What Does the Yield Curve Tell Us About Exchange Rate Predictability?[*]

Yu-chin Chen, University of Washington
Kwok Ping Tsang, Virginia Tech

This version: May 2009

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 explain 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 provide an intuitive explanation to the uncovered interest parity puzzle by relating excess currency returns to inflation and business cycle risk.

Keywords: Exchange Rate Forecasting, Term Structure of Interest Rates, Uncovered Interest Parity

JEL: E43, F31, G12, G15

---

[*] First version: October 2008. We thank Vivian Yue for providing us the yield curve data, and Charles Nelson, Richard Startz, Wen-Jen Tsay and seminar participants at the Boston Federal Reserve Bank, the Academia Sinica, and the University of Kansas for valuable comments. This work is partly undertaken while Chen was a visiting scholar at Academia Sinica, and she gratefully acknowledges its hospitality as well as financial support from the National Science Council of Taiwan. Chen: Department of Economics, University of Washington, Box 353330, Seattle, WA 98195; yuchin@u.washington.edu. Tsang: Department of Economics, Virginia Tech, Box 0316, Blacksburg, VA, 24061; byront@vt.edu.

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 1 to 24 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 Nelson Siegel factors have well known macroeconomic interpretations and capture expected dynamics of future economic activity, our findings provide support for the asset pricing approach of exchange rate determination, and imply that the currency risk premia are driven by differential expectations about countries' future output and inflation, for example.

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 cross-country differences in money supply, output, inflation, and others. As measuring market expectations is

---

[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).

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 capture market expectations and test the asset approach by exploiting information contained in the shape of the yield curves. 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.[3] Extending this lesson to the international context, we look at cross-country yield curve *differences*, and extract three Nelson-Siegel (1987) factors - *relative* level, slope, and curvature -to summarize the expectation information contained there within.[4] The Nelson-Siegel representation has several advantages over the conventional no-arbitrage factor yield curve models. It is flexible enough to adopt to the changing shapes of the yield curve, and the model is parsimonious and easy to estimate.[5] It is also more successful in describing the *dynamics* of

---

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

[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 its 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] In addition, as discussed in Diebold, Rudebusch and Aruoba (2006), the Nelson-Siegel model avoids potential misspecification due to the presence of temporary arbitrage opportunities in the bonds market.

the yield curve over time, which is important for our goal of relating the evolution of the yield curve to movements in the expected exchange rate fundamentals.[6]

We look at three currency pairs over the period August 1985 to July 2005: the Canada dollar, the British pound, and the Japan yen relative to the US dollar.[7] Using monthly yield data, we fit the three Nelson-Siegel relative factors to the zero-coupon yield differences between the three countries and the US at maturities from three month to ten years. Our in-sample predictive regressions show that all three relative yield curve factors can help predict bilateral exchange rate movements and explain excess currency returns one month to two years ahead, with the slope factor being the most robust across currencies. We find that a one-percentage point rise in the relative slope or level factors of a country produces an annualized 3-4% appreciation of its currency subsequently, with the magnitude of the effect declining over the horizon. The responses of excess currency returns tend to be even larger. Movements in the curvature factor have a much smaller effect on exchange rates of roughly one-to-one, and it is also the least robust. We pay special attention to address the inference bias inevitable in our small sample long-horizon regressions, which we discuss in more details 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.[8] 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.[9]

---

[6] Diebold and Li (2006) show that by imposing an AR(1) structure on the factors, the Nelson-Siegel model has strong forecasting power for future yield curves. The no-arbitrage models are often successful in fitting a cross-section of yields, but don't do as well in the dynamic setting (e.g. Duffee 2002). In a companion paper (Chen and Tsang 2009b), we use the dynamic Nelson-Siegel model to jointly look at the yield curve, the exchange rate and its fundamentals.

[7] 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.

[8] 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).

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

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: the empirical regularity that the currencies of high interest rate countries tend to appreciate subsequently, rather than depreciate according to the foreign exchange market efficient condition.[10] In particular, we find that deviations from UIP − the currency risk premium − systematically 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 high home risk premium. Since the flattening of the yield curve is typically considered 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.[11] A similar explanation can also be applied to the case of a large level factor, which reflects high expected future inflation.[12] Both of these scenarios can induce higher perceived risk about holding the domestic currency, as its payoff would

---

[10] 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.

[11] 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 U.S. 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, 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.

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

be negatively correlated with the marginal utility of consumption. This explains our observed rise in excess home currency returns, i.e. the risk premium associated with domestic currency holding. As for the implication for the UIP puzzle, we note that since a rise in the short-term interest rate either flattens the slope of the yield curve or raises its overall level (or both), the home currency may subsequently appreciate instead of depreciate according to UIP, if the risk premium adjustment is large enough. Even though we do not explicitly model expectations and perceived risks in this paper, our results are in accordance with simple economic intuitions.[13]

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 U.S., 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), Clarida et al (2003), and de los Rios (2009).[14] Yield differences relate to exchange rate forwards via the covered interest parity condition. However,

---

[13] In Chen and Tsang (2009b), we explore the interface and joint dynamics of the exchange rate, its fundamentals, and the relative yield curves using the dynamic latent factor framework of Diebold, Rudebusch and Aruoba(2006).

[14] Clarida et al (2003) finds 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. de los Rios (2008) imposes further imposed the no-arbitrage restriction and find further forecast improvements.

given that the exchange rate forwards are only available up to a year or so, our yield curve approach can potentially capture a much a wider range of relevant market information by looking at yields all the way up to 10 years or beyond.

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 and pursue it in a separate paper.[15] Our conjecture here is that market expectations are extremely difficult to capture appropriately in simple models, contributing to previous difficulties in fitting the fundamental-based 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 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 while having

---

[15] 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. On the finance side, recent efforts using arbitrage-free affine or quadratic factor models have also shown success in connecting the term structure with the dynamics of exchange rates (see, for example, Inci and Lu (2004) and references therein.) Our paper differs from these previous papers in our emphasis on the macroeconomic fundamental connections between the yield curves and the exchange rates, through the use of the Nelson-Siegel factors. As discussed earlier, the Nelson-Siegel approach offers several advantages over the no-arbitrage factor models for our purposes.

well-established connection with macroeconomic variables. Lastly, we present a short discussion on excess returns and 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:

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

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:

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

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), 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 models the central banks as adjusting the short-term interest rates in response to the targetted output gap and inflation, and together with uncovered interest rate parity condition, it delivers a set of fundamentals similar to the ones above. In the Taylor rule model, we assume the monetary policy instruments, the home interest rate i_t and the foreign rate i_t^*, are set as follows:

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

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 the foreign central bank to explicitly target 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, ρ^H:

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

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

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

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}:

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

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}:

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

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 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, 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):

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

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).[16]

---

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

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.[17] 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 is rejected frequently, 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.[18] 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:

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

where i_t^m is the continuously-compounded zero-coupon nominal yield on a *m*-month bond. The parameter λ controls the speed of exponential decay. As discussed earlier, one of the main advantages of the Nelson-Siegel approach, compared to the popular no-arbitrage affine or quadratic

---

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

[18] 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.

factor models, is that the three factors, L_t, S_t, and C_t, are easy to estimate and 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, and 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.[19] 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.[20]

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

---

[19] 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.

[20] 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 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.

between the yield curve factors and macroeconomic dynamics.[21] . Ang, Piazzesi and Wei (2006) estimate a VAR model for the US yield curve and GDP growth. By imposing 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 4 to 12 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 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.[22] 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.[23]

---

[21] 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.

[22] 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.

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

To capture the arguments in the vast literature above, below we provide a simple illustrative example of how the level and slope factors incorporate expectations of future inflation and output dynamics. We begin with a monetary policy rule for the short-term rate i_t:

$$i_t = \rho + \pi_t^* + \phi_\pi(\pi_t - \pi_t^*) + \phi_y \tilde{y}_t + \phi_X X_t + u_t \tag{10}$$

where ρ is the constant long-run real rate, and the vector X_t contains variables that the central bank reacts other than inflation π_t and output gap $\tilde{y}_t$, and it has a long-run value of zero. Following Ireland (2007), we assume the long-run inflation target π_t^* to evolve exogenously as a random walk. The above policy rule ensures that in the long run, $i_{LR} = \rho + \pi_{LR}^*$.

Next, we can write the yield of maturity m as:

$$i_t^{(m)} = \frac{1}{m}\sum_{i=1}^{m-1} E_t\{i_{t+i}\} + \theta_t^{(m)} \tag{11}$$

The above expression can be invoked by the expectations hypothesis, though it has little to say about $\theta_t^{(m)}$ (i.e. assuming it to be constant). A canonical no-arbitrage affine model of term structure will also give us a similar expression, and the $\theta_t^{(m)}$ will be determined by the way we specify the price of risk (i.e. the price of risk can be driven by the variables in the monetary policy rule). Substituting the monetary rule (10) into (11), we have:

$$i_t^{(m)} = \frac{1}{m}\sum_{i=1}^{m-1} E_t\{\rho + \pi_{t+i}^* + \phi_\pi(\pi_{t+i} - \pi_{t+i}^*) + \phi_y \tilde{y}_{t+i} + \phi_X X_{t+i} + u_{t+i}\} + \theta_t^{(m)} \tag{12}$$

The level factor can be obtained as the infinite maturity yield, by taking limit of m in the above expression:

$$L_t = i_t^{(\infty)} = \rho + \pi_t^* + u_t + \theta_t^{(\infty)} \tag{13}$$

The last equality is approximately correct when $m \to \infty$ as the three other terms have long-run averages of zero. Level factor is driven by the long-run inflation target and the term premium at infinite maturity. The slope factor is defined as the difference between the short term yield and the level factor:

$$S_t = i_t - i_t^{(\infty)} = \phi_\pi(\pi_t - \pi_t^*) + \phi_y \tilde{y}_t + \phi_X X_t - \theta_t^{(\infty)} \tag{14}$$

The slope factor is also driven by the long-run term premium, and also the inflation gap, output gap, and other relevant exogenous variables. Notice that, as an identity:

$$i_t = L_t + S_t \tag{15}$$

We are decomposing the short term interest rate, which is controlled by the central as a policy instrument, into two components: a secular component which reflects changes in the inflation target, and a cyclical component which reflects the short term deviations from targets.

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:

$$i_t^m - i_t^{m*} = L_t^R + S_t^R\left(\frac{1-e^{-\lambda m}}{\lambda m}\right) + C_t^R\left(\frac{1-e^{-\lambda m}}{\lambda m} - e^{-\lambda m}\right) \tag{16}$$

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:

$$rx_{t+m} = i_t^{m*} - i_t^m + \Delta s_{t+m} \tag{17}$$

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.[24] We note that under the assumption of rational expectations, excess returns in equation (17) 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):

$$\text{UIP:}\quad \Delta s_{t+m} = i_t^m - i_t^{m*} + \rho_{t+m}^F + \varepsilon_{t+m} \qquad (18)$$

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

---

[24] 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.

Fama-Bliss (1987) methodology.[25] For the rest of the paper, we treat the U.S. as the home country, and we measure exchange rate S as the U.S. dollar price per unit of the foreign currency.[26] A lower number means an appreciation of the home currency, the USD. For all horizons, we define exchange rate change as the annualized change of the log exchange rate s.

We fit the Nelson-Siegel (1987) yield curve as equation (16) 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.[27] 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 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

---

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

[26] 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 (2 days earlier).

[27] 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.

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 U.S. yield curve in each of these country pairs.[28] Within each country the three factors are also correlated, but there is no consistent pattern.

Finally, excess currency return is computed as:

$$rx_{t+m} = i_t^{m*} - i_t^m + \frac{1200(s_{t+m} - s_t)}{m} \tag{19}$$

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.

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 (20):[29]

$$\frac{1200(s_{t+m} - s_t)}{m} = \beta_{m,0} + \beta_{m,1} L_t^R + \beta_{m,2} S_t^R + \beta_{m,3} C_t^R + u_{t+m} \tag{20}$$

$$rx_{t+m} = \gamma_{m,0} + \gamma_{m,1} L_t^R + \gamma_{m,2} S_t^R + \gamma_{m,3} C_t^R + v_{t+m} \tag{21}$$

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.[30] 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.

---

[28] 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.

[29] Since 1-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.

[30] We run equations (20) and (21) 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.

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 1 month, our LHS variable overlaps across observations, and u_{t+m} or v_{t+m} in equations (20) and (21) 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 1-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 1-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 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 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):

$$r_{t,t+1} = \alpha + \beta x_t + u_{t+1}$$

$$x_t = \rho x_{t-1} + \epsilon_t \tag{22}$$

where $r_{t,t+1}$ is the 1-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.[31] 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:

$$R_{t,t+m} = \alpha_m + \beta_m x_t + u_{m,t+1} \tag{23}$$

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 it 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.

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

---

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

4. Main Results

Our main exchange rate predictive results based on equation (20) are presented in panel (a) in Tables 2-4, and the corresponding ones for excess returns, equation (1), 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.[32] 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 one percentage point 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-squares 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 one percentage point 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

---

[32] 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". In addition, Krippner (2006) found that the failure of the UIP in CAD/USD rate is mainly attributed to the cyclical component of the interest rates.

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 6-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.

United Kingdom: All the three factors predict exchange rate changes and excess returns, and all are both quantitatively and statistically significant. For example, a one percentage point 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. Discussions and Robustness Tests

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.[33]

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 macroeconomic dynamics. 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

---

[33] 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.

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 1 to 4 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 - correspond to the current slope factor. Our sample period is 1985Q3 to 2005Q2, and to match SPF's quarterly data for the U.S., we create quarterly average from our monthly U.S. factors (not relative).[34] 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.

$$E_t\Delta y_{t+m} = \alpha_{Sm} + \beta_{Sm}S_t + \beta_{ym}\Delta y_t + u_{Smt} \tag{24}$$

$$A_{t+m} = \gamma_{Sm} + \delta_{Sm}S_t + \delta_{ym}\Delta y_t + v_{Smt} \tag{25}$$

$$E_t\pi_{t+m} = \alpha_{Lm} + \beta_{Lm}L_t + \beta_{\pi m}\pi_t + u_{Lmt} \quad \text{for m= 3, 6, 9, and 12} \tag{26}$$

The first two regressions checks 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 3 quarters to a year ahead, as well as higher perceived

---

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

probability of an economic downturn in six months to a year horizon. A larger level factor consistently maps to higher expected inflation across all future horizons.[35]

5.3 Interpretation and Discussion

To provide an alternative test to the present value approach to exchange rate determination, this paper sidesteps explicit structural modeling of market expectations, including perceived risks. While our results do not constitute an explicit test for any specific model, our positive results nevertheless 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 and rising inflation. Our results show that under these scenarios, everything else equal, its currency will be less desirable and 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 can be considered the risk premium associated with holding this currency. Our result shows that the currency 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 correspondingly rise in ρ^F.[36] This pattern makes intuitive sense. Take, for example, the case of a high relative level factor abroad, signaling higher expected inflation relative to home. The purchasing power of the nominal currency erodes when inflation rate is high, and the net present value model points to a correspondingly weaker currency, eroding both the real and relative returns of foreign currency. As documented in previous literature such as Piazzesi and

---

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

[36] In the notation of equation (18), this means either S^Ror L^R is low, and excess return, or ρ^F is high.

Schneider (2006), inflation and consumption growth are negatively correlated.[37] This suggests a negative covariance between foreign currency returns and the marginal utility; foreign currency is thus risky. A similar argument can be made about the slope factor, which reflects business cycle or output growth dynamics. When the relative slope is flatter in the foreign country, agents expect low output and a weaker currency abroad. The low payoff from the foreign currency in states of nature where output and consumption are low (marginal utility high) again makes it a bad hedge and a risky asset. While this is only an illustrative sketch, our positive findings suggest further exploration in using a (international) macro-finance approach to jointly study the fundamentals , the yields, and the exchange rate would be warranted.

The finding that a high level or a flatter slope raises the risk premium 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 it (if the long rates do not respond), or raising the whole curve (if the longer maturity rates go up as well).[38] 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 (18), 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 foreign interest rate, instead of depreciating according to simple UIP. Putting it differently, our finding suggests that to predict relative currency movements, it is not enough to look at the current short rates (UIP), as it fails to capture the relative risks the market perceives about the two currencies. Looking at the rest of the yield curves helps. If the country with the higher short rate faces lower long-maturity yields (e.g. a downward-sloping yield curve) relative to the other country's yields, its currency would tend to appreciate subsequently, as the

---

[37] Using post-war US data, they found inflation to be negatively correlated with current, past, and future consumption growth. Inflation risk therefore explains the positive (yield) term premia.

[38] 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.

market prices in a large risk premium in anticipation of less favorable economic conditions in this country.

We note that our results are consistent with the longer-horizon UIP literature, e.g. Meredith and Chinn's (1998), which finds that the UIP holds better at 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 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.

Even though this paper does not explicitly model the structural interface between macro dynamics and the yield curve-exchange rate behavior, our finding offers an 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." In addition, the positive results in this paper motivate further extensions of the joint macro-finance approach of yield curve modeling, pioneered by Diebold, Piazzesi, and Rudebusch (2005), into the international arena.

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 condition.

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 country's yield curves can predict the relative value of their currencies.

References

[1] **Ang, Andrew and Geert Bekaert** (2006): "Stock Return Predictability: Is it There?" *Review of Financial Studies*, Vol. 20, No. 3, pp. 651-707.

[2] **Ang, Andrew, Monika Piazzesi and Min Wei** (2006): "What Does the Yield Curve Tell us about GDP Growth?" *Journal of Econometrics*, 131, pp. 359-403.

[3] **Barr, David G. and John Y. Campbell** (1997): "Inflation, Real Interest Rates, and the Bond Market: A Study of UK Nominal and Index-Linked Government Bond Prices," *Journal of Monetary Economics*, Vol. 39, 361-83.

[4] **Bekaert, Geert, Seonghoon Cho and Antonio Moreno** (2006): "New-Keynesian Macroeconomics and the Term Structure," working paper.

[5] **Bekaert, Geert, Min Wei and Yuhang Xing (**2007): "Uncovered interest rate parity and the term structure, " Journal of International Money and Finance, Elsevier, vol. 26(6), pages 1038-1069.

[6] **Boudoukh, Jacob, Richardson, Matthew P. and Whitelaw, Robert F.** (2005): "The Information in Long-Maturity Forward Rates: Implications for Exchange Rates and the Forward Premium Anomaly," NBER Working Paper No. *11840*.

[7] **Campbell, John Y. and Robert Shiller** (1988): "The Dividend-Price Ratio and Expectations of Future Dividens and Discount Factors," *Review of Financial Studies*, 1, 405-27.

[8] **Chen, Yu-chin and Kenneth S. Rogoff** (2003): "Commodity Currencies," *Journal of International Economics*, Vol. 60, No. 1, 133-60.

[9] **Chen, Yu-chin and Kwok Ping Tsang** (2009): "Expectations, Learning, and Exchange Rates: Evidence from Surveyed Data," working paper.

[10] **Chen, Yu-chin and Kwok Ping Tsang** (2009b): "The Exchange Rates, Yield Curves, and Macroeconomic Fundamentals: A Dynamic Latent Factor Approach"," working paper.

[11] **Clarida, Richard and Daniel Waldman** (2008): "Is Bad News About Inflation Good News for the Exchange Rate?" forthcoming, in John Y. Campbell (ed.), *Asset Prices and Monetary Policy*, University of Chicago Press.

[12] **Clark, Todd E. and Kenneth D. West** (2006): "Using Out-of-sample Mean Squared Prediction Errors to Test the Martingale Difference Hypothesis," *Journal of Econometrics*, 135, pp.155-186.

[13] **De los Rios, Antonio Diez** (2009), "Can Affine Term Structure Models Help Us Predict Exchange Rates?" *Journal of Money*, *Credit* and Banking, Vol. 41.issue 4, pages 755-766.

[14] **Dewachter, Hans and Macro Lyrio (2006): "Macro Factors and the Term Structure of Interest Rates," *Journal of Money, Credit and Banking*, Vol. 38, No. 1, 119-40.**

[15] **Diebold, Francis X., C. Li and Vivian Yue** (2007): "Global Yield Curve Dynamics and Interactions: A Generalized Nelson-Siegel Approach," forthcoming at the *Journal of Econometrics*.

[16] **Diebold, F.X., Piazzesi, M. and Rudebusch, G.D.** (2005), "Modeling Bond Yields in Finance and Macroeconomics," *American Economic Review*, 95, 415-420

[17] **Diebold, F.X., Rudebusch, G.D. and Aruoba, B.** (2006): "The Macroeconomy and the Yield Curve: A Dynamic Latent Factor Approach," *Journal of Econometrics*, 131, 309-338.

[18] **Diebold, Francis X., Monika Piazzesi and Glenn D. Rudebusch** (2005): "Modeling Bond Yields in Finance and Macroeconomics," *American Economic Review*, Vol. 95, No. 2, 415-20.

[19] **Dotsey, Michael** (1998): "The Predictive Content of the Interest Rate Term Spread for Future Economic Growth," *Federal Reserve Bank of Richmond Economic Quarterly*, 84, 31–51.

[20] **Dueker, Michael J.** (1997): "Strengthening the Case for the Yield Curve as a Predictor of U.S. Recessions," *Federal Reserve Bank of St. Louis Review*, 79, 41–51.

[21] **Duffee, Gregory R.** (2002): "Term Premia and Interest Rate Forecasts in Affine Models," *Journal of Finance,* 57, 405-443.
[22] **Eichenbaum, Martin and Charles L. Evans** (1995): "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates," *Quarterly Journal of Economics*, Vol. 100, No. 4, p.975-1009.
[23] **Elliott, G., Rothenberg, T. J. & J.H. Stock** (1996) "Efficient Tests for an Autoregressive Unit Root," *Econometrica*, Vol. 64, No. 4, pp. 813-836.
[24] **Engel, Charles and Kenneth D. West** (2005): "Exchange Rates and Fundamentals," *Journal of Political Economy*, Vol. 113, No. 3, pp. 485-517.
[25] **Estrella, Arturo** (2005): "Why Does the Yield Curve Predict Output and Inflation?" *Economic Journal*, Vol. 115, Issue 505, p.722-744.
[26] **Estrella, Arturo, and Gikas A. Hardouvelis** (1991): "The Term Structure as a Predictor of Real Economic Activity," *Journal of Finance*, 46, 555–76.
[27] **Fama, Eugene and Robert R. Bliss** (1987): "The Information in Long-Maturity Forward Rates," *American Economic Review*, Vol. 77, No. 4, pp. 680-692.
[28] **Frankel, Jeffery** (1979): "*On the mark*: A theory of floating exchange rates based on real interest differentials," *American Economic Review* Vol. 69, pp. 610–623.
[29] **Frankel, Jeffery, and Andrew Rose** (1995): "Empirical research on nominal exchange rates," in *Handbook of International Economics* vol. 3, Gene Grossman and Kenneth Rogoff (eds.), (Amsterdam: Elsevier Science Publishers B.V., 1995): 1689-1729.
[30] **Gourinchas, Pierre-Olivier and Aaron Tornell** (2004): "Exchange Rate Puzzles and Distorted Beliefs" *Journal of International Economics*, 64, pp.303-333.
[31] **Hamilton, James D. and Dong Heon Kim** (2002): "A Reexamination of the Predictability of Economic Activity Using the Yield Spread," *Journal of Money, Credit and Banking*, Vol. 34, No. 2, 340-60.
[32] **Haubrich, Joseph G., and Ann M. Dombrosky** (1996): "Predicting Real Growth Using the Yield Curve," *Federal Reserve Bank of Cleveland Economic Review*, 32, 26–35.
[33] **Inci Ahmet Can, Lu Biao** (2004): "Exchange rates and interest rates: Can term structure models explain currency movements?" *Journal of Economic Dynamics and Control*, 28 (8), pp. 1595-1624.
[34] **Ireland, Peter N**. (2007): "Changes in the Federal Reserve's Inflation Target: Causes and Consequences," *Journal of Money, Credit, and Banking.*
[35] **Krippner, Leo** (2006), "A Yield Curve Perspective on Uncovered Interest Parity", University of Waikato, Department of Economics Working Paper.
[36] **Kozicki, Sharon and Peter A. Tinsley** (2001): "Shifting Endpoints in the Term Structure of Interest Rates," *Journal of Monetary Economics*, Vol. 52, 855-79.
[37] **Mark, Nelson C.** (1995): "Exchange Rates and Fundamentals: Evidence on Long-Horizon Predictability," *American Economic Review*, 85, 1, 201--218. Reprinted in L. Sarno and M.P. Taylor eds., *New Developments in Exchange Rate Economics*, Edward Elgar, Cheltenham, UK (2001).
[38] **Mark, Nelson C.** (2001): *International Macroeconomics and Finance: Theory and Econometric Methods*, Blackwell Publishing.
[39] **Mark, Nelson C. and Sul, Donggyu** (2001): "Nominal Exchange Rates and Monetary Fundamentals: Evidence from a Small Post-Bretton Woods Panel," *Journal of International Economics*, vol. 53(1), 29-52.
[40] **Meese, R. and Kenneth S. Rogoff** (1983): "Empirical Exchange Rate Models of the Seventies: Do they Fit Out of Sample," *Journal of International Economics,* 14, 3-24.
[41] **Meredith, Guy and Menzie D. Chinn** (1998): "Long-Horizon Uncovered Interest Rate Parity," *NBER* working paper no. 6797.

[42] **Mishkin, Frederic** (1990a): "What Does the Term Structure Tell Us About Future Inflation?" *Journal of Monetary Economics*, Vol. 25, p.77-95.

[43] **Mishkin, Frederic** (1990b): "The Information in the Longer Maturity Term Structure about Future Inflation," *Quarterly Journal of Economics*, vol. CV, no. 442, 815-828.

[44] **Molodtsova, Tanya, Alex Nikolsko-Rzhevskyy and David H. Papell** (2008): "Taylor Rules with Real-Time Data: A tale of Two Countries and One Exchange Rate," forthcoming, *Journal of Monetary Economics.*

[45] **Molodtsova, Tanya and David H. Papell** (2008): "Out-of-Sample Exchange Rate Predictability with Taylor Rule Fundamentals," mimeo, University of Houston.

[46] **Moon, Roger, Antonio Rubia and Rossen Valkanov** (2004): "Long-Horizon Regressions when the Predictor is Slowly Varying," working paper.

[47] **Mussa, Michael** (1976): "The Exchange Rate, the Balance of Payments, and Monetary and Fiscal Policy under a Regime of Controlled Floating," *Scandinavian Journal of Economics*, 78, 229-48.

[48] **Nelson, Charles R. and M. Kim** (1993): "Predictable Stock Returns: The Role of Small Sample Bias," *Journal of Finance*, 48, 641-61.

[49] **Nelson, Charles R. and Andrew F. Siegel** (1987): "Parsimonious Modeling of Yield Curves," *Journal of Business*, Vol. 60, No. 4, pp. 473-489.

[50] **Obstfeld, Maurice and Kenneth S. Rogoff** (1996): *Foundations of International Macroeconomics* (MIT Press, Cambridge, MA).

[51] **Parker, Jonathan A. and Christian Julliard** (2005): "Consumption Risk and the Cross Section of Expected Returns," *Journal of Political Economy*, Vol. 113, No. 1, pp. 185-222.

[52] **Plosser, Charles I., and K. Geert Rouwenhorst** (1994): "International Term Structures and Real Economic Growth," *Journal of Monetary Economics*, 33, 133–55.

[53] **Rogoff, Kenneth S.** (1980): "Expectations and Exchange Rate Volatility," unpublished PhD thesis, MIT.

[54] **Rogoff, Kenneth S. and Vania Stavrakeva** (2008): "The Continuing Puzzle of Short Horizon Exchange Rate Forecasting," *NBER working paper* No. 14071.

[55] **Rudebusch, Glenn D. and Tao Wu** (2007): "Accounting for a Shift in Term Structure Behavior with No-Arbitrage and Macro-Finance Models," *Journal of Money, Credit and Banking*, vol. 39(2-3), 395-422.

[56] **Rudebusch, Glenn D. and Tao Wu** (2008): "A Macro-Finance Model of the Term Structure, Monetary Policy and the Economy," *Economic Journal*, vol. 118(530), 906-926.

[57] **Sarno, Lucio** (2005): "Viewpoint: Towards a Solution to the Puzzles in Exchange Rate Economics: Where do we Stand?" *Canadian Journal of Economics*, Vol. 38, No. 3, 673-708.

[58] **Stock, James H. and Mark W. Watson** (1999): "Forecasting Inflation," *Journal of Monetary Economics*, Vol. 44, Issue 2, p.293-335.

[59] **Thornton, Daniel L.** (2006): "Tests of the Expectations Hypothesis: Resolving the Campbell-Shiller Paradox," *Journal of Money, Credit and Banking*, 38(2), pp. 511-42.

[60] **Valkanov, Rossen** (2003): "Long-Horizon Regressions: Theoretical Results and Applications," *Journal of Financial Economics*, 68, 201-32.

[61] **Wang, Jian and Jason J. Wu** (2009): "The Taylor Rule and Forecast intervals for Exchange Rates," *FRB International Finance Discussion Paper No. 963.*

[62] **Wu, Shu** (2007): "Interest Rate Risk and the Forward Premium Anomaly in Foreign Exchange Markets, " *Journal of Money, Credit and Banking*, 2007, vol. 39, issue 2-3, pages 423-442.

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

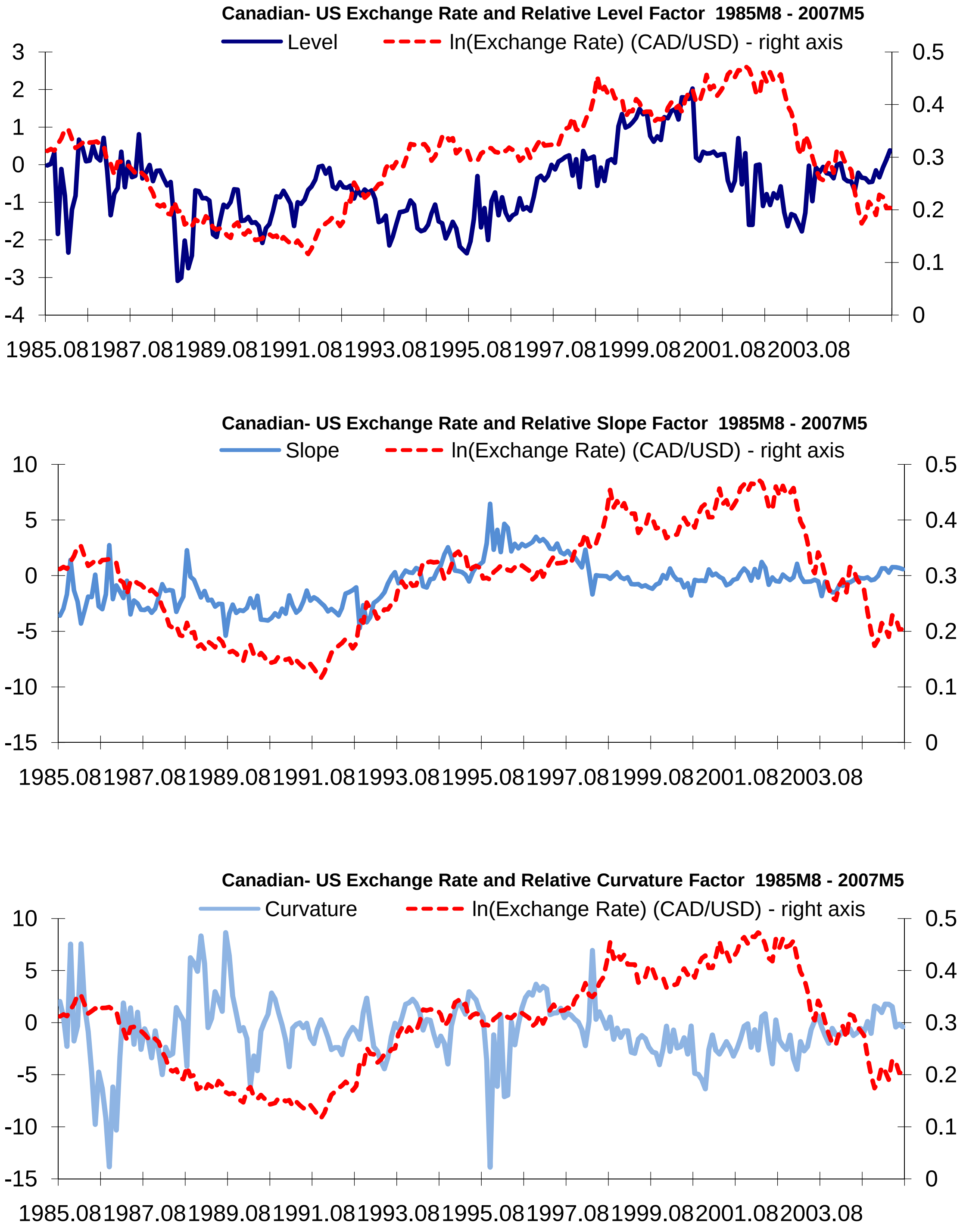
	m=3	**m=6**	**m=9**	**m=12**
$\boldsymbol{\delta_{Sm}}$	-0.546	0.985*	1.813*	1.989*
	(0.743)	(0.486)	(0.336)	(0.335)
N. obs.	80	80	80	80
Adj. R^2	0.243	0.182	0.267	0.321

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**
$\boldsymbol{\beta_{Lm}}$	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

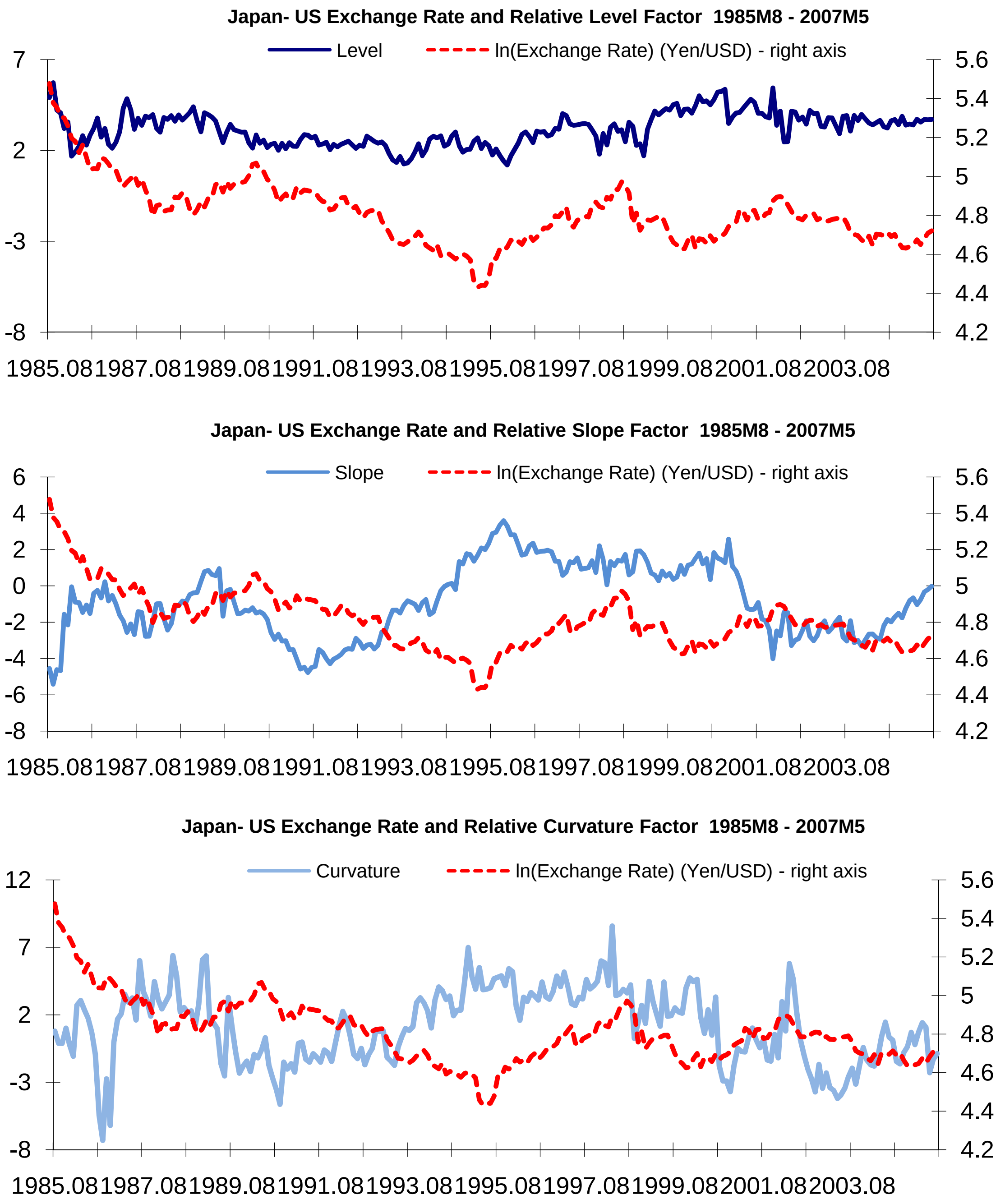
Note: * indicates significance level of 10% or below. We use quarterly data from the Survey of Professional Forecasters maintained by the Federal Reserve Bank of Philadelphia. The factors are quarterly average of the monthly data (though we obtain similar results when we use the first month of each quarter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

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



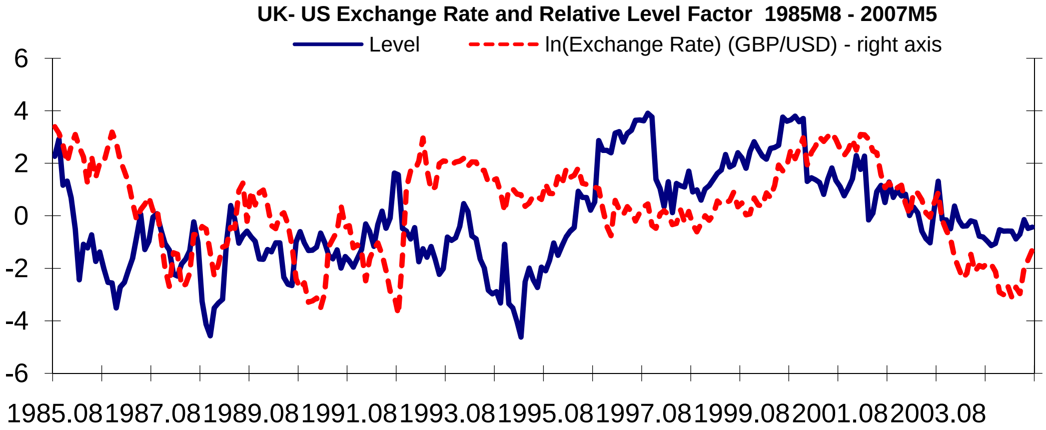
Note: The relative term structure factors are calculated by the following procedure: in each period, we subtract the yields of the country from those of the US with matching maturities. We then fit the Nelson-Siegel yield curve on the yield differences to obtain the level, slope and curvature factors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

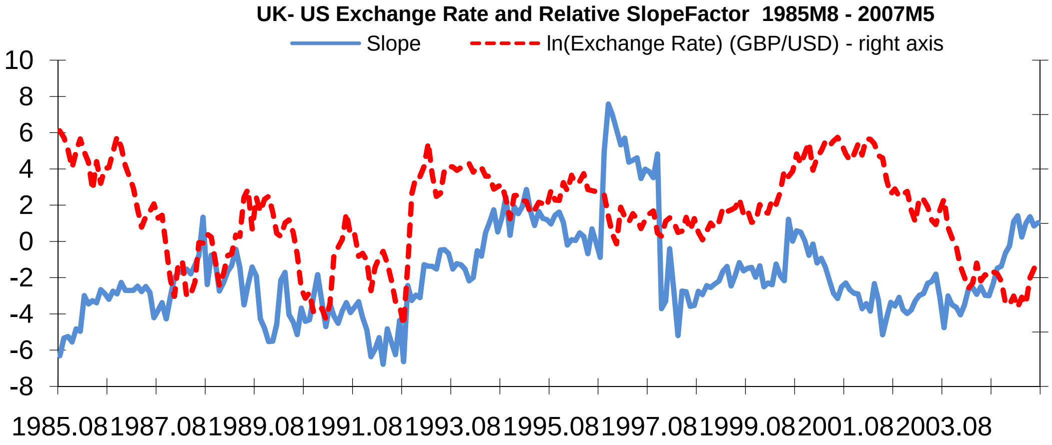
Figure 2: The Japan-US Exchange Rate and Relative Factors

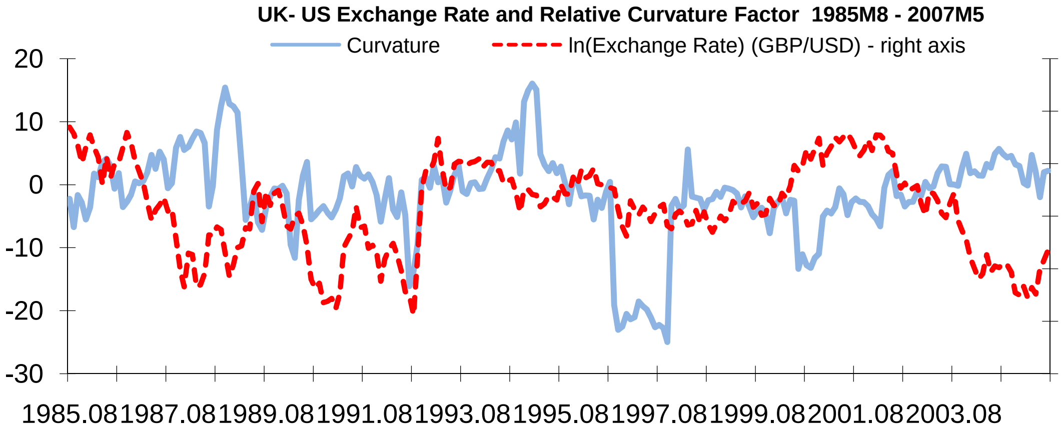


Note: The relative term structure factors are calculated by the following procedure: in each period, we subtract the yields of the country from those of the US with matching maturities. We then fit the Nelson-Siegel yield curve on the yield differences to obtain the level, slope and curvature factors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

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







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 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 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**
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
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
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**
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
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
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 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.