Risk and Expectations in Exchange Rate Determination: A Macro-Finance Approach*

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Abstract. This paper first explores the roles of risk and expectations in explaining currency returns, and then proposes an exchange rate model that combines key elements from both the finance and macro literature. Postulating that the observed deviations from market efficiency conditions in the sovereign bond markets and in the foreign exchange markets may stem from the same time-varying risk, we test whether term premiums extracted from bond yields across countries can predict subsequent currency return differentials. Using monthly data between 1984 and 2009 for seven countries, we construct measures of term premiums based on several modeling concepts for the terms structure of interest rates, including Nelson-Siegel (1987), Dai and Singleton (2002), Diebold, Piazessi, and Rudebusch (2005), and Cochrane and Piazzesi (2005). We find that term premiums can explain up to 20%-30% of the variations in subsequent currency returns. We then propose a joint macro-finance model for the exchange rate and demonstrate the importance of capturing both risk and expectations about future macroeconomic conditions in explaining exchange rate dynamics at short to medium horizons.

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1 Introduction

This paper proposes to model nominal exchange rates by incorporating both macroeconomic determinants and latent financial risks, bridging the gap between two important strands of recent research. First, against decades of negative findings in testing exchange rate models, recent work by Engel, Mark and West (2007), Molodtsova and Papell (2009) among others, shows that models in which monetary policy follows an explicit Taylor (1993) interest rate rule deliver improved empirical performance, both in in-sample fits and in out-of-sample forecasts.[1] These papers emphasize the importance of expectations, in particular about future macroeconomic dynamics, and argue that the nominal exchange rate should be viewed as an asset price embodying the net present value of its expected future fundamentals.[2] While generally recognizing the presence of risk, this literature largely ignores risk in empirical testing and renders it an "unobservable".[3] On the finance side, research shows that systematic sources of financial risk, as captured by latent factors, drive excess currency returns both across currency portfolios and over time.[4] These papers firmly establish the role of risk but are silent on the role of macroeconomic conditions, including monetary policy actions, in determining exchange rate. They thus fall short on capturing the potential feedback between macroeconomic forces, expectations formation, and perceived risk in exchange rate dynamics. This paper argues that the macro and the finance approaches should be combined, and proposes a joint framework to capture intuition from both bodies of literature by incorporating information from the term structures of interest rates.

We present an open economy model where central banks follow a Taylor-type interest rate rule that stabilizes expected inflation, output gap, and the real exchange rate.[5]

[1] This approach works well for modeling exchange rates of countries that have credible inflation control policies.

[2] Since the Taylor-rule fundamentals – measures of inflation and output gap – affect expectations about future monetary policy actions, changes in these variables induce nominal exchange rate responses.

[3] Engel, Mark, and West (2007), for example, establish a link between exchange rates and fundamentals in a present value framework. After explicitly recognizing the possibility that risk premiums may be important in explaining exchange rates, they "do not explore that avenue in this paper, but treat it as an unobserved fundamental." Molodstova and Papell (2009), show that Taylor rule fundamentals (interest rates, inflation rates, output gaps and the real exchange rate) forecast better than the commonly used interest rate fundamentals, monetary fundamentals and PPP fundamentals. Again, they explain exchange rate using only observed fundamentals and do not account for risk premium. This is an obvious shortcoming in modeling short-run exchange rate dynamics. Faust and Rogers (2003) for instance argue that monetary policy accounts for very little of the exchange rate volatility.

[4] See Inci and Lu (2004), Lustig et al. (2009), and Farhi et al. (2009), and references therein for the connection between risk factors and currency portfolio returns. Bekaert et al. (2007), for instance, point out that risk factors driving the premiums in the term structure of interest rates may also drive the risk premium in currency returns. In addition, Clarida and Taylor (1997) uses the term structure of forward exchange premiums to forecast spot rates. de los Rios (2009) and Krippner (2006) connect the interest rate term structure factors and exchange rate behavior. These papers do not examine the role of macroeconomic fundamentals or monetary policy.

[5] Note that following Clarida, Gali, and Gertler (1998), the incorporation of the exchange rate term to

The international asset market efficiency condition - the risk-adjusted uncovered interest parity (UIP) - implies that nominal exchange rate is the net present value of expected future paths of interest differentials and risk premiums between the country pair. This framework establishes a direct link between the exchange rate and its current and expected future macroeconomic fundamentals; it also allows country-specific risk premiums over different horizons to affect exchange rate dynamics. Since exchange rate in this formulation relies more on expectations about the future than on current fundamentals, properly measuring expectations and time-varying risk becomes especially important in empirical testing. Previous papers largely fail to address this appropriately.[6] We propose to use information from cross-country yield curves to separately identify and test the importance of expectations about future macroeconomic conditions and systematic risk in driving currency behavior. We then combine the latent yield curve factors with monetary policy targets (unemployment and inflation rates) into a vector autoregression (VAR) to study their dynamic interactions with bilateral exchange rate changes.[7]

The joint macro-finance strategy has proven fruitful in modeling other financial assets such as the yield curves themselves.[8] As stated in Diebold et al (2005), the joint approach captures both the macroeconomic perspective that the short rate is a monetary policy instrument used to stabilize the economy, as well as the financial perspective that yields of all maturities are risk-adjusted averages of expected future short rates. Our exchange rate model is a natural extension of this idea into the international context. First, the no-arbitrage condition for international asset markets explicitly links exchange rate dynamics to cross-country yield differences at the corresponding maturities and a time-varying currency risk premium. Yields at different maturities - the shape of the yield curve - are in turn determined by the expected future path of short rates and perceived future uncertainty (the "term premiums"). The link with the macroeconomy comes from noticing that the short rates are monetary policy instruments which react to macroeconomic fundamentals. Longer yields therefore contain market expectations about future macroeconomic conditions. On the other hand, term premiums in the yield curve measure the market pricing of system-

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an otherwise standard Taylor rule has become commonplace in recent literature, especially for modeling monetary policy in non-US countries. See, for example, Engel and West (2006) and Molodtsova and Papell (2009).

[6] Previous literature often ignores risk or makes overly simplistic assumptions about these expectations, such by using simple VAR forecasts of macro fundamentals as proxies for expectations. For instance, Engel and West (2006) and Mark (1995) fit VARs to construct forecasts of the present value expression. Engel et al. (2007) note that the VAR forecasts may be a poor measure of actual market expectations and use surveyed expectations of market forecasters as an alternative. See discussion in Chen and Tsang (2009).

[7] Chen and Tsang (2009) show that the Nelson-Siegel factors between two countries can help predict movements in their exchange rates and excess returns. It does not, however, consider the dynamic interactions between the factors and macroeconomic conditions.

[8] Ang and Piazzesi (2003), among others, illustrate that a joint macro-finance modeling strategy provides the most comprehensive description of the term structure of interest rates.

atic risk of various origins over different future horizons.[9] Under the reasonable assumption that a small number of underlying risk factors affect all asset prices, currency risk premium would then be correlated with the term premiums across countries. From a theoretical point of view, the yield curves thus serve as a natural measure to both the macro- and the finance-aspect of the exchange rates. From a practical standpoint, the shape and movements of the yield curves have long been used to provide continuous readings of market expectations; they are a common indicator for central banks to receive timely feedback to their policy actions. Recent empirical literature, such as Diebold et al. (2006), also demonstrates strong dynamic interactions between the macroeconomy and the yield curves. These characteristics suggest that empirically, the yield curves are also a robust candidate for capturing the two "asset price" attributes of nominal exchange rates: expectations on future macroeconomic conditions and perceived time-varying risks.

For our empirical analyses, we look at monthly exchange rate changes for six country pairs - Australia, Canada, Japan, New Zealand, Switzerland, and the UK relative to the US - over the period from January 1984 to May 2009.[10] For each country pair, we extract three Nelson-Siegel (NS, 1987) factors from the zero-coupon yield *differences* between them, using yield data with maturities ranging from three months to ten years. These three latent risk factors, which we refer to as the *relative level*, *relative slope*, and *relative curvature*, capture movements at the long, short, and medium part of the *relative* yield curves between the two countries. The Nelson-Siegel factors are well known to provide excellent empirical fit for the yield curves, providing a succinct summary of both expectations about future macroeconomic dynamics as well as the systematic sources of risk that may underlie the pricing of different financial assets. Taking into account the possibility of structural breaks, we first confirm results established in Chen and Tsang (2011) that these yield curve factors indeed have robust explanatory power for subsequent exchange rate behavior. We then proceed to examine the specific role of risk versus expectations in these results.

In order to construct measures of risk from the yield curve data, we employ five alternative methods based on different concepts of terms structure modeling that are well-known in the literature. These include the Nelson Siegel latent factor model, Dai and Singleton (2002)'s affine model, the macro-finance framework discussed in Deibold, Piazzesi, and Rudebusch (DPR 2005) and Diebold, Rudebusch, and Aruoba (DRA 2006), and also the Cochrane and Piazzesi (CP, 2005) approach.[11] Based on these alternative and admittedly all incomplete

[9] Kim and Orphanides (2007) and Wright (2009), for example, provide a comprehensive discussion of the bond market term premium, covering both systematic risks associated with macroeconomic conditions, variations in investors' risk-aversion over time, as well as liquidity considerations and geopolitical risky events.

[10] We present results based on the dollar cross rates, though the qualitative conclusions extend to other pair-wise combinations of currencies.

[11] As an example, we use an estimated VAR that allows for dynamic interactions between macro fundamentals and the yield curve factors, to construct measures of *expected relative yields* for different maturities

measures of risk, we demonstrate that term premiums in the sovereign bond markets can systematically explain subsequent excess currency returns in the foreign exchange markets. This provides support for the view that a same set of country-specific time-varying latent risks is priced into both the bond and the currency markets. We then show that both "expectations" and risk contained in the yield curves act as important determinants for quarterly exchange rate changes, providing empirical support for the present value models of exchange rate determination. We view this result as a clear indication that neither the macro nor the finance (risk) side of exchange rate determination should be ignored.

Given the above findings, we propose a macro-finance model to capture the joint dynamics of exchange rates, the macroeconomy, and the relative yield curve factors which embody both risk and expectations. Since our short sample size and overlapping observations preclude accurate estimates of long-horizon regressions, we evaluate the performance of our macro-finance model in predicting exchange rate at various horizons by way of the rolling iterated VAR approach, as in Campbell (1991), Hodrick (1992), and more recently in Lettau and Ludvigson (2005).[12] We iterate the full-sample estimated VAR(1) to generate exchange rate predictions at horizons beyond one month, and compare the mean squared prediction error of our model to that of a random walk. We also compute the implied long-horizon R^2 statistics to assess our model fit at different horizons.

Our main results are as follows: 1) empirical exchange rate equations based on only macro-fundamentals or only latent risk factors can miss out on the two crucial elements that drive currency dynamics: risk and expectations; 2) decomposing the yield curves into expectations for future macrodynamics versus term premiums, we show that both are important and can explain up to 20-30% of the variations in quarterly exchange rate changes; 3) even though the yield curves contain information about future macro dynamics, macro fundamentals themselves are still important in exchange rate modeling. Their dynamics should be jointly modeled with the yield curve and currency behavior; 4) our macro-finance model delivers improved performance over the random walk, with the yield curve factors playing a bigger role in the shorter-term, and the macro fundamentals becoming increasingly relevant in longer horizons such as a year. Overall, these findings support the view that exchange rates should be modeled using a joint macro-finance framework.

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between each country-pair. We then take the difference between the actual relative yields and these fitted ones to separate out the time-varying *relative bond term premiums.*

[12] While it is more common in the macro-exchange rate literature to compare models using out-of-sample forecasts (Meese and Rogoff 1983), we adopt this iterated VAR procedure used in recent finance literature to evaluate long horizon predictability. Out-of-sample forecast evaluation can be an unnecessarily stringent test to impose upon a model. For both theoretical and econometric reasons, it is not the most appropriate test for the validity of a model (see Engel, Mark, West 2007).

2 Theoretical Framework

2.1 Exchange Rate, Expectations, and Risk

We present the basic setup of a Taylor-rule based exchange rate model below while emphasizing our proposal for addressing the issues previous papers tend to ignore. Consider a standard two-country model where the home country sets its interest rate, i_t , and the foreign country sets a corresponding i_t^*. To be consistent with our empirical results below, we designate the United States as the foreign country. We assume that the Fed follows a standard Taylor rule, reacting to inflation and output (or unemployment) deviations from their target levels, but the home country targets the real exchange rate, or purchasing power parity, in addition. This captures the notion that central banks often raise interest rates when their currency depreciates, as discussed in Clarida, Gali, and Gertler (1998) and previous work.[13] The monetary policy rules can be expressed as:

$$\begin{aligned} i_t &= \mu_t + \beta_y \widetilde{y}_t + \beta_\pi \pi_t^e + \delta q_t + u_t \\ i_t^{US} &= \mu_t' + \beta_y' \widetilde{y}_t^{US} + \beta_\pi' \pi_t^{US,e} + u_t' \end{aligned} \tag{1}$$

where $\widetilde{y}_t$ is the output gap, π_t^e is the expected inflation, and $q_t (= s_t - p_t + p_t^{US})$ is the real exchange rate, defined as the nominal exchange rate, s_t, adjusted by the CPI-price level difference between home and abroad, $p_t - p_t^{US}$. μ_t absorbs the inflation and output targets and the equilibrium real interest rate, and the stochastic shock u_t represents policy errors, which we assume to be white noise. The corresponding foreign or US variables are denoted with superscript "US", and all variables except for the interest rates in these equations are in logged form. For notation simplicity, we assume the home and US central banks to have the same policy weights, and that $\beta_y = \beta_y' > 0$, $\delta > 0$, $\beta_\pi = \beta_\pi' > 1$, and μ_t and μ_t' are time-invariant.

Under rational expectations, efficient market condition equates cross-border interest rate differentials of maturity m, $i_t^{R,m}$,with the expected rate of home currency depreciation and the currency risk premium over the same horizon.[14] This is the risk-adjusted uncovered interest parity condition (UIP):

$$i_t^{R,m} = i_t^m - i_t^{m,US} = E_t \Delta s_{t+m} + \rho_t^m, \forall m \tag{2}$$

Here $\Delta s_{t+m} \equiv s_{t+m} - s_t$, and ρ_t^m denotes the risk premium associated with holding home

[13] It is common in the literature to assume that the Fed reacts only to inflation and output gap, yet other central banks put a small weight on the real exchange rate. See Clarida, Gali, and Gertler (1998), Engel, West, and Mark (2007), and Molodtsova and Papell (2009), among many others.

[14] By assuming rational expectations, we do not explore role of systematic expectations errors in ρ.

relative to US investment between time t and $t+m$. A key assumption we make (and test) is that ρ_t^m depends on the general latent risk factors associated with asset-holding *within* each country over the same period, and that these latent risks are also embedded in the term premiums at home and in the US.

Approximating the policy rules, eqs.(1), with $m=1$, we can express the exchange rate in the following differenced expectation equation by combining them with eq.(2):

$$s_t = \gamma f_t^{TR} + \kappa \rho_t^1 + \psi E_t s_{t+1} + v_t \tag{3}$$

where $f_t^{TR} = [p_t - p_t^{US}, \widetilde{y}_t - \widetilde{y}_t^{US}, \pi_t^e - \pi_t^{USe}]'$; v_t is a function of policy error shocks u_t and u_t^{US}; and coefficient vectors, γ, κ,and ψ, are functions of structural parameters defined above.[15] Iterating the equation forward, the Taylor-rule based model can deliver a net present value (NPV) equation where exchange rate is determined by the current and the expected future values of cross-country differences in macro fundamentals and risks:

$$s_t = \lambda \sum_{j=0}^{\infty} \psi^j E_t(f_{t+j}^{TR}|I_t) + \zeta \sum_{j=0}^{\infty} \psi^j E_t(\rho_{t+j}^1|I_t) + \varepsilon_t \tag{4}$$

where ε_t incorporates shocks, such as that to the currency risk (ζ_t), and is assumed to be uncorrelated with the macro and bond risk variables.

This formulation shows that the exchange rate depends on both expected future macro fundamentals and differences in the perceived risks between the two countries over future horizons. From this standard present value expression, we deviate from previous literature by making an attempt to find proxies for both terms. We derive our exchange rate estimation equations by emphasizing the use of latent factors extracted from the yield curves to proxy the two present-value terms on the right-hand side of eq.(4). We show in the next section that the Taylor-rule fundamentals are exactly the macroeconomic indicators the yield curves appear to embody information for, and of course, the term premiums θ_t and θ_t^{US} are by definition a component of each country's yield curves. Exploiting these observations, we do not need to make explicitly assumptions about the statistical processes driving the Taylor-rule macro fundamentals to estimate eq.(4), as previous papers tend to do. Instead, we allow macro variables to interact dynamically with the latent yield curve factors.[16]

Since nominal exchange rate is best approximated by a unit root process empirically, we focus our analyses on exchange rate change, Δs_{t+m}, as well as excess currency returns, which

[15] Since these derivations are by now standard, we do not provide detailed expressions here but refer readers to e.g. Engel and West (2005) for more details.

[16] The use of the yield curves to proxy expectations about future macro dynamics and risks makes our model differ from the traditional approach in international finance, which commonly assume that the macro-fundamentals evolve according to a univariate VAR (e.g. Mark (1995) or Engel and West (2005), among others). See Chen and Tsang (2011) for a more detailed discussions.

we define as:

$$XR_{t+m} = i_t^m - i_t^{m,US} - \Delta s_{t+m} (= \rho_t^m) \tag{5}$$

Note that XR measures the excess return from home investment.

2.2 The Yield Curve, the Macroeconomy, and Risk

The yield curve or the term structure of interest rates describes the relationship between yields and their time to maturity. Traditional models of the yield curve posit that the shape of the yield curve is determined by the expected future paths of interest rates and perceived future uncertainty (the term premiums).[17] A large body of research over the past decades has convincingly demonstrated that the yield curve contains information about expected future economic conditions such as output growth and inflation. The underlying framework for our analysis builds upon the recent macro-finance models of the yield curve and expresses a large set of yields of various maturities as a function of just a small set of unobserved factors, while allowing them to interact with macroeconomic variables. We utilize this approach to first connect the yield curve factors with the first summation in the exchange rate model, eq.(4), above. In the next sections, we show that bond market term premiums can be extracted from the yield curves to proxy for the second summation in eq.(4).

The recent macro-finance yield curve 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 framework offers deeper insight into the relationship between the yield curve and macroeconomic dynamics. As we show in the next sub-section, longer-term yields reflect the expected path of future short-term interest rates, which in turn are set by monetary policy rules, eqs.(1). Theoretically, it is therefore clear that long-maturity yields i_t^m reflect market expectations about future macroeconomic fundamentals.

Two empirical strategies are typically adopted in the literature to test this macro-finance view of the yield curve, and both utilize a small number of factors to summarize the shape of the yield curve (which are typically referred to as the level, slope, and the curvature factors; see Appendix A). The first, more atheoretical approach does not provide structural modeling of the macroeconomic fundamentals and the yield curve, but capture their joint dynamics using a general VAR. Ang, Piazzesi and Wei (2006), for example, 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 an unconstrained regression

[17] 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.

of GDP growth on the term spread.[18] Another body of studies model the macroeconomic variables structurally. For instance, using a New Keynesian framework, Rudebusch and Wu (2007, 2008) find 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. They model the slope factor as behaving like a Taylor-rule, reacting to the output gap and inflation. When the central bank tightens monetary policy, the slope factor rises, forecasting lower growth in the future.[19]

The above body of literature demonstrates the dynamic connection between latent yield curve factors and macroeconomic indicators both theoretically and empirically, thereby justifying their potential usefulness for proxying (at least) the first present value term on the right hand side of eq.(4). Since exchange rate fundamentals are in cross-country differences, we propose to proxy the first discounted sum in eq.(4) with the cross-country *differences* in their yield curve factors. Extending the approaches such as Diebold and Li (2006) into the international setting, we use the Nelson-Siegel (1987) exponential components framework to distill the entire relative yield curves, period-by-period, into a three relative factors that evolves dynamically. Specifically, assuming symmetry and exploiting the linearity in the factor-loadings, we extract three factors of relative level (L_t^R), relative slope (S_t^R), and relative curvature (C_t^R) as follows:[20]

$$i_t^{R,m} = i_t^m - i_t^{m,US} = L_t^R + S_t^R \left(\frac{1-\exp(-\lambda m)}{\lambda m} \right) + C_t^R \left(\frac{1-\exp(-\lambda m)}{\lambda m} - \exp(-\lambda m) \right) + \epsilon_t^m \tag{6}$$

As the number of yields is larger than the number of factors, eq.(6) cannot fit all the yields perfectly, so an error term ϵ_t^m is appended for each maturity as a measure of the goodness of fit.[21] The macro-finance approach of yield curve modeling can thus be broadened to study

[18]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. Diebold, Rudebusch and Aruoba (2006) took a similar approach using the Nelson-Siegel framework instead of a no-arbitrage affine model.

[19]Dewachter and Lyrio (2006) and Bekaert et al (2006) are two other examples taking the structural approach. Dewachter and Lyrio (2006), using an affine model for the yield curve with macroeconomic variables, 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. 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.

[20]See Appendix A for further discussion. The interpretation of the relative factors extends readily from their single-country counterparts. For example, an increase in the relative level factor means the vertical gap between the entire home yield curve and the U.S. one becomes more positive (or less negative).

[21]The parameter λ, is set to 0.0609, in accordance with the literature. It controls the particular maturity the loading on the curvature is maximized.

the joint dynamics of exchange rate, cross-country macro fundamental differences, and their relative yield curve factors.

2.3 The Expectation Hypothesis and the Term Premiums

The relative yield curve factors are linked to the exchange rate not only through the monetary policy and macro expectations channel. The second summation on the right hand side of eq. (4) shows that the term premiums embedded in the yields may also capture another important determinant of exchange rate dynamics and excess currency return: risk. Empirically, both the currency market and the bond market exhibit significant deviations from their respective risk-neutral efficient market conditions - the UIP and the expectation hypothesis (EH) - with the presence of time-varying risk being the leading explanation for both empirical patterns.[22] As such, another measure of interest in our exchange rate model (eq.(4)) is the term premiums θ_t and θ_t^{US} embodied in the home and foreign yield curves. Based on the expectations hypothesis, the term premium perceived at t associated with holding a long bond until $t+m$ (θ_t^m) is the difference between the current long yield of maturity m and the average of the current one-period yield and its expected value in the upcoming $m-1$ periods:[23]

$$\theta_t^m \equiv i_t^m - \frac{1}{m}\sum_{j=0}^{m-1} E_t\left[i_{t+j}^1\right] \tag{7}$$

The typically upward-sloping yield curves reflect the positive term premiums required to compensate investors for holding bonds of longer maturity. As mentioned earlier, these risks may include systematic inflation, liquidity, and other consumption risks over the maturity of the bond. While previous research has documented these premiums to be substantial and volatile (Campbell and Shiller (1991); Wright (2009)), there appears to be less consensus on their empirical or structural relationship with the macroeconomy.[24]

For our purposes, we use the relative term premiums across countries to measure the difference in the underlying risks perceived by investors over different investment horizons;

[22] Fama (1984) and subsequent literature documented significant deviations from uncovered interest parity. In the bond markets, the failure of the expectation hypothesis is well-established; Wright (2009) and Rudebusch and Swanson (2009) are recent examples of research that studies how market information about future real and nominal risks are embedded in the bond term premiums.

[23] We note that as horizon m increases, the average of future short rate forecasts (the summation term) will approach the sample mean. So when m is large, the relative term premium of maturity m will roughly equal to the relative yields of maturity m minus a constant.

[24] A common view among practitioners is that a drop in term premium, which reduces the spread between short and long rates, is expansionary and predicts an increase in real activity. Bernanke (2006) agrees with this view. However, based on the canonical New Keynesian framework, movements in the term premium do not have such implications. For example, Rudebusch, Sack, and Swanson (2007) point out that only the expected path of short rate matters in the dynamic output Euler equation, and the term premium should not predict changes in real activity in the future.

we do not explicitly motivate term premium movements beyond eq.(7) and expectation errors.[25] In the empirical section below, we derive five measures of the time-varying term premiums based on alternative frameworks of yield curves, and study their linkage with exchange rate dynamics and currency risk premiums.[26] We argue that analogous to the expectation hypothesis and factor modeling for bond yields, each bond premium of maturity j perceived *at time t*, θ_t^j,should correlated with some latent risk factors, the weighted average of expected future short-term bond premium $\sum_{k=0}^{j-1} E_t w_k \left[\theta_{t+k}^1\right]$. However, unlike the EH for the yields, there is no arbitrage condition to determine the weights w_k. In other words, under the assumption that only a limited number of latent risk factors are present, a combination of bond premiums at different horizons should span these risk. In section 3 below, we use risk premiums of three different horizons.[27]

3 Background Empirics

3.1 Data Description

The main data we examine consists of monthly observations from January 1984 to May 2009 for Australia, Canada, Japan, New Zealand, Switzerland, the United Kingdom and the United States. All rates are annualized. Please see Data Appendix for details and their sources.

Tables 1A-1C report the summary statistic of the data. For three-month exchange rate change Δs_{t+1} in the top panel of **Table A1**, a positive mean value indicates that averaged over the full sample, the country's currency experienced a quarterly depreciation against the US dollar. We see that the US dollar has gained over all currencies except the Australian and New Zealand dollars. Japanese Yen and Swiss Franc have the largest average quarterly appreciation of over $2-3\%$ annual rates per quarter, though their standard deviations are comparable to those of other countries. The two commodity currencies (AUS and NZ) were not especially volatile, though certainly have the widest swings, and the high relative standard errors of UK (SD over mean) are mostly due to the EMS crisis. Turning to excess returns, XR_{t+3}. with the exception of Sweden, we see that all currencies on average offer excess quarterly returns relative to US dollar investment. This would be consistent with

[25] Note that under the rational expectation paradigm, ρ_t^m will be model-dependent.

[26] The linkage between the bond and currency premiums is also explored in Bekaert et al (2007), though our model further incorporates dynamics of the macroeconomy fundamentals into the expectation formation process.

[27] The choice of three premiums is also consistent with the idea of three Nelson-Siegel factors. Our argument is that each of the relative NS factors have a component that is related to expectations of future macro-dynamics, and another that is latent risk. Given that we know the three relative factors explain currency dynamics, we use yield curve models to decompose them into risk vs. expectation parts.

the idea that the US dollar (along the Swiss Franc) is commonly considered safe haven currencies. Relative standard errors are uniformly smaller in XR_{t+3} than in Δs_{t+1}, though as in exchange rate changes, we do observe large fluctuations at orders that are atypical for other macro-fundamentals. From **Figures 1 and 2**, we see episodes of exchange rate volatility, with the recent financial crisis period being especially noticeable in all currencies except JP and SW.[28]

Table 1B presents statistics on the relative Nelson-Siegel factors. We see that with the exception of Japan and Switzerland, all countries have a higher "level" factor than the US on average. This suggests that long yields, which reflect long-run inflation expectations are higher in these countries compared to those in the US (see Chen and Tsang (2011) for a more complete discussion of the relative factors.) It is not surprising that we see Japan's average level to be lower in the US (-3%), given its deflationary spiral that started in the early 1990s. For Canada, Japan, and Switzerland, the slope factor is relatively more volatile than their level factor, but the reverse is true in the UK. For relative curvature, we see that in AU, NZ, SW, and UK, the relative SD is higher than those for relative slope and level, indicating that the middle part of the relative yield curves move around more.

Table 1C reports the summary statistics for the two macro variables we use: the relative unemployment rate and inflation rate between each of the six countries to those of the US. Here we see Australia, New Zealand, and even the UK relatively speaking, having significantly more volatility in their inflation behavior.

3.2 Linking Bond Yields and Currency Movements

In this section, we confirm findings in Chen-Tsang (2011) that relative Nelson-Siegel yield curve factors have predictive power for subsequent (quarterly) exchange rate changes and excess currency returns. Here we cover a larger set of country-pairs, and the data sample covers the recent financial crisis. As such, we put an emphasis on possible structural breaks in the yield curve-exchange rate relation.

For each of the six country pairs, we run the following regressions and report the results in **Tables 2A and 2B**:

$$\Delta s_{t+3} = \alpha_0 + \alpha_1 L_t^R + \alpha_2 S_t^R + \alpha_3 C_t^R + \epsilon_{t+3} \quad (8)$$

$$XR_{t+3} = \beta_0 + \beta_1 L_t^R + \beta_2 S_t^R + \beta_3 C_t^R + \epsilon_{t+3} \quad (9)$$

To address possible parameter instabilities, we test for endogenous structural breaks in the regression. This table reports results based on Andrews (1993) break tests, which

[28] The absence of drastic changes in the value of these latter two currencies relative to the USD is likely due to the fact that all three are viewed to some degree as safe haven currencies.

identified breaks in mid-2000's for all the countries except for Japan and Switzerland. This is consistent with casual observations on their exchange rate patterns in **Figures 1 and 2**, as discussed earlier.[29]

From **Table 2**, we first note that with the exception of Switzerland (this will be a recurring theme for the rest of the paper), the predictive power of the relative yield curve is apparent. Contrary to results typical in the empirical exchange rate literature which tend to find essentially no explanatory power, especially at the monthly or quarterly frequency, we see that the regressions here can produce adjusted R^2 on the order of 20% or 30%. We also note that the pre-break regression coefficients are consistent with prior findings: an increase in the relative level and slope factors in a country tends to lead to subsequent appreciation of the currency as well as higher excess return.[30] The post-break data can indicate a significant change in the coefficients, sometimes to a sign reversal, especially for the relative slope factor. We conjecture that this may be due to the behavior of the US slope factor (yield spread) over the crisis period.[31] We then test the joint significance of relative factors in explaining currency behavior. Again, with the exception of Switzerland, the p-values from the χ^2 test are all below 1%, indicating strongly rejections of the hypothesis that yield curves contain no information about subsequent currency behavior. These results establish the predictive power of the relative factors, and show that information in the cross country yield curves are important for understanding currency behavior.

4 Decomposing the Yield Curves: Expectations vs Risk Premiums

In Section 2, we show that the yield curves relate to the exchange rate via two channels: 1) they embody expectations about future macroeconomic variables, and 2) they capture perceived risk about future periods (the two discounted sums in eq. (4)). The focus of this section is to decompose these two elements and explore their contribution to exchange rate and excess currency return behavior. While the general perceived risk is not observable, we isolate or extract partial measures of perceived risk from the yield curves based on the

[29] We also tested for multiple breaks using the Bai and Perron break test. In all cases, Bai and Perron identified the same break we have chosen, though sometimes with an additional, less significant break. Given our sample size, we choose to keep only one break at most and follow results from the Andrews (1993) test. We did not test for breaks in the volatility.

[30] For intuition and discussion, we refer interested readers to Chen and Tsang (2011).

[31] We have also conducted the same analysis using other currencies as the base, we find qualitatively the same results, with sometimes weaker fit. To conserve space, we report results for the US-cross rates only for the rest of the paper. In addition, we report results only for the 3-month exchange rate changes, since this is one of the horizons that prior explorations tend to find the most difficult to model.

concept of bond market term premiums.

Term premium is defined as the difference between the long-term yield and the expected short yields of the same horizon. We can interpret it as the extra compensation required on top on what the pure expectations hypothesis predicts. The NS model we discussed above can be used to extract premia as follows: assuming that the factors follow a VAR(1) (as in Diebold et al. (2006)), we can iterate the VAR to obtain in-sample forecasts of the factors. Using the NS formula (6), we can then obtain the predicted 1-month yield for any horizon. Subtracting the average expected 1-month yields from the actual yield of the same horizon (which is the right-hand side of (7)), we obtain the term premia for that horizon.

Since we use the VAR(1) model to calculate the premia, in each period t the premia will be functions of the three factors in the same period t. As a result, when using three of the premia as calculated above to explain exchange rate change or excess return, what we are doing is *equivalent* to using the three factors (as in **Table 2**) as explanatory variables. The results in **Table 2** then implies that term premia calculated using the NS model do contribute to exchange rate and excess currency return behavior.

There are other ways to construct term premiums, here we first report the summary statistics based on one of the alternative methodologies we employed in this paper (summary statistics for the premia calculated based on the NS model are available upon request).

4.1 Behavior of Term Premiums

While in the NS model the term premium is calculated based on yields only, here we take a macro-finance approach in generating term premium. Specifically, we posit that (see references in the introduction) longer-term yields embody not only expected future short yields but also expected future macroeconomic conditions such as inflation and output and unemployment conditions. This reflects the idea that if, based on current macroeconomic condition, inflation is expected to be high over the coming year, the one-year yield will be higher than otherwise, to take into account this expected high inflation. DPR (2005) formalized this idea that yield curves and macro dynamics (specifically inflation and output gap) are jointly determined. One justification is that future short yields are determined by macroeconomic conditions via monetary policy actions such as a Taylor type rule. The perceived risk beyond this expectation would thus be the one-year yield net of this expected yield based on both future short yields and macro conditions. This “macro-yield” measure is thus a narrower concept of risk.

Table 3 presents the summary statistics based on a more restrictive concept of risk. We can see that the relative risk premiums tend to be quite small. For example, the three-month Australian premium averages to just 8 basis points, while the Swiss premium, being the largest, is around 18 basis points (lower than the US). The relative premiums for 10-year bonds can be larger, with Japan and Switzerland being a couple percentage points lower than the US. Overall, the relative term premiums are not very volatile. Although, as **Figures 3 and 4** indicate, they CAN contain important information at the onset of major unexpected events such as the 2008 crisis. From **Figures 3 and 4**, we see clearly that pre and post, the perceived riskiness of various sovereign bonds at different horizons shifted significantly between 2008 and 2009.

4.2 Relating Risk in the Bond and FX Markets

To test the idea that the same systematic latent risk is priced in both the bond and currency markets, we test how much of the currency risk premiums relative term premiums can explain. Since we do not directly observe "risk in the relative bond markets", we rely on certain structural concepts to identify risk. For example, of the two premiums we saw in the previous tables, one (NS) is constructed based on a VAR that has only the three NS factors, and the other (*DPR*) is based on a macro-finance framework that explicitly incorporates joint dynamics between macro variables and the yield curves.

We consider three alternative measures in addition. Two of them are conceptually similar to the NS model and the DPR model. Rather than using the difference between successive expected future short yields (constructed using the NS factors) and the conventional fitted longer-term yield (also generated with the NS factors), we compute the term premiums using actual longer-term yields (minus expected future short yields). These two measures, which we call *NS-Actual* and *DPR-Actual*, are the above two measures plus, from a mechanical perspective, the additional Nelson-Siegel fitting errors. Conceptually, however, these fitting errors are term-specific deviations from the Nelson-Siegel fitted yields, which can reflect term-specific risk perceived at the particular point in time (relative to the N-S implied value). As such, these two risk measures based on actual yields are broader than the earlier two measures (in practice, it is certainly possibly that these fitted errors are purely noise). The last two concepts of term premium are not NS-based. First we estimate an three-factor affine model in the style of Dai and Singleton (2002). The factors are the three principal components of the yields, and the term premia are calculated as the difference between the fitted yields and the implied yields when investors are risk neutral (see Appendix C for a description of the procedure). Next we follow Cochrane and Piazzesi (2005). We extract a factor for excess bond returns of maturity of 1 year or above (see Appendix B for a description of the procedure), which is used together with the 3-month to explain excess currency return.[32]

[32] Due to space limit, we do not report the summary statistics for the four alternative measures of term

We include the 3, 12, and 120-month relative premiums in order to as a proxy for the expected future short premiums in equation (X), the NPV equation in Section 2.[33][34]

$$XR_{t+3} = \beta_0 + \beta_1\theta_t^{R,3} + \beta_2\theta_t^{R,12} + \beta_3\theta_t^{R,120} + \epsilon_{t+3} \tag{10}$$

We see that individual coefficients can be quite large and varied, mostly due to the fact that the relative premiums are quite small, as discussed earlier. The relative premiums at different maturities can be correlated both statistically and conceptually (i.e. longer term relative premiums should compensate the same shorter-term latent risk that shorter premiums do, but the weighting or loading on it would differ. This is the rational for us to include three relative premiums to allow for more flexibility in approximating the infinite sum of expected future short-term yields). The interpretation of individual coefficients is thus not very informative or meaningful. We thus focus on testing for their joint significance, as well as their joint explanatory power, as indicated by the adj-R^2. We report these in **Tables 5 and 6**.

We see that the five different concepts of risk premiums deliver two remarkably consistent messages. By looking at the joint Wald test results, we first see that for five of the six currency pairs (Swiss franc being the exception again), the relative premiums are strong and robust determinants of currency excess returns, supporting the view that differential risks in the relative bond markets are priced into the corresponding FX values. Looking at the goodness of fit criterion (adjusted R^2), we see that term premiums can explain 10 to over 30% of the variations in excess currency returns. This is quite an impressive portion in light of the near-zero R^2 typical in this literature.

Comparing rows (1) and (2), the narrower concept of risk (*DPR*) have lower R^2 than the broader concept "NS" (this complements the results will show in **Table 6** where XR is regressed on expected yields, where we see the expected yields based on DPR have higher explanatory power). The comparison between measures using actual yields, rows 3 and 4, are not as clear cut, i.e. the NS-fitted errors could be mostly noise, though in a few instances, using the actual yields do improve upon previous narrower concepts, e.g. adj-R^2 went up by several percents in *DPR-Actual* from *DPR* for Australia, New Zealand, and the United Kingdom.

premium. They are available upon request.

[33]Note that we use the same structural break as identified in Tables 2A/B. If the Quandt-Andrews test is conducted on this regression, a similar break date would be chosen.

[34]We choose to include only three premia in the regression for two reasons. First, as explained above, in the NS model the premia will be functions of the three factors, and using three premia is equivalent to using the three factors. Since the three factors can capture the yields well and that the three factors have good explanatory power, using three premia is clearly preferred to using fewer. Second, since the premia are in general quite correlated with each other, using more than three premia can lead to the collinearity problem.

5 The Joint Macro-Finance Approach

We regress three-month exchange rate changes on both the macro variables and the relative yield factors (controlling for structural breaks again), and test for the joint significance of each group using the Wald statistics. **Table 7** shows that except for Canada, the null hypothesis that the latent yield factors do not explain exchange rate changes (*No Yields*) is strongly rejected. (Note that for once, Switzerland shows positive result; the null that yields have no explanatory power is rejected at the 10% level.) The null hypothesis that the (contemporaneous) macro variables have no contribution (*No Macro*) is rejected for Canada and New Zealand only. Note that this result does not imply macro fundamentals overall do not affect exchange rate movements, but that contemporaneous macro fundamentals have no additional explanatory power once the yield curve factors are included. As discussed in Section 2 (and in Chen and Tsang (2011)), the yield curves themselves contain expectations about future macro-fundamentals. We also that for all countries, except Switzerland, we can strongly reject the hypothesis that neither macro fundamentals nor yield factors can predict exchange rate movement next quarter. Note that the explanatory power of these variables can be quite high: the adjusted R^2 can be up to 20% to over 35%. This level of explanatory power is rare in the context of explaining short-term currency movement such as at the quarterly level here. Even in this context where dynamic interactions among these variables are ignored, we already see that both macro and term structure factors are very relevant for explaining currency movements.

5.1 A Dynamic Macro-Yield Model of Nominal Exchange Rate

Given the above results, we now extend the dynamic framework of Diebold and Li (2006) and Ang et al. (2006) to the international setting, and estimate a VAR system of the relative latent yield factors, Taylor rule macro fundamentals, and the monthly exchange rate change. Following previous work in both the international macro and finance literature, we do not structurally estimate a Taylor rule, nor impose any structural restrictions in our VAR estimations.[35] We use the atheoretical forecasting equations to capture any endogenous feedback among the variables. We estimate a six-variable VAR(1), though increasing the order of the VAR system does not change our conclusions below.

We provide two measures of how well the joint model describe exchange rate movements. First, following Hodrick (1992), we calculate the partial R^2 for each variable for explaining exchange change at various horizons (see Appendix D for a detailed discussion on the method). Though the variable that enters the VAR system is the one-month exchange

[35] This non-structural VAR approach follows from Engel and West (2006), Molodtsova and Papell (2009) and so forth on the exchange rate side, and Diebold et al (2006), among others, on the finance side.

rate change, we can use the method to calculate the explanatory power of each variable for exchange rate change of longer horizons. **Table 8** shows the results for explaining exchange rate change at 1, 3, 6 and 12-month in the future. As expected, exchange rate change itself has little use for predicting its future movements (except for New Zealand where the R^2 is quite large). The three NS factors, especially the slope and curvature factors, contribute substantially to explaining exchange rate change at all horizons. For example, the slope factor accounts for 15% of the variance of exchange rate change at the 12-month horizon. Once again, the factors have relatively lower R^2 for Switzerland. The contribution of the two macroeconomic variables mainly appears at longer horizons. For example, inflation and unemployment each explains over 10% of the variance of Canada's exchange rate change at the 12-month horizon.

Next, we compare the in-sample fit of the joint model with a model that has only the two macroeconomic variables and exchange rate change (macro) and the "model" that exchange rate change has a sample mean of zero (random walk, RW).[36] Since the VAR system only has the 1-month exchange rate change as one of the six variables, we iterate the estimated VAR forward to obtain predicted 1-month exchange rate changes for different horizons. We then sum up the predicted values to obtain the predicted 3, 6, and 12-month exchange rate changes. We calculate the root mean squared error (RMSE) for the joint model, macro-only model, and the random walk model (which is simple the sum of squared exchange rate change). **Table 9** reports the results. The RMSE ratio is calculated as the RMSE of the joint or macro-only model divided by the RMSE of the random walk model, and a ratio less than one implies that the random walk model is inferior. For horizons up to 6 months, the joint model in general has lower RMSE ratio than the macro-only model. Consistently with our earlier results, the macro-only model improves at the longer 12-month horizon. We also calculate the Diebold-Mariano statistic for each case by regressing the difference in squared errors on a constant, and a constant that is significantly larger than zero implies that the corresponding model significantly predicts better than the random walk model in sample. The joint model significantly fits better than a simple random walk for most cases.

6 Conclusions

This paper incorporates both macroeconomic and financial elements into exchange rate modeling. Separating out the term premiums from the yields, we show that investors' expectation about the future path of monetary policy and their perceived risk both drive exchange rate dynamics. We then propose a joint model where macroeconomic fundamentals targeted in

[36] Using the actual sample mean instead of zero does not change the results much.

Taylor-rule monetary policy to interact with latent risk factors embedded in cross-country yield curves to jointly determine exchange rate dynamics. As the term structure factors capture expectations and perceived risks about the future economic conditions, they fit naturally into the present-value framework of nominal exchange rate models. Our joint macro-finance model fits the data well, especially at shorter horizons, and provides strong evidence that both macro fundamentals and latent financial factors matter for exchange rate dynamics.

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Appendix

A. Yield Curve and the Nelson-Siegel (1987) Factors

Diebold, Piazzesi and Rudebusch (2005) advocate the factor approach for yield curve modeling as it provides a succinct summary of the few sources of systematic risks that underlie the pricing of various tradable financial assets. Among the alternative model choices, this paper mainly adopts the Nelson-Siegel latent factor framework without imposing the no-arbitrage condition.[37] The classic Nelson-Siegel (1987) model summarizes the shape of the yield curve using three factors: L_t (level), S_t (slope), and C_t (curvature). Compared to the no-arbitrage affine or quadratic factor models, these factors are easy to estimate, can capture the various shapes of the empirically observed yield curves, and have simple intuitive interpretations.[38] The three factors typically account for most of the information in a yield curve, with the R^2 for cross-sectional fits around 0.99. While the more structural no-arbitrage factor models also fit cross-sectional data well, they do not provide as good a description of the dynamics of the yield curve over time.[39] As our focus is to connect the dynamics of the yield curves with the evolution of macroeconomy and the exchange rate, our model extends the dynamic Nelson-Siegel model proposed in Diebold et al (2006) to the international setting, as presented in Section Y.Y.[40]

B. The Cochrane-Piazzesi (CP, 2005) Factors

Following Cochrane and Piazzesi (2005) we look at annual excess returns. To be consistent with our paper all yields considered here are "relative" yield between two countries (with US as home). Holding period return of a 12n-month bond from now to next year can be calculated as:

$$r_{t+12}^{(12n)} \equiv n i_t^{(12n)} - (n-1) i_{t+12}^{(11n)}$$

[37] Since the Nelson-Siegel framework is by now well-known, we refer interested readers to Chen and Tsang (2009a) and references therein for a more detailed presentation of it.

[38] The level factor L_t, with its loading of unity, has equal impact on the entire yield curve, shifting it up or down. The loading on the slope factor S_t equals 1 when $m = 0$ and decreases down to zero as maturity m increases. The slope factor thus mainly affects 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 curve 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 the curvature of the yield curve is at medium maturities. See Chen and Tsang (2009a) and references therein.

[39] See, e.g. Diebold et al (2006) and Duffee (2002).

[40] As discussed in Diebold et al (2006), this framework is flexible enough to match the data should they reflect the absence of arbitrage opportunities, but should transitory arbitrage opportunities actually exist, we then avoid the mis-specification problem.

That is, you buy the $12n$-month bond now and sell it as a $11n$-month bond next year. The above defines the return of such a transaction. Excess return is then defined as:
,

$$rx_{t+12}^{(12n)} \equiv r_{t+12}^{(12n)} - i_t^{(12)}$$

The term tells you the extra return you get from the transaction over a riskless $12n$-month bond. In the data, we have 12, 24, ..., 120-month bonds. The ten yields allow us to define $rx_{t+12}^{(24)}, ..., rx_{t+12}^{(120)}$, a total of nine excess returns.

The CP regression involves regressing the average of the excess returns on the 12-month yield and the forward rates $f_t^{(24)}, ..., f_t^{(120)}$, where the definition is

$$f_t^{(12n)} \equiv n i_t^{(12n)} - (n-1) i_t^{(11n)}$$

The regression is then

$$\frac{1}{9} \sum_{i=2}^{10} rx_{t+12}^{(12i)} = \gamma_0 + \gamma_1 i_t^{(12)} + \gamma_2 f_t^{(24)} ... + \gamma_{10} f_t^{(120)} + \epsilon_{t+12}$$

The fitted value is the CP factor. We are different from the original CP setting that a) we are using relative yields and b) we extend the maturities to 10-year from 5-year.

C. The Dai-Singleton (2002) Factors

We follow the discussion in Wright (2009) and let $P_t^{(n)}$ denote the price at time t of an n-period zero-coupon bond. For a zero-couple bond, we know $i_t^{(n)} = -\log\left(P_t^{(n)}\right)/n$. Under no-arbitrage, the price of the bond should be consistent with the pricing kernel that $P_t^{(n)} = E_t\left(\prod_{j=1}^{n} M_{t+j}\right)$, where the pricing kernel M_{t+1} is conditionally lognormal:

$$M_{t+1} = \exp\left(-i_t^{(1)} - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\epsilon_{t+1}\right)$$

The term $\lambda_t = \lambda_0 + \lambda_1 X_t$ is a function of the state variables X_t, which in our case are the three principal components X_t of the yields. The shocks in the model ϵ_t follow an iid $N(0, I)$. The one-period yield $i_t^{(1)}$ is also an affine function of the state variables, $i_t^{(1)} = \delta_0 + \delta_1' X_t$. The state variables follow a first-order VAR:

$$X_{t+1} = \mu + \Phi X_t + \Sigma\epsilon_{t+1}$$

Using the log-normality assumption and the VAR model for the state variables X_t, we can express bond prices as a function of the state variables and other parameters:

$$P_t^{(n)} = \exp\left(A_n + B_n' X_t\right)$$

$$A_{n+1} = \delta_0 + A_n + B_n'\left(\mu - \Sigma\lambda_0\right) + \frac{1}{2} B_n' \Sigma\Sigma' B_n$$

$$B_{n+1} = \left(\Phi - \Sigma\lambda_1\right)' B_n - \delta_1$$

That is, bond prices (and hence bond yields) are determined recursively through A_n and B_n. The bond prices are calculated as if agents are risk-neutral ($\lambda_0 = \lambda_1 = 0$) but the state variables follow a different law of motion:

$$X_{t+1} = \mu^* + \Phi^* X_t + \Sigma\epsilon_{t+1}$$

But that $\mu^* = \mu - \Sigma\lambda_0$ and $\Phi^* = \Phi - \Sigma\lambda_1$. Following the usual practice, we first estimate for each country the parameters of the model by maximum likelihood (where each yield except the one-period yield has a normally distributed prediction error). Next, we calculate the fitted yields of the above model and the implied yields when $\lambda_0 = \lambda_1 = 0$. The difference between the two sets of yields gives us the term premia of different maturities. The maximum likelihood results are available upon request.

D. VAR Multi-Period Predictions

To compute the partial R^2 for each variable and their total contribution in the VAR, we follow the procedure as described in Hodrick (1992). The method is also adopted in Campbell and Shiller (1988), Kandel and Stambaugh (1988) and Campbell (1991), among others. The VAR models described in Section (5) can be written as:

$$f_t = A f_{t-1} + \eta_t$$

where the constant term μ is omitted for notational convenience. Denote the information set at time t as I_t, which includes all current and past values of f_t. A forecast of horizon m can be written as $E_t\left(f_{t+m}|I_t\right) = A^m f_t$. By repeated substitution, first-order VAR can be expressed in its MA(∞) representation:

$$f_t = \sum_{j=0}^{\infty} A^j \eta_{t+j}$$

The unconditional variance of f_t can then be expressed as:

$$C(0) = \sum_{j=0}^{\infty} A^j Q A^{j'}$$

Denoting $C(j)$ as the jth-order covariance of f_t, which is calculated as $C(j) = A^j C(0)$, the variance of the sum, denoted as V_m, is then:

$$V_m = mC(0) + \sum\nolimits_{j=1}^{m-1} (k-j)\left[C(j) + C(j)'\right]$$

We are not interested in the variance of the whole vector but only that of the long-horizon exchange rate change, ds_t, which is the third element in the vector f_t. We can define $e_3' = (0,0,1,0,0,0)$, and express the variance of the m-period exchange rate change as $e_3' V_m e_3$.

To assess whether a variable in f_t, say the level factor L_t^R, explains exchange rate change $\Delta s_{t+m} = s_{t+m} - s_t$, we run a long-horizon regression of Δs_{t+m} on L_t^R. The VAR model for f_t allows us to calculate the coefficient from this regression based on only the VAR coefficient estimates. Since the level factor is the fourth element in f_t, the coefficient is defined as:

$$\beta_4(m) = \frac{e_3'\left[C(1) + ... + C(m)\right] e_4}{e_4' C(0) e_4}$$

where vector e_4 is defined as $e_4 = (0,0,0,1,0,0)$. The numerator is the covariance between Δs_{t+m} and L_t^R ,and the denominator is the variance of L_t^R. Finally, the R^2 as reported in the paper is calculated as:

$$R_4^2(m) = \beta_4(m)^2 \frac{e_4' C(0) e_4}{e_3' V_m e_3}$$

The R^2 for all other variables in the vector f_t can be suitably obtained by replacing e_4 with e_1, e_2, e_3, e_5, e_6.

To calculate the total R^2 for all explanatory variables, we calculate the innovation variance of the exchange rate change as $e_1' W_m e_1$, where

$$W_m = \sum_{j=1}^{m} (I-A)^{-1}\left(I - A^j\right) Q \left(I - A^j\right)' (I-A)^{-1\prime}$$

The total R^2 is then:

$$R^2(m) = 1 - \frac{e_1' W_m e_1}{e_m' V_m e_m}$$

For the calculation to be valid, we need A to be stationary.

E. Data Appendix

Yield data: Our zero-coupon bond yield include maturities from 3 to 120 months (3 months increment) from Wright (2011). Most yields are from the central bank of each country, and each set of yields are constructed using different methods. Please refer to Wright (2011) for details on the construction of the data. The yields are from the last trading day of each month. While yields of all countries end on May 2009, some begin earlier. Yields for UK and US are available from January 1984, for Australia it is February 1987, for Canada it is January 1986, for Japan it is January 1985, for New Zealand it is January 1990, and for Switzerland it is January 1988.

Macroeconomic data: We obtain headline CPI and unemployment rate from the FRED database (http://research.stlouisfed.org/fred2/). Inflation rate is defined as 12-month percentage change of the CPI. Unemployment rate is regressed on a quadratic trend, and the residual is defined as unemployment gap.

Exchange rate data: End-of-period monthly exchange rates are again obtained from the FRED database. We express first-differenced (Δ) logged exchange rate as $\Delta s_t = s_t - s_{t-1}$. (We note that we only report results based on the per-dollar rates below, but found qualitatively similar results using the non-dollar currency pairs.)

Table 1A. Summary Statistics for 3-Month Exchange Rate Change and Excess Currency Return

		AU	CA	JP	NZ	SW	UK
Δs_{t+3}	Mean	0.918	-0.253	-3.413	0.437	-2.681	-0.173
	Median	-1.199	0.260	-0.843	-1.887	-2.195	-0.944
	SD	24.857	13.775	24.426	26.219	24.529	22.607
	Min	-87.722	-59.364	-85.335	-94.472	-74.968	-70.201
	Max	143.673	67.855	60.489	111.824	67.875	109.343
	AR(1)	0.706	0.658	0.708	0.728	0.689	0.713
	No. of obs.	302	302	302	302	302	302
XR_{t+3}	Mean	3.258	2.072	1.591	3.141	-0.165	3.021
	Median	4.350	1.610	-1.404	5.026	-0.474	3.730
	SD	23.345	14.337	25.239	23.264	23.655	22.775
	Min	-138.346	-67.019	-65.182	-90.420	-63.787	-102.003
	Max	90.398	59.702	80.829	97.252	67.548	75.639
	AR(1)	0.713	0.663	0.721	0.754	0.709	0.717
	No. of obs.	265	278	290	230	254	302

Note: Sample period for exchange rate change Δs_{t+3} is from January 1984 to May 2009. Exchange rate is defined as the home currency price of one USD. Excess return XR_{t+3} is defined as the return difference between investing in the home bond over that of the US bond. Because yield data are not available for the whole sample (see Table 1B), we have few observations for excess returns. Both variables are expressed in annualized percentage.

Table 1B. Summary Statistics for Relative Level, Slope and Curvature Factors

		AU	CA	JP	NZ	SW	UK
L^R	Mean	1.503	0.416	-3.034	0.821	-2.326	0.338
	Median	0.915	0.379	-2.937	0.756	-2.163	0.168
	SD	1.490	0.798	0.916	0.683	0.840	1.153
	Min	-0.773	-1.759	-5.243	-0.781	-5.460	-1.915
	Max	6.271	2.227	-0.928	3.690	-0.743	3.325
	AR(1)	0.939	0.946	0.917	0.859	0.907	0.955
S^R	Mean	1.236	0.712	0.687	2.170	1.247	2.193
	Median	0.957	0.584	0.956	2.452	0.913	2.371
	SD	1.792	1.614	2.163	1.485	2.546	1.946
	Min	-1.959	-3.556	-3.618	-1.657	-2.834	-1.845
	Max	7.039	4.578	4.747	4.923	8.405	6.686
	AR(1)	0.951	0.956	0.972	0.916	0.983	0.962
C^R	Mean	0.447	0.234	-1.138	1.293	-0.302	0.389
	Median	0.437	0.290	-1.298	1.155	-0.234	0.116
	SD	2.577	1.741	2.632	2.216	2.304	2.478
	Min	-10.965	-4.003	-5.988	-3.524	-5.913	-4.916
	Max	7.664	4.942	7.160	7.568	7.802	6.400
	AR(1)	0.720	0.829	0.902	0.821	0.855	0.916
	No. of obs.	268	281	293	233	257	305
	Start date	Feb 1987	Jan 1986	Jan 1985	Jan 1990	Jan 1988	Jan 1984

Note: We estimate the Nelson-Siegel yield curve model to obtain the level, slope and curvature factors for each country. The US factors are then subtracted from those of the other countries to get the relative level L^R, slope S^R, and curvature C^R reported here. Yield data for all countries end in May 2009 but have different start dates. Relative factors are reported in (annualized) percentage points.

Table 1C. Summary Statistics for Macroeconomic Fundamentals

		AU	CA	JP	NZ	SW	UK
u_t^R	Mean	-0.009	-0.016	0.068	0.045	0.027	0.020
	Median	0.146	0.082	0.218	0.093	0.254	0.381
	SD	0.758	0.758	1.049	1.033	0.795	1.001
	Min	-2.257	-1.739	-2.726	-2.675	-3.019	-2.544
	Max	1.451	2.137	1.859	1.971	1.399	1.389
	AR(1)	0.937	0.948	0.973	0.964	0..956	0.976
	No. of obs.	305	305	305	281	305	305
π_t^R	Mean	0.634	-0.455	-2.214	1.055	-1.111	0.009
	Median	0.358	-0.611	-2.225	0.035	-1.297	-0.353
	SD	2.173	1.010	0.744	3.836	1.056	1.613
	Min	-3.491	-3.253	-3.732	-3.174	-2.517	-2.564
	Max	6.213	1.973	0.273	14.808	2.072	5.169
	AR(1)	0.987	0.948	0.940	0.991	0.970	0.975
	No. of obs.	305	305	305	305	305	305

Note: Relative unemployment rate u_t^R is constructed as the difference between the quadratically detrended unemployment rates in the home country and in the US. Relative inflation rate π_t^R is defined as the 12-month change of the CPI in each country relative to that in the US. Sample periods for all data are from January 1984 to May 2009, with the exacption that the New Zealand unemployment data is not available prior to January 1986. Both variables are reported in annualized percentage points.

Table 2A. 3-Month Exchange Rate Change on Relative Factors

$$\Delta s_{t+3} = \alpha_0 + \alpha_1 L_t^R + \alpha_2 S_t^R + \alpha_3 C_t^R + \epsilon_{t+3}$$

	AU	CA	JP	NZ	SW	UK
Constant	4.902*	2.005	-0.124	8.295**	-5.304	7.179***
	(2.676)	(1.452)	(7.399)	(3.916)	(6.795)	(2.711)
L^R	-2.110	-2.202	0.116	0.166	-2.737	-5.557***
	(1.504)	(1.618)	(2.265)	(2.906)	(2.819)	(1.793)
S^R	-1.339	-1.022**	-3.687***	-2.794**	-1.538	-3.584***
	(1.058)	(0.421)	(1.118)	(1.156)	(1.121)	(1.082)
C^R	-2.372***	-1.070	0.865	-2.843***	0.460	-1.686
	(0.815)	(0.951)	(0.849)	(1.092)	(1.126)	(1.092)
$Constant \times D$	-25.051	-7.654**		-54.312***		-20.034***
	(15.578)	(3.895)		(14.509)		(5.251)
$L^R \times D$	17.555	-14.195		0.503		4.288
	(15.290)	(9.876)		(16.269)		(7.040)
$S^R \times D$	21.032***	26.232***		27.854***		17.168***
	(6.784)	(8.485)		(5.933)		(4.404)
$C^R \times D$	-6.376	-9.969***		-3.388*		2.101
	(3.297)	(3.869)		(1.750)		(2.299)
p-value	0.001	0.001	0.010	0.000	0.538	0.000
Adj. R^2	0.225	0.181	0.071	0.323	0.016	0.266
No. of obs.	265	278	290	230	254	278
Break Date	Sep-05	Jun-04	-	Mar-06	-	Feb-05

Note: We first regress three-month exchange rate changes on the three relative NS factors and then apply the Quandt-Andrews test (with 15% trimming) to detect the presence of any structural breaks in the regression. We find significant breaks for Australia, Canada, New Zealand and the United Kingdom but not for Japan and Switzerland, as reported in the last row. When applicable, a structural break dummy variable D, which equals 1 from the break date onward and 0 prior, is then incorporated into the regression. Coefficient estimates are reported above. P-value is for the Wald test that factors jointly have no explanatory power ($H_0 : \alpha_1 = \alpha_2 = \alpha_3 = 0$, along with the coefficients for the structural break interaction terms when applicaple). Newey-West standard errors are reported in the parentheses below each estimates. Asterisks indicate significance levels at 1% (***), 5% (**), and 10% (*) respectively.

Table 2B. 3-Month Excess Currency Return on Relative Factors

$$XR_{t+3} = \beta_0 + \beta_1 L_t^R + \beta_2 S_t^R + \beta_3 C_t^R + \epsilon_{t+3}$$

	AU	CA	JP	NZ	SW	UK
Constant	-4.646*	-1.792	0.308	-8.057**	5.398	-6.697**
	(2.671)	(1.455)	(7.392)	(3.911)	(6.777)	(2.697)
L^R	3.121**	3.154*	0.890	0.806	3.725	6.523***
	(1.506)	(1.619)	(2.264)	(2.907)	(2.809)	(1.791)
S^R	2.259**	1.946***	4.581***	3.706***	2.418**	4.482***
	(1.056)	(0.423)	(1.117)	(1.157)	(1.120)	(1.079)
C^R	2.406***	1.105	-0.778	2.896***	-0.361	1.721
	(0.814)	(0.952)	(0.849)	(1.094)	(1.126)	(1.091)
$Constant \times D$	25.513	7.644**		54.302***		19.750***
	(15.595)	(3.889)		(14.483)		(5.230)
$L^R \times D$	-18.147	14.279		-0.724		-4.351
	(15.300)	(9.865)		(16.218)		(6.965)
$S^R \times D$	-20.923***	-26.235***		-27.738***		-16.964***
	(6.787)	(8.482)		(5.920)		(4.360)
$C^R \times D$	6.405*	10.060***		3.421*		-1.986
	(3.296)	(3.875)		(1.752)		(2.281)
p-value	0.000	0.000	0.001	0.000	0.177	0.000
Adj. R^2	0.239	0.204	0.112	0.326	0.052	0.298
No. of obs.	265	278	290	230	254	278
Break Date	Sep-05	Jun-04	-	Mar-06	-	Feb-05

Note: The break dates are chosen by the Quandt-Andrews test and incorporated into the regressions as described above for Table 2A. P-value is for the Wald test that factors jointly have no explanatory power ($H_0 : \beta_1 = \beta_2 = \beta_3 = 0$, along with the coefficients for the structural break interaction terms when applicape). Newey-West standard errors are reported in the parentheses below each estimates. Asterisks indicate significance levels at 1% (***), 5% (**), and 10% (*) respectively.

Table 3. Summary Statistics for DPR-Fitted Relative Term Premiums

		AU	CA	JP	NZ	SW	UK
3-Month	Mean	0.088	0.026	-0.030	0.101	-0.176	0.004
	Median	0.099	0.040	-0.036	0.105	-0.145	0.054
	SD	0.118	0.095	0.045	0.060	0.146	0.153
	Min	-0.392	-0.275	-0.154	-0.048	-0.604	-0.470
	Max	0.459	0.281	0.089	0.272	0.089	0.325
	AR(1)	0.688	0.887	0.951	0.936	0.922	0.952
12-Month	Mean	0.465	0.153	-0.411	0.457	-0.806	0.000
	Median	0.441	0.155	-0.411	0.469	-0.668	0.191
	SD	0.338	0.410	0.253	0.295	0.630	0.610
	Min	-0.356	-1.095	-1.128	-0.335	-2.649	-1.939
	Max	1.298	1.294	0.259	1.289	0.319	1.317
	AR(1)	0.892	0.890	0.933	0.923	0.925	0.946
120-Month	Mean	1.318	0.498	-2.548	0.858	-1.838	0.036
	Median	1.131	0.333	-2.425	0.821	-1.364	-0.094
	SD	1.112	0.758	0.920	0.631	2.127	0.892
	Min	-0.708	-1.262	-4.850	-0.776	-9.003	-2.143
	Max	4.445	2.764	-0.492	3.192	1.651	2.430
	AR(1)	0.939	0.939	0.928	0.896	0.955	0.928
	$corr_{3,12}$	0.582	0.984	0.967	0.937	0.991	0.994
	$corr_{3,120}$	0.182	0.445	0.700	0.511	0.388	0.441
	$corr_{12,120}$	0.497	0.573	0.833	0.670	0.494	0.525
	No. of obs.	268	281	293	233	257	305

Note: The DPR-Fitted relative term premium is one of the five term premiums we construct for each country pair. It is computed by first estimating a.$VAR(1)$ with only the three relative NS factors: $f_t - \mu = A(f_{t-1} - \mu) + \eta_t$ where $f_t = \left(u_t^R, \pi_t^R, \Delta s_t, L_t^R, S_t^R, C_t^R\right)$. The estimated VAR is used to generate expected relative factors for future horizons. Using the Nelson-Siegel formula, expected relative 1-month yields and the fitted relative $m-$month yields can be constructed using the expected relative factors. The relative m-month term premium, $\theta_t^{R,m}$, is defined as the difference between the fitted relative $m-$month yield and the average expected relative $1-$month yields over m consecutive months: $\theta_t^{R,m} \equiv \widehat{i}_t^{R,m} - \frac{1}{m}\sum_{j=0}^{m-1} E_t\left[\widehat{i}_{t+j}^{R,1}\right]$. See text for details.

Table 4. Predicting 3-Month Excess Currency Return with Relative Term Premiums

$$XR_{t+3} = \beta_0 + \beta_1\theta_t^{R,3} + \beta_2\theta_t^{R,12} + \beta_3\theta_t^{R,120} + \epsilon_{t+3}$$
$$H_0 : \beta_1 = \beta_2 = \beta_3 = 0$$

Premiums $\theta^{R,m}$	AU	CA	JP	NZ	SW	UK
1) NS-Actual						
p-value	0.005	0.046	0.001	0.000	0.466	0.000
Adj. R^2	0.158	0.065	0.111	0.158	0.012	0.160
2) DPR-Actual						
p-value	0.003	0.000	0.000	0.000	0.484	0.000
Adj. R^2	0.125	0.137	0.124	0.219	0.011	0.172
3) Affine						
p-value	0.000	0.000	0.000	0.000	0.443	0.004
Adj. R^2	0.175	0.104	0.129	0.265	0.016	0.179
4) DPR-Fitted						
p-value	0.015	0.000	0.000	0.002	0.012	0.035
Adj. R^2	0.101	0.152	0.120	0.154	0.057	0.107
5) CP						
p-value	0.049	0.001	0.002	0.001	0.620	0.000
Adj. R^2	0.031	0.095	0.083	0.154	0.004	0.161
No. of obs.	265	278	290	230	254	278

Note: Four different types of relative term premiums are used in the above regression: 1) "NS-Fitted" is desribed in Table 3A; 2) "DPR-Fitted" is described in Table 3B; 3) "NS-Actual" is constructed as in NS-Fitted, except actual m-month relative yields are used instead of the fitted ones in the last step, i.e:.$\theta_t^{R,m} \equiv i_t^{R,m} - \frac{1}{m}\sum_{j=0}^{m-1} E_t\left[\widehat{i}_{t+j}^{R,1}\right]$ and 4) "DPR-Actual" is DPR-Fitted with actual m-month relative yields. The fifth epscification, 5) "CP", .replaces $\theta_t^{R,12}$ and $\theta_t^{R,120}$with the Cochrane-Piazzesi (2005) factor. Structural breaks identified in Table 2A are included for Australia, Canada, New Zealand, and United Kingdom. The p-value is for the Wald test that premiums are jointly insignificant ($H_0 : \beta_1 = \beta_2 = \beta_3 = 0$, along with the coefficients for the interaction terms when applicable). Newey-West standard errors are used for the Wald test.

Table 5. Predicting 3-Month Exchange Rate Change with Relative Term Premiums

$$\Delta s_{t+3} = \beta_0 + \beta_1 \theta_t^{R,3} + \beta_2 \theta_t^{R,12} + \beta_3 \theta_t^{R,120} + \epsilon_{t+3}$$

$$H_0 : \beta_1 = \beta_2 = \beta_3 = 0$$

Premiums $\theta^{R,m}$	AU	CA	JP	NZ	SW	UK
1) NS-Actual						
p-value	0.007	0.054	0.009	0.000	0.687	0.000
Adj. R^2	0.161	0.061	0.075	0.163	0.002	0.155
2) DPR-Actual						
p-value	0.008	0.572	0.003	0.000	0.681	0.000
Adj. R^2	0.041	0.010	0.086	0.130	0.000	0.141
3) Affine						
p-value	0.001	0.009	0.002	0.000	0.700	0.007
Adj. R^2	0.157	0.085	0.093	0.284	0.000	0.179
4) DPR-Fitted						
p-value	0.018	0.001	0.004	0.002	0.052	0.038
Adj. R^2	0.097	0.145	0.080	0.173	0.034	0.100
5) CP						
p-value	0.071	0.016	0.017	0.001	0.785	0.000
Adj. R^2	0.026	0.090	0.055	0.145	-0.002	0.157
No. of obs.	265	278	290	230	254	278

Note: The five different sets of regressors are used as explained in Table 4. Structural breaks identified in Table 2A are included for Australia, Canada, New Zealand, and United Kingdom. The p-value is for the Wald test that premiums are jointly insignificant ($H_0 : \beta_1 = \beta_2 = \beta_3 = 0$, along with the coefficients for the interaction terms when applicable). Newey-West standard errors are used for the Wald test.

Table 6. Predicting Exchange Rate Change with Relative Expected Yields

$$\Delta s_{t+3} = \beta_0 + \beta_1 \widehat{i}^{R,3} + \beta_2 \widehat{i}^{R,12} + \beta_3 \widehat{i}^{R,120} + \epsilon_{t+3}$$

$$H_0 : \beta_1 = \beta_2 = \beta_3 = 0$$

Expectation $\widehat{i}^{R,m}$	AU	CA	JP	NZ	SW	UK
1) NS						
p-value	0.001	0.001	0.010	0.000	0.538	0.000
Adj. R^2	0.225	0.181	0.071	0.323	0.016	0.266
2) DPR						
p-value	0.000	0.000	0.005	0.000	0.224	0.000
Adj. R^2	0.239	0.275	0.087	0.320	0.031	0.275
3) Affine						
p-value	0.000	0.041	0.008	0.000	0.295	0.000
Adj. R^2	0.264	0.072	0.077	0.324	0.029	0.275
No. of obs.	265	278	290	230	254	278

Note: Exchange rate change is regressed on the relative expected yields of 3-month, 12-month and 120-month maturities. There are two different sets of expected yields: 1) expected yields calculated with only factors in the VAR and 2) expected yields calculated with factors and macroeconomic variables in the VAR. Interaction terms for the structural break in Table 2A are included for Australia, Canada, New Zealand, and United Kingdom. The p-value is for the Wald test of the null $\alpha_1 = \alpha_2 = \alpha_3 = 0$ (plus the coefficients for the interaction terms when applicable), i.e. the expected yields have zero coefficients. Newey-West standard errors are used for the Wald test.

Table 7. Explaining Exchange Rate Change
Macroeconomic Fundamentals, Yield Factors, or Both?

$$\Delta s_{t+3} = \alpha + \beta_1 L_t^R + \beta_2 S_t^R + \beta_3 C_t^R + \beta_4 u_t + \beta_5 \pi_t + \epsilon_{t+3}$$

	AU	CA	JP	NZ	SW	UK
Wald test p-values						
No Yields?	0.000	0.290	0.008	0.000	0.067	0.000
No Macro?	0.297	0.000	0.315	0.009	0.111	0.269
RW?	0.000	0.000	0.020	0.000	0.152	0.000
Adj. R^2	0.242	0.317	0.083	0.352	0.032	0.296
No. of obs.	265	278	290	230	254	278

Noe: The row labeled "No Yields" reports the p-values of the Wald tests for the null hypothesis that relative yield curve factors have no explanatory power ($\beta_1 = \beta_2 = \beta_3 = 0$), and the "No Macro" row tests the null hypothesis that macroeconomic fundamentals do not matter ($\beta_4 = \beta_5 = 0$). "RW" tests the null that exchange rate follows a random walk with a possible drift α ($\beta_i = 0, \forall i$). Interaction terms for the structural breaks identified in Table 2A are included in the regressions when applicable, and the relevant coefficients are jointly tested. Newey-West standard errors are used for the regressions

Table 8. Explaining Exchange Rate Changes Δs_{t+k}
with Macroeconomic Fundamentals and Yield Curve Factors
Hodrick's (1992) Partial R^2

Horizon $k =$	Ex. Rate	Level	Slope	Curvature	Unemploy.	Inflation	Total R^2
Australia							
1	0.000	0.000	0.011	0.025	0.007	0.005	0.040
3	0.002	0.000	0.034	0.035	0.021	0.016	0.072
6	0.002	0.000	0.061	0.033	0.042	0.030	0.098
12	0.003	0.000	0.096	0.028	0.076	0.055	0.135
Canada							
1	0.000	0.003	0.015	0.006	0.019	0.041	0.066
3	0.003	0.007	0.045	0.011	0.055	0.111	0.154
6	0.008	0.010	0.083	0.010	0.094	0.174	0.229
12	0.012	0.009	0.131	0.007	0.145	0.231	0.292
Japan							
1	0.001	0.001	0.024	0.010	0.000	0.001	0.037
3	0.004	0.002	0.064	0.030	0.000	0.002	0.099
6	0.006	0.007	0.109	0.058	0.000	0.003	0.166
12	0.009	0.018	0.155	0.098	0.000	0.003	0.241
New Zealand							
1	0.018	0.004	0.032	0.045	0.039	0.012	0.094
3	0.026	0.009	0.080	0.078	0.089	0.028	0.190
6	0.031	0.012	0.128	0.084	0.136	0.046	0.259
12	0.033	0.013	0.173	0.065	0.192	0.066	0.309
Switzerland							
1	0.005	0.001	0.004	0.003	0.000	0.000	0.027
3	0.005	0.003	0.012	0.007	0.001	0.002	0.061
6	0.006	0.004	0.022	0.009	0.002	0.005	0.092
12	0.006	0.004	0.041	0.012	0.005	0.016	0.120
United Kingdom							
1	0.003	0.002	0.010	0.001	0.000	0.005	0.027
3	0.003	0.004	0.026	0.003	0.000	0.014	0.064
6	0.003	0.005	0.043	0.005	0.000	0.023	0.101
12	0.003	0.006	0.062	0.008	0.000	0.034	0.137

Note: The partial R^2 reports the contribution of each variable in explaining Δs_{t+k} for $k = 1, 3, 6, 12$. It is constructed by first estimating $f_t - \mu = A(f_{t-1} - \mu) + \eta_t$, where $f_t = \left(u_t^R, \pi_t^R, \Delta s_t, L_t^R, S_t^R, C_t^R\right)$, and then using $\widehat{A}$ and the estimated covariance matrix of the $VAR(1)$, as in Hodrick (1992). Please refer to Appendix B for details. Note that individual R^2's do not add up to the total R^2 as the variables are correlated. For Switzerland the last four observations are dropped to prevent the VAR from being non-stationary.

Table 9. Predicting Exchange Rate Change In-Sample: Model Comparisons

RMSE Ratios and Diebold-Mariano Statistics

Horizon k	AU	CA	JP	NZ	SW	UK
$k=1$						
RMSE Ratio (Joint/RW)	0.978	0.967*	0.977*	0.947**	0.987	0.976
	(1.586)	(1.900)	(1.767)	(2.361)	(1.175)	(1.622)
RMSE Ratio (Macro/RW)	0.994	0.978	0.993	0.978	0.998	0.993
	(0.676)	(1.648)	(1.025)	(1.557)	(0.293)	(0.805)
$k=3$						
RMSE Ratio (Joint/RW)	0.957**	0.939**	0.949**	0.881***	0.983	0.930***
	(2.061)	(2.007)	(2.201)	(3.625)	(0.909)	(2.918)
RMSE Ratio (Macro/RW)	0.979	0.948**	0.983	0.955**	0.999	0.978
	(1.525)	(2.050)	(1.648)	(2.428)	(0.080)	(1.431)
$k=6$						
RMSE Ratio (Joint/RW)	0.954*	0.942	0.904***	0.822***	0.969	0.922**
	(1.716)	(1.600)	(2.812)	(4.857)	(1.287)	(2.582)
RMSE Ratio (Macro/RW)	0.962**	0.923**	0.968*	0.942***	0.997	0.969
	(2.039)	(2.449)	(2.032)	(2.650)	(0.193)	(1.600)
$k=12$						
RMSE Ratio (Joint/RW)	0.982	0.949	0.927	0.822***	0.929**	1.017
	(0.500)	(1.335)	(1.493)	(5.569)	(2.301)	(-0.453)
RMSE Ratio (Macro/RW)	0.935***	0.910**	0.944***	0.962	0.990	0.964
	(2.888)	(2.443)	(2.282)	(1.589)	(0.450)	(1.463)

Note: Predicted exchange rate changes $E_t(\Delta s_{t+k})$ for $k = 1, 3, 6, 12$ are generated by estimating a $VAR(1)$: $f_t - \mu = A(f_{t-1} - \mu) + \eta_t$ using the full sample, and then iterating it forward k-periods. For the macro-finance model (labelled "Joint"),

$f_t = \left(u_t^R, \pi_t^R, \Delta s_t, L_t^R,\ S_t^R, C_t^R\right)$, and for the macro model (labelled "Macro"), $f_t = \left(u_t^R, \pi_t^R, \Delta s_t\right)$. RMSE ratio reports the model root mean squared prediction errors over the ones from a random walk prediction ($E_t(\Delta s_{t+k}) = 0$). A ratio below 1 means the model has explanatory power. The number in the parentheses below each ratio is the t-statistics from the Diebold-Mariano test of equal predictability, where a rejection indicates superior prediction from the model over the random walk. Asterisks indicate significance levels at 1% (***), 5% (**), and 10% (*) respectively..

Figure 1: 3-Month Exchange Rate Change

(Annualized %; Home Currency/USD)

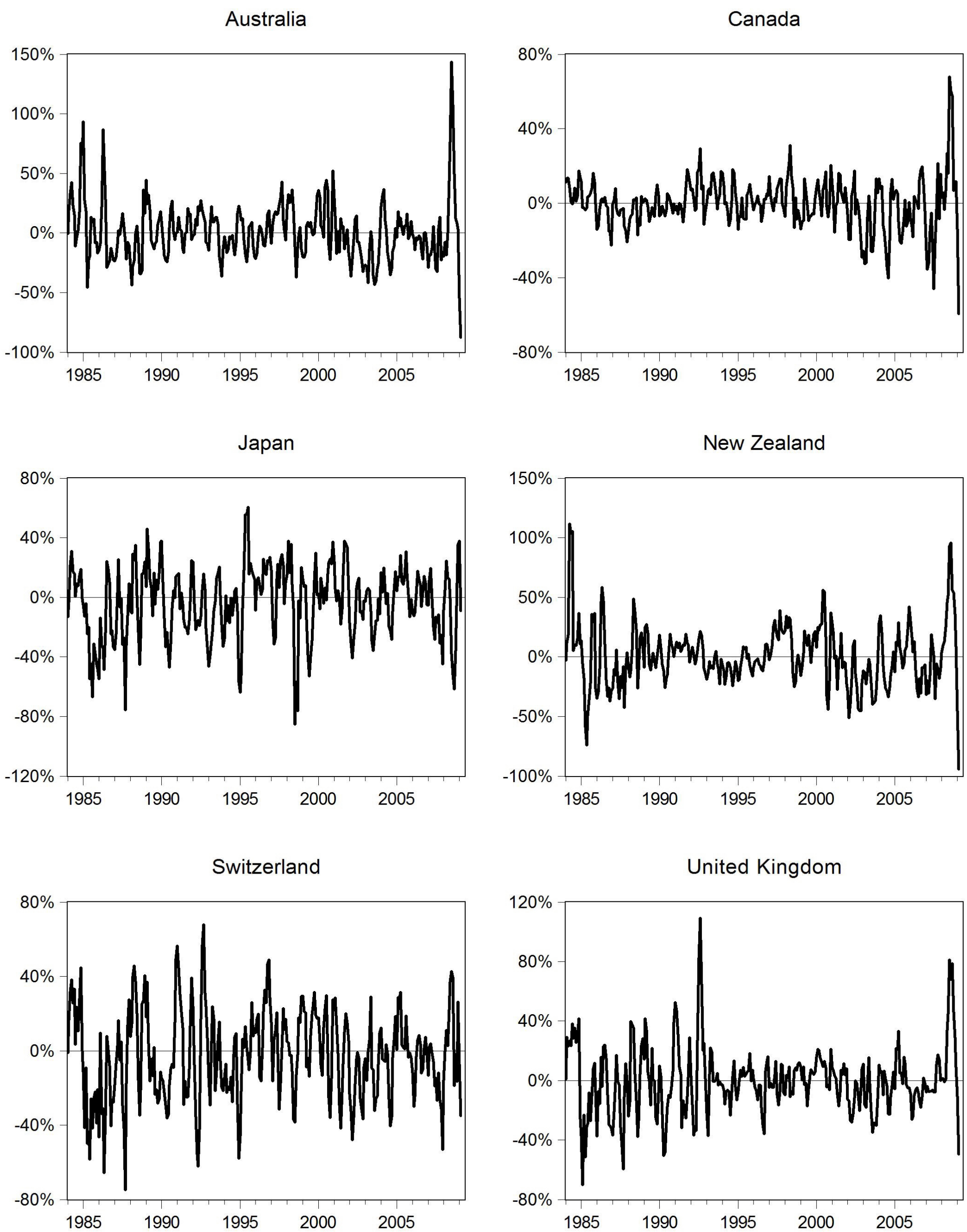


Figure 2. 3-Month Excess Currency Return

(Annualized %; Home over USD return)

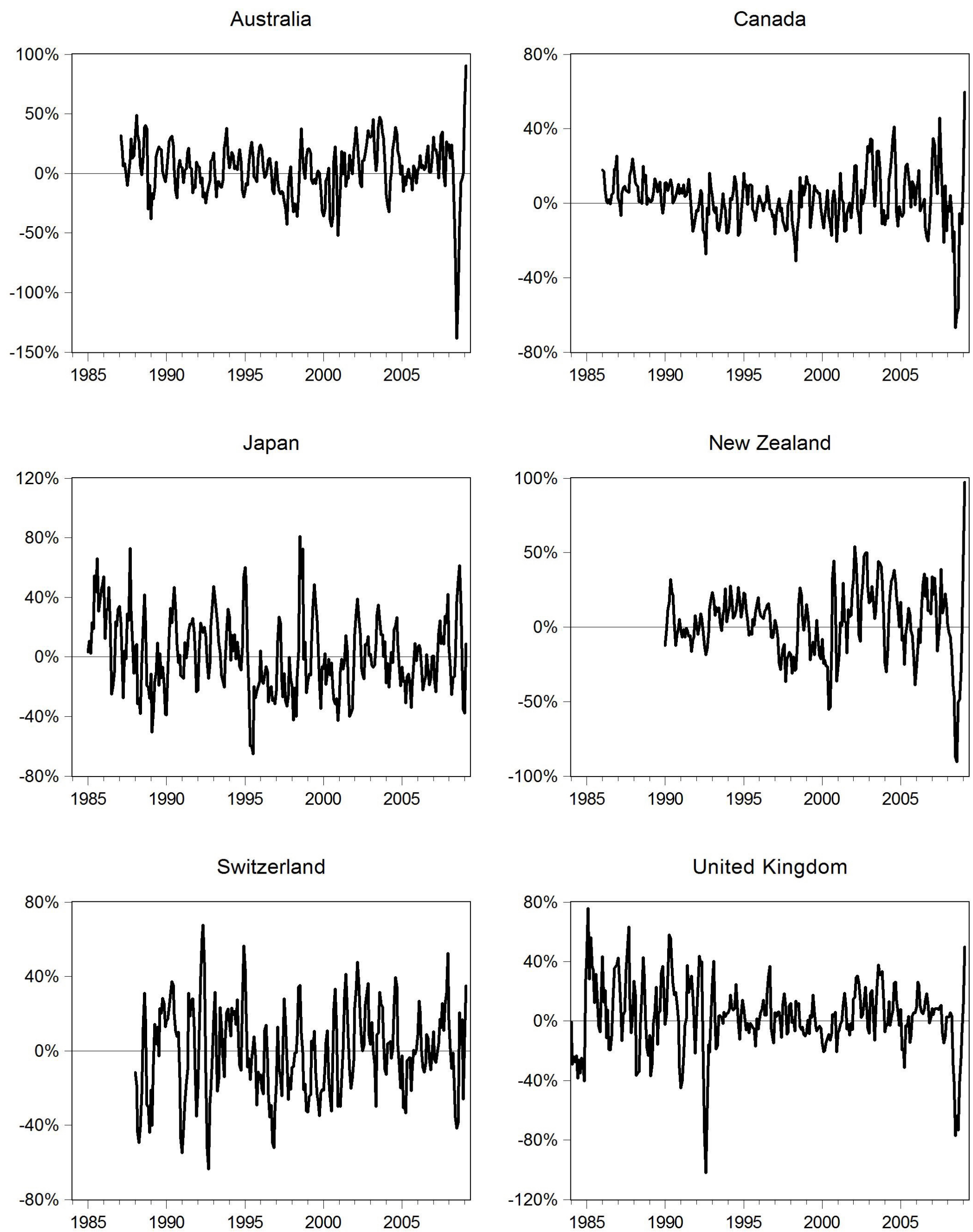
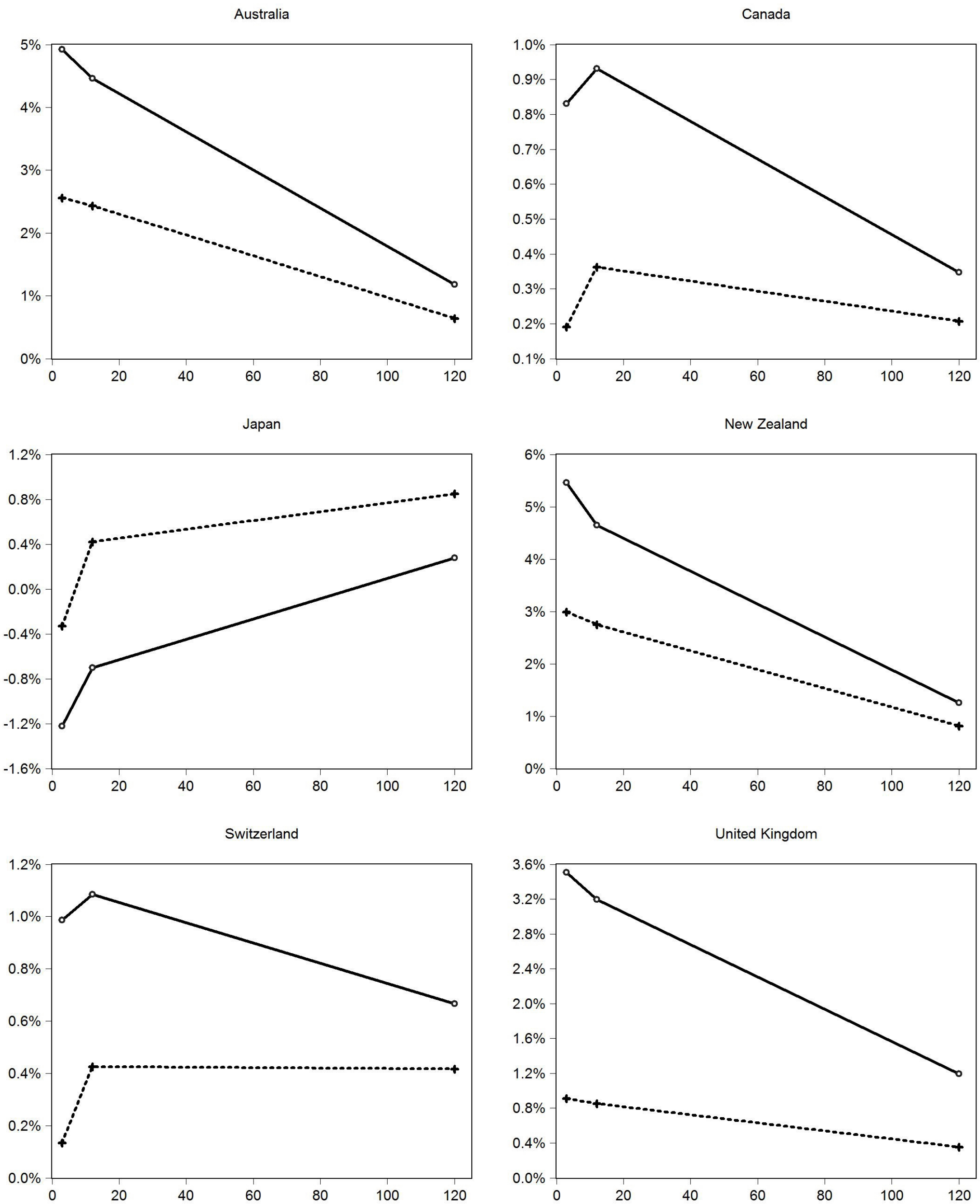
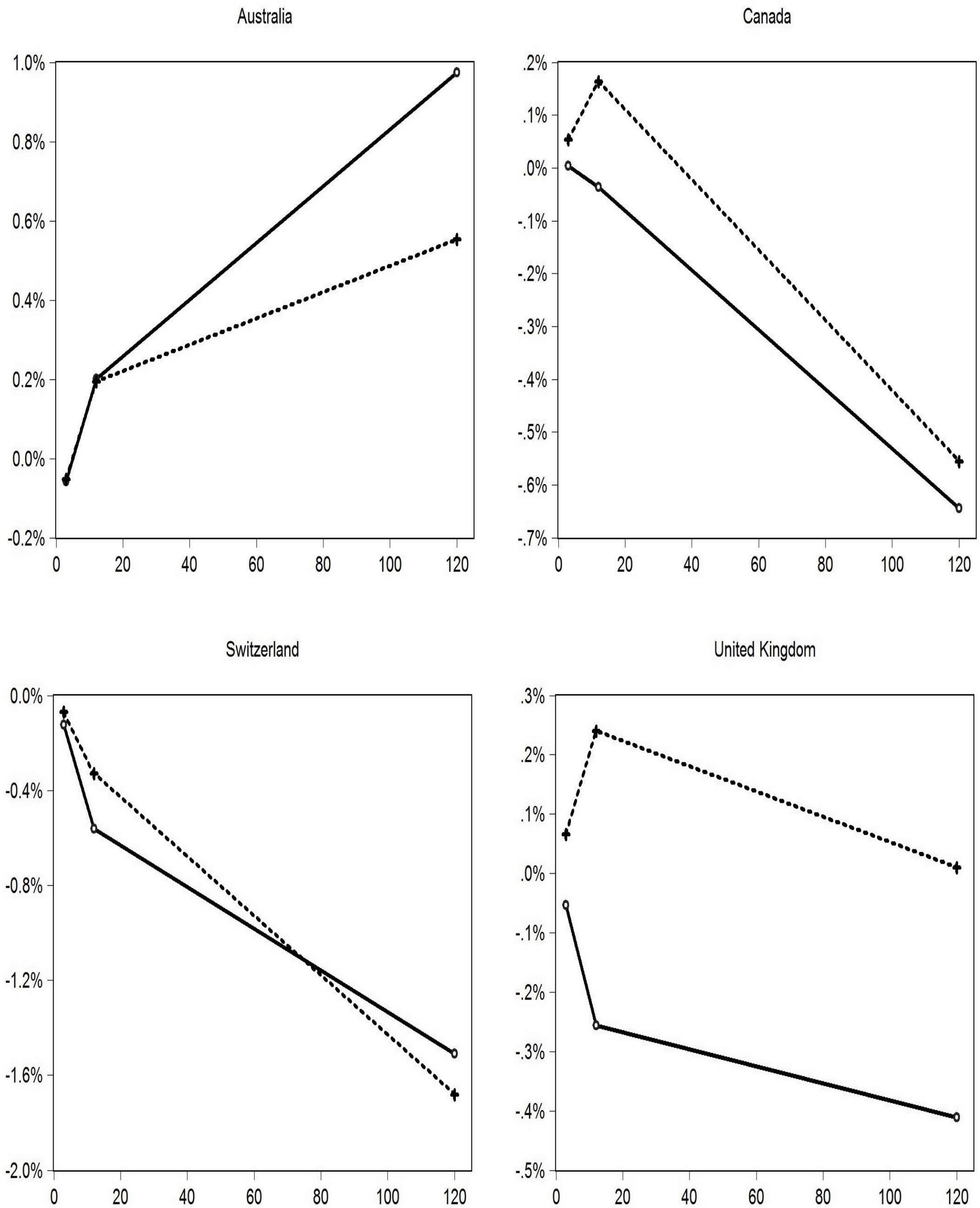


Figure 3. Expected Relative Yields Before and After August 2008



Note: 3-,12-, and 120-month relative expected yields reported as monthly averages over Jan-Aug 2008 (solid line) and Sep 2008-May 2009 (dashed line).

Figure 4. Relative Term premiums Before and After August, 2008



Note: 3-,12-, and 120-month relative premiums reported as monthly averages over Jan-Aug 2008 (solid line) and Sep 2008-May 2009 (dashed line).