0.171	0.143	0.256	0.241
N. obs.	153		228		230	
UK	0.077	0.070	0.167	0.113	0.232	0.165
N. obs.	108		159		187	

Note: We compare the adjusted R-squares. Due to the missing observations in yields of short maturity, we adjust the sample for the factor model to make sure that we are comparing the two models using the same sample.