Predicting risk premia in short-term interest rates and exchange rates*

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Preliminary version

Abstract

We assess the ability of yield curve factors to predict risk premia in short-term interest rates and exchange rates across a large sample of major advanced economies. We find that the *same* tick-shaped linear combination of (relative) bond yields predicts risk premia in both short-term interest rates and exchange rates at return-forecasting horizons of up to six months for *all* (but one) countries and currencies in our sample. Our single forecasting factor loads positively on the short and long end of the curve and negatively on the medium-term and is therefore inversely related to Nelson-Siegel's curvature factor. In line with recent interpretations of the yield curve factors, our findings suggest that the hump of the yield curve bears important information about future monetary policy. A relatively high curvature predicts a surprise monetary policy tightening, i.e. a rise in short-term interest rates beyond expectations and, coincidentally, an appreciation of the home currency in line with uncovered interest rate parity.

Keywords: Exchange rates, Interest rates, Risk premia, Yield curve, Predictability.

JEL-Classification: C23, C53, G11.

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Non-technical summary

The relationship between short-term interest rates and exchange rates is of tremendous importance for policy makers and researchers alike. The well-known, but empirically unstable, principle of uncovered interest rate parity (UIP) predicts a future depreciation of higher interest rate currencies and vice versa. An alternative, but equivalent, representation of UIP posits that a surprise increase in short-term interest rates (as well as a change in expectations about the future path of short-term interest rates) results in an concurrent appreciation of the exchange rate. The latter connotation is in line with the findings of several event studies and folk wisdom among FX market analysts that a tightening of monetary policy, or mounting expectations thereof, results in an appreciation of the home currency (ceteris paribus).

In this paper, we aim to exploit this very relationship to improve the forecast of exchange rates. We find that predictors of short-term interest rate surprises which are well documented in the literature, help predict exchange rate. In a nutshell, we find that a curvature-shaped yield curve factors is able to predict short-term interest rate surprises in advanced (G10) economies as well as future risk premia in exchanges rates vis-à-vis the US dollar.

Despite some success in predicting short-term exchange rate movements based on high-frequency micro-data, forecasting exchange rates has remained difficult ever since the seminal paper by Meese and Rogoff (1983). This contrasts with the still growing evidence on interest rate surprises and excess bond returns which appears much more rewarding. Risk premia in interest rate futures (i.e., the short-run deviation from expectations hypothesis) have been shown to be well predicted by macro and financial business cycle variables, including the slope of the Treasury yield curve. Applied to longer-maturity U.S. Treasury bonds, it has been shown that excess bond returns over a one year horizon can be forecasted by a single yield curve factor, a linear combination of forward rates at the one- to five-year maturity. Several other contributions show that the wealth of information embedded in the yield curve significantly improves the forecast of short-term interest rates when benchmarked against the expectations hypothesis.

This paper aims to fill the gap between the literature on interest rate predictability and exchange rate predictability. The rationale is straightforward: If short-term interest rate rate surprises can be predicted by means of a yield curve factor and if these surprises are contemporaneously linked to exchange rate surprises, the same yield curve factor (or rather the differential of this factor across two economies) should itself carry information about future exchange rates beyond the forward discount.

We document that a single forecasting factor, a tick-shaped linear combination of sovereign bond yields which is highly negatively correlated with the curvature factor in the Nelson-Siegel model, can predict both surprises in eurocurrency deposit rates and future exchange rate risk premia one month to six months ahead. Using data on bilateral exchange rates against the US dollar, we show in a panel of nine currencies that a relatively high curvature predicts a rise in short-term interest rates beyond expectations (implied in the longer term interest rates) in the months ahead as well as an appreciation of the home currency. Importantly, we find that this result is robust at the individual currency level for all currencies, except the Japanese yen.

Economically, our findings provide support to the hypothesis that the curvature factor captures an independent factor of a central bank's monetary policy stance. A high curvature of the yield curve reflects expectations about a future rise in short-term interest rates beyond fundamental economic relationships which are captured by the first two yield curve factors (level and slope).

1 Introduction

The relationship between short-term interest rates and exchange rates is of tremendous importance for policy makers and researchers alike. The well-known, but empirically unstable, uncovered interest rate parity (UIP) condition predicts a future depreciation of higher interest rate currencies and vice versa (see, for instance, Bilson, 1981; Fama, 1984). An equivalent representation of UIP, that is based on its forward solution (see, for instance, Engel and West, 2005, 2010) posits that a surprise increase in short-term interest rates (as well as a change in expectations about the future path of short-term interest rates) results in an concurrent appreciation of the exchange rate (Froot and Ramadorai, 2005). The latter connotation is in line with the findings of several event studies and folk wisdom among market participants that a (surprise) tightening of monetary policy, or mounting expectations thereof, results in an appreciation of the home currency (ceteris paribus) (Fatum and Scholnick, 2008).[1]

While forecasting exchange rates has remained difficult ever since the seminal contribution by Meese and Rogoff (1983), forecasting surprises in short-term interest rates and bond yields appears much more rewarding (ever since Fama and Bliss, 1987). Piazzesi and Swanson (2008) demonstrate that risk premia in interest rate futures (i.e. short-run deviations from the expectations hypothesis) are well predicted by business cycle and financial variables, including the slope of the Treasury yield curve. Applied to longer-maturity U.S. Treasury bonds, Cochrane and Piazzesi (2005) show that one-year bond excess returns can be forecasted by a single yield curve factor, a linear combination of forward rates at the one- to five-year maturity. This single yield curve factor is closely correlated with the curvature factor in the Nelson and Siegel (1987) model of the yield curve (Møller, 2014). Kessler and Scherer (2009) and Sekkel (2011) extend the analysis to several other international bond markets.

Several other contributions show that the wealth of information embedded in the yield

[1]Stavrakeva and Tang (2015, 2016) have demonstrated that a significant share of the variation in major exchange rate pairs can be attributed to monetary policy surprises and evolving expectations about the future path of monetary policy rates.

curve significantly improves the forecast of short-term interest rates when benchmarked against the expectations hypothesis. For instance, Nyholm (2016) finds that the curvature factor has a consistently positive impact on the short rate in a rotated dynamic Nelson-Siegel model of the US yield curve. Relatedly, Moench (2012) finds that an unanticipated increase in the curvature raises short-term yields in the quarters ahead as the path of future short-term rates becomes steeper. Finally, Diebold and Li (2006) show that the use of Nelson-Siegel factors greatly increases the forecasting performance of short-term interest rates compared to models that solely rely on the information provided by the expectations hypothesis.

In this paper, we aim to exploit the predictability of surprises in short-term interest rates to improve forecasts of exchange rate excess returns. The rationale is straightforward: If short-term interest rate surprises can be predicted by means of a yield curve factor, and if interest rate surprises are contemporaneously linked to exchange rate movements, as suggested by UIP, the same yield curve factor (or rather the differential of this factor across two economies) should itself carry information about future exchange rate risk premia.

We find that a single forecasting factor, a tick-shaped linear combination of spot rates which is highly negatively correlated with the curvature factor in the Nelson-Siegel model, can predict, in-sample, both surprises in money market rates, defined as deviations from the expectations hypothesis, and future exchange rate risk premia one month to six months ahead. A relatively high curvature predicts a rise in short-term interest rates beyond expectations (implied in longer term interest rates) and, ceteris paribus, an appreciation of the home currency over the one- to six-months horizon. Importantly, we find that this result is robust at the individual currency level for all currencies, except the Japanese yen.

Our empirical findings are in line with the theoretical relationship implied by UIP in which the currency risk premium is determined inter alia by short-term interest rate surprises and evolving expectations about the future path of short-term rates (see, for instance, Froot and Ramadorai, 2005; Stavrakeva and Tang, 2015).

Economically, our findings provide support to the hypothesis that the curvature factor captures an independent factor of the monetary policy stance, as suggested by Dewachter and Lyrio (2006). They argue that a high curvature of the yield curve reflects expectations about a future rise in short-term interest rates beyond fundamental economic relationships which are captured by the first two yield curve factors (level and slope). This rather qualitative interpretation of the curvature factor is substantiated by its loading structure where the curvature effectively amounts to the difference of medium-term (2 year) yields over an average of short-term and long-term yields (also see, Diebold and Li, 2006). Gürkaynak et al. (2007) and Nyholm (2016) therefore describe the curvature as the expected speed at which the short rate converges to the long rate (abstracting from term premia). Moench (2012) provides a very similar interpretation of his finding that a surprise change in the curvature predicts a flattening of the yield curve and a decline in GDP growth.

Our results are, moreover, consistent with the only existing study on the predictability of exchange rates on the basis of yield curve factors. Chen and Tsang (2013) find for two out of three bilateral exchange rates vis-à-vis the US dollar a positive relationship between the relative curvature factor and the future change in the value of the home currency.[2]

The rest of the paper is organised as follows. Section 2 describes the asset pricing model approach to exchange rate determination which sets the theoretical foundation for the link between monetary policy and exchange rate dynamics. Section 3 lays out the empirical strategy. The empirical results are presented and discussed in Section 4 and Section 5. Section 6 concludes.

[2] However, the authors do not allude to the theoretical channel of that particular result nor do they provide any economic interpretation for it. Instead, they focus in the interpretation of their results on the negative relationship of the exchange rate with the relative level and the relative slope of the yield curve which they relate to changes in the risk premia rather than to the predictive information these factors contain about the future path of relative interest rates.

2 The theoretical link between exchange rates and interest rates

The theoretical framework behind our analysis follows the intuition provided by Stavrakeva and Tang (2015, 2016) who establish the link between the exchange rate and interest rates based on the forward-iterated UIP condition (see also Engel and West, 2005, 2010). In this representation, the current level of the log exchange rate of currency j in units of US dollar, $s_t^{j/USD}$, is determined by expectations about the future path of short-term interest rate differentials ($i_t^j - i_t^{USD}$) in addition to the future path of expected currency risk premia ($\lambda_t^{j/USD}$). In particular, Equation (1) posits that expectations about higher domestic interest rates relative to US interest rates should result in an exchange rate that is appreciated vis-à-vis the dollar relative to long-run unconditional mean ($E_t \lim_{h\to\infty} s_{t+h} = \bar{s}^{j/USD}$), assuming exchange rate stationarity.

$$s_t^{j/USD} = -E_t[\sum_{k=1}^{\infty} i_{t+h}^j - i_{t+h}^{US} + \lambda_{t+h}^{j/USD}] + E_t \lim_{h\to\infty} s_{t+h}, \tag{1}$$

with UIP implied expectations corresponding to

$$E_t \Delta s_{t+1}^{j/USD} = i_t^j - i_t^{US} + \lambda_t^{j/USD}. \tag{2}$$

Hence, the expectational error, $xr_{t+1}^{j/USD}$, can be expressed as

$$\begin{aligned} xr_{t+1}^{j/USD} \equiv \Delta s_{t+1}^{j/USD} - E_t \Delta s_{t+1}^{j/USD} = -(\tilde{i}_{t+1}^j - E_t \tilde{i}_{t+1}^j) \\ - \sum_{h=2}^{\infty} (E_{t+1} \tilde{i}_{t+h}^j - E_t \tilde{i}_{t+h}^j) - \sum_{k=1}^{\infty} (E_{t+1} \lambda_{t+h}^{j/USD} - E_t \lambda_{t+h}^{j/USD}) \\ + (E_{t+1} \lim_{h\to\infty} s_{t+h} - E_t \lim_{h\to\infty} s_{t+h}), \end{aligned} \tag{3}$$

where $\tilde{i}_t^j = i_t^j - i_t^{US}$. We focus on the first two terms of the right-hand side of Equation (3) which correspond, respectively, to the surprise in the relative short-term interest rate differential and the change in expectations about the future path of short term interest rate differentials ($\tilde{i}^j_{t+h}$) that occurred between t and $t+1$. Stavrakeva and Tang (2015) have shown that these two terms are of economic significance, accounting for 20% to 40% of the variability of major exchange rate pairs. Finally, we assume that all expected risk premia, $\lambda^{j/USD}_{t+h}$, are either zero or constant over time such that the dynamic of the expectational error coincides with that of the foreign exchange excess return (or the ex-post currency risk premium) in a world where exchange rate expectations ($E_t\Delta s^{j/USD}_{t+1}$) are solely based on interest rate rate differentials.[3]

We show that we can improve forecasts of the exchange rate risk premium, $xr^{j/USD}_{t+1}$, using yield curve factors as we can forecast short-term interest rate surprises, which are the inverse of risk premia of either a short-term deposit rates or interest rate futures (Piazzesi and Swanson, 2008). Specifically, under the expectations hypothesis of the term structure, the realised risk premium of the two-period interest rate ($rx^2_{j,t+1}$) in economy j, which is equivalent to (minus) the surprise on the one-period interest rate, can be expressed as

$$rx^{j,2}_{t+1} \equiv p^{j,1}_{t+1} - p^{j,2}_t - i^{j,1}_t = -(i^{j,1}_{t+1} - E_t i^{j,1}_{t+1}) = -(i^{j,1}_{t+1} - (i^{j,2}_t - i^{j,1}_t)), \tag{4}$$

where i^h_t is the interest rate at the h-period maturity and p^h_t the natural logarithm of the zero-coupon bond price with the same maturity in economy j. The first identity is the definition of the risk premium of a two period bond, defined inter alia by Cochrane and Piazzesi (2005). It equates to the return from buying a two-period bond in period t (at price p^2_t) and selling this bond with a remaining maturity of one period in period $t+1$ (at price p^1_{t+1}) in excess of the one-period risk free return at period t (that is i^1_t). The second identity translates the bond risk premium in terms of interest rates where $p^h_t = -i^h_t$. As we are interested in risk premia of short-term deposit rates rather than long-term bonds, the interest rate risk premium can be realised by holding a two-period deposit over two consecutive one-period deposits. The last identity makes this more obvious; the interest

[3]Note that the expectational error, as defined Equation (3) is entirely unexpected. By contrast, the standard UIP risk premium $\lambda^{j/USD}_t$, by the way it is defined in Equation (2), is the expected compensation for exchange rate risk. By assuming the latter to be zero or constant, we can refer to the former as realisations of the currency risk premium (net of a constant expected risk premium).

rate risk premium corresponds to the difference between the two-period rate (at period t) and two consecutive one-period rates (at periods t and $t+1$).

To sum up, the relative interest rate risk premium (of economy j vis-à-vis the US), defined as surprises under the expectation hypothesis ($\tilde{i}^{j,1}_{t+1} - E_t\tilde{i}^{j,1}_{t+1}$), is an an important component of the exchange rate risk premium, defined as ex-post deviations from interest rate parity (see first term in equation Equation (3)). Being able to forecast the former might improve forecasts of the latter. Indeed, we show in the subsequent section that a single yield curve factor (one that is inversely related to the curvature of the yield curve) predicts risk premia in interest rates (rx^{2h}_{t+1}) at horizons from two months up to twelve months; and we show that this very factor is negatively related to future risk premia of G10 currencies ($xr^{j/USD}_{t+h}$) vis-à-vis the US dollar over the same horizons as predicted by Equation (3).

3 Empirical strategy

We aim to improve in-sample projections of exchange rate risk premia by exploiting the predictability of risk premia in short-term interest rates which, according to UIP, are directly linked to currency risk premia. In this spirit, our empirical framework follows a three-step procedure. First, we confirm the predictability of risk premia in short-term interest rates based on summary measures of the yield curve. Second, we test the theoretical prediction of UIP as presented in Equation (3). Specifically, we assess whether risk premia in short-term interest rates are a contemporaneous determinant of exchange rate risk premia, i.e. of exchange rate movements that go beyond UIP implied expectations. Third, building upon the first two steps, we test whether the same yield curve measure that predicts risk premia in short-term interest rates, in its relative terms, is able to predict risk premia in exchange rates.

The starting point of our empirical framework is to investigate, in-sample, the predictive content of the yield curve for risk premia in short-term money market rates. To this end, we follow the literature on risk premia in bond markets which regresses bond excess returns on initial forward rates (Cochrane and Piazzesi, 2005; Sekkel, 2011; Kessler and Scherer, 2009). However, we modify the approach of Cochrane and Piazzesi (2005) along two dimensions. First, Cochrane and Piazzesi (2005) focus on one-year excess returns on bonds with a remaining maturity, n, with n being equal to or greater than two years ($n = 2, 3, 4, 5$). As discussed earlier, deviations from UIP are determined by unexpected changes in current and the expected future path of *short-term* interest rates (see Equation (3)). For this reason, we relate the initial yield curve to risk premia in short-term interest rates rather than longer-term maturity bond yields. We consider risk premia in short-term deposit rates with a remaining maturity, n,

$$rx_{t+1}^{(n)} \equiv [rx_t^{(2)} \; rx_t^{(6)} \; rx_t^{(12)} \; rx_t^{(24)}], \quad n = [2, 6, 12, 24],$$

where n corresponds to two months, six months, twelve months and 24 months. Moreover, in contrast to Cochrane and Piazzesi (2005), who consider one-year return horizons across maturities, we focuss on return horizons that vary across the maturities of the deposit rates. Specifically, the return horizon, h, corresponds to half the maturity, n, of the deposit rate

$$h = \frac{n}{2} \quad h = [1, 3, 6, 12],$$

that is we consider return horizons, h, of one month, three months, six months and one year. Hence, Equation (4) can be generalised to

$$rx_{t+1}^{j,2h} = -(i_{t+1}^{j,h} - E_t i_{t+1}^{j,h}) = -(i_{t+1}^{j,h} - (i_t^{j,2h} - i_t^{j,h})), \tag{5}$$

The second modification concerns the approximation of the yield curve on the right hand side of the Cochrane and Piazzesi (2005) predictive regression. Whereas the literature on bond excess returns exploits the information available in a distinct part of the yield curve, typically using forward rates with maturities of one to five years, we take a slightly different approach and relate risk premia in short-term interest rates to the information embedded in the entire yield curve, including the very short and long end of the curve.

The idea is to maintain the same degree of flexibility on the relationship between the yield curve and risk premia as Cochrane and Piazzesi (2005), but, at the same time, to cater for the distinct challenge of predicting risk premia in short-term rates (and exchange rates), as opposed to longer-term maturity bonds.[4] Specifically, we approximate the information embedded in the yield curve by using three-months, two-year and ten-year spot yields. We do that for a number of reasons. First, for in-sample predictions of risk premia in short-term interest rates (as well as in exchange rates) it appears essential to also exploit information embedded in the very short-end (three-months) of the yield curve. Second, various studies have pointed to the predictive power of yield curve factors including information from the long-end, for surprises in short-term interest rates (Diebold and Li, 2006; Nyholm, 2016). Third, and most importantly, Diebold and Li (2006) show that, given their respective loading structures, the three Nelson-Siegel yield curve factors—which explain almost the entire cross-sectional variation of the yield curve—can, in turn, be almost perfectly approximated by a linear combination of bond yields at these three different maturities.[5]

Following the above logic, we regress risk premia in short-term interest rates on three-month, two-year and ten-year spot yields,[6]

$$rx_{t+h}^{j,2h} = \alpha^j + \beta_1^h y_t^{j,3m} + \beta_2^h y_t^{j,2y} + \beta_3^h y_t^{j,10y} + \epsilon_{t+h}^j, \tag{6}$$

where risk premia in money market instruments of economy j, $rx_{t+h}^{j,2h}$, are derived based on Equation (4). We run regressions for all G10 economies,[7] and use monthly end-of-period

[4]As a matter of fact, we failed to obtain an elegant shape of the loading structure, derived by Cochrane and Piazzesi (2005). Like Kessler and Scherer (2009), we find zig-zag shaped loading structures on the five forward yields for the majority of economies and maturities. Sekkel (2011) resolved this issue by dropping the 2 and 4 year forward yields. However, given the non-overlapping information contained in forward yields, this approach effectively leaves him with gaps in the yield curve.

[5]Diebold and Li (2006) show that the level corresponds to the ten-year bond yield and the slope to the difference between the three-months and the ten-year yield, while the curvature is almost perfectly correlated with the difference between the two-year yield and the average of the ten-year and the three-months yield.

[6]Given the approximations provided by Diebold and Li (2006), this regression is effectively an unrestricted version of regressing the risk premium on all three Nelson-Siegel yield curve factors in which the factor loadings are restricted to mimic the long end, the slope and curvature of the term structure.

[7]The G10 economies include Australia, Canada, Germany, Japan, New Zealand, Norway, Switzerland, Sweden, the United Kingdom and the United States

data, with the sample period spanning April 1997 to December 2015.[8] The coefficients of Equation (6) return the loadings of the optimal in-sample single forecasting factor, $\widehat{FF}_t^{j,h}$.

In the second step of our empirical framework we test whether risk premia in short-term interest rates are a contemporaneous driver of exchange rate risk premia, in line with the theoretical prediction of UIP (see Equation (3)).

$$xr_{t+h}^{j/USD,h} = \alpha^{j,h} + \beta_1^h(rx_{t+h}^{j,2h} - rx_{t+h}^{US,2h}) + \epsilon_{t+h}^{j,h}, \tag{7}$$

where (ex-post) exchange rate risk premia ($xr_{t+h}^{j/USD,h}$) can be approximated by the forecast error of the forward exchange rate ($s_{t+h}^{j/USD} - f_t^{j/USD,h}$, with $f_t^{j/USD,h}$ being the natural logarithm of the h months forward exchange rate), relying on covered interest parity ($f_t^{j/USD,h} = s_t^{j/USD} + (i_t^{j,h}) - i_t^{US,h})$). We consider all G10 currencies vis-à-vis the US dollar.[9]

Finally, we investigate for all G10 currencies vis-à-vis the US dollar whether the same linear combination of initial spot rates that predicts risk premia in short-term interest rates, in its relative terms, is able to predict risk premia in exchange rates. We run in-sample panel regressions of exchange rate risk premia for each forecast horizon h

$$xr_{t+h}^{h,j/USD} = \alpha^{j,h} + \beta_1^h(y_t^{j,3m} - y_t^{US,3m}) + \beta_2^h(y_t^{j,2y} - y_t^{US,2y}) + \beta_3^h(y_t^{j,10y} - y_t^{US,10y}) + \epsilon_{t+h}^j. \tag{8}$$

The next section describes the results of our three-step empirical analysis.

[8] To account for over-lapping information in two consecutive risk premia for h¿1, standard errors are corrected for within-panel first order autocorrelation.

[9] That is the Australian dollar, the British pound, the Canadian dollar, the euro (Deutsche mark before 1999), the Japanese yen, the New Zealand dollar, the Norwegian krone, the Swiss franc and the Swedish krona. We use monthly end-of-period data, with the sample period spanning from April 1997 to December 2015. Following Corte et al. (2016), we eliminate the following observations from our sample: Japan from May 1998 to July 1998; Norway from July 1998 to August 1998; Sweden from July 1998 to August 1998. In addition we eliminate: Norway from September 1992 to November 1992; New Zealand: February 1998; Sweden: December 1999

4 Empirical results

4.1 Predicting interest rate risk premia

Table 1 presents the results for the regressions based on the unrestricted yield curve approximation (Equation (6)). We find that a single linear combination of spot rates at the three-months, two-year and ten-year maturity has some predictive power for risk premia in short-term money market instruments. Importantly, Figure 1 illustrates that the loading structure of this single forecasting factor, the linear combination of spot rates, has a tick-shape across all considered return horizons. This suggests that the yield curve contains some predictive information about risk premia in short-term money market instruments, and that this information can be summarized by a tick-shaped linear combination of spot rates.

Next, we take our analysis from the panel to the currency level. We run time-series regressions of the unrestricted yield curve model (Equation (6)) for all G10 countries. The results are presented, separately for each return horizon, in Figure 2. We find that the same tick-shaped function of spot rates bears predictive information for risk premia in two- and six-months money market instruments (with a return horizon of one and three months, respectively) across all countries in our sample (upper two charts in Figure 2). For bonds with a remaining maturity of one year and a six-months return horizon (lower left chart), the evidence for a tick-shaped relationship is less robust, but still holds for the bulk of countries in our sample. Finally, for risk premia on two year bonds with a one-year return horizon (lower right chart), we do not find any solid evidence for a tick-shape of the single forecasting factor. By contrast, the linear combination of spot rates resembles a tent for a number of countries, in line with the existing evidence on the predictability of risk premia in two-year bonds with a one-year return horizon, both in the US (Cochrane and Piazzesi, 2005) and at the international level (Sekkel, 2011).

4.2 Linking interest rate and exchange rate risk premia

Next, we assess whether unanticipated movements in short-term interest rates are positively correlated with movements in the exchange rate that stretch beyond its UIP prediction (i.e. the exchange rate movements reflected by the forward exchange rate). The results of this exercise are presented in Table 2. We find a positive and statistically highly significant relationship between risk premia in short-term interest rates and exchange rates at return horizons of up to one year. The positive elasticity suggests that higher than expected returns on domestic (relative to US) short-term interest rates are associated with a depreciation of the domestic currency vis-à-vis the US dollar up to a return horizon of one year. Given the inverse relation between interest rate surprises and interest rate returns, an equivalent reading is that a stronger than expected decline in domestic short-term rates relative to US short-term rates is contemporaneously related to a depreciation of the domestic currency.

4.3 Predicting currency risk premia

Table 3 presents the results for the unrestricted forecasting regression of currency risk premia based on the linear combination of spot yields (Equation (8)). We again find that a linear combination of spot rate differentials (over US Treasury yields) has some power for forecasting currency risk premia at forecast horizons up to 12 months ahead. Figure 3 shows the pattern of the regression coefficients. The single forecasting factor for currency risk premia has the same tick-shape as has been observed for risk premia in short-term interest rates.

Figure 4 plots the results from the currency-by-currency regressions of Equation (8). The tick-shaped linear combination of spot rates holds at all return horizons and for all currencies, with the single exception of the Japanese yen. For all other currencies, a tick-shaped linear factor of relative bond yields predicts excess currency returns from one month to one year ahead.

Taken together, our findings suggest that the *same* tick-shaped linear combination of spot rates predicts risk premia in both short-term maturity interest rates and exchange rates at forecast horizons up to six months; and the results hold for all but one country/currency in our G10 panel. The single forecasting factor loads positively on the short and long end of the curve and negatively on the medium-term and is therefore inversely related to the Nelson-Siegel curvature factor. Figure 5 plots the regression coefficients of three principal components of the three-months, two year and ten-year yield as a function of yield maturity, also providing suggestive evidence that the single forecasting factor closely resembles the Nelson-Siegel curvature factor. Against this background, the next section directly links risk premia in short-term interest rates and exchange rates to the three Nelson-Siegel factors.

5 Risk premia and the Nelson-Siegel factors

Our empirical approach has not yet imposed any functional form on the yield curve factor predicting short-term interest rate and exchange rate risk premia. By regressing risk premia on a combination of spot rates, rather than on pre-defined yield curve factors, such as the Nelson-Siegel factors, the linear combination of the forecasting factor is entirely data-determined.[10] In this section, we directly regress risk premia on the Nelson-Siegel yield curve factors to test whether we find further support to the assessment that the curvature factor carries the greatest informational content among the three Nelson-Siegel factors when it comes to predicting risk premia in short-term interest rates and exchange rates.

We extract the Nelson-Siegel factors from period-by-period OLS regressions of Equation

[10]Despite the high degree of flexibility warranted by this approach, the very same tick-shaped function of spot yields forecasts risk premia in both short-term maturity interest rates and exchange rates at maturities up to six months and for nine of the G10 countries/currencies; and this factor is found to be highly negatively correlated with the curvature factor of the Nelson-Siegel model of the yield curve.

(9) using G10 zero-coupon yields at maturities from three months to ten years.

$$y_t^m = L_t + S_t(\frac{1 - e^{\lambda m}}{\lambda m}) + C_t(\frac{1 - e^{\lambda m}}{\lambda m} - e^{\lambda m}), \quad (9)$$

where y^m is the set of zero-coupon nominal yields on m-months bonds.[11] The three time-varying factors L_t, S_t, C_t capture the level (L), slope (S) and curvature (C) of the yield curve at each period t.

We run in-sample panel regressions to test the predictive content of the three Nelson-Siegel factors for risk premia in short-term interest rates. We again consider one-month, three-months, six-months and one-year return-forecasting horizons, h, of money market instruments (bonds) with a remaining maturity of $2h$.

$$rx_{t+h}^{j,2h} = \alpha^{j,h} + \beta_1^h L_t^j + \beta_2^h S_t^j + \beta_3^h C_t^j + \epsilon_{t+h}^j \quad (10)$$

The results are presented in Table 4. For the panel of ten advanced economies the curvature factor contributes statistically significantly to the prediction of risk premia in short-term money market instruments with a remaining maturity of up two years. The negative sign implies that a lower curvature is associated with higher future interest rate risk premia and, accordingly, with lower than expected future short-term interest rates. This suggests that a country with a relatively lower curvature factor is more likely to experience an (unexpected) decline in short-term (up to six-months) interest rates than a country with a relatively higher curvature factor. The other two Nelson-Siegel factors, the level and slope of the yield curve, are not statistically significant for any return horizon below one year.

Turning to exchange rate risk premia, we run in sample regressions of exchange rate risk premia on the relative Nelson-Siegel factors at the panel level at each forecast horizon, similar to Chen and Tsang (2013) .

$$xr_{t+h}^{j/USD,h} = \alpha^{j,h} + \beta_1^h(L_t^j - L_t^{US}) + \beta_2^h(S_t^j - S_t^{US}) + \beta_3^h(C_t^j - C_t^{US}) + \epsilon_{t+h}^j \quad (11)$$

[11]Following Diebold and Li (2006), λ, the speed of exponential decay, is set to 0.0609.

The results are presented in Table 5. For the panel of nine currencies against the US dollar the relative level factor is statistically significant in predicting currency risk premia for up to six months ahead. The relative slope factor is statistically insignificant across forecast horizons. Finally, the elasticity of the relative curvature factor (β_3^h) is negative and statistically significant for in-sample predictions up to 12 months ahead. The negative sign implies that a lower curvature in country j relative to the US curvature is associated to a future depreciation of that currency vis-à-vis the US dollar, e.g. a 1 percentage point decline in the relative curvature factor predicts more than a 5% drop in currencies' risk premium over the three-months horizon.

To further investigate the ability of each of the three Nelson-Siegel factors to predict exchange rate risk premia we also consider currency-by-currency estimates of Equation (11).[12] Results are presented in Table 6 to Table 9 for the one, three, six and 12-months horizon, respectively. At each forecast horizon, it is the curvature among the three Nelson-Siegel factors that carries most predictive information for the largest number of currencies. For instance, at the one-month horizon the beta coefficient turns out to be negative and statistically significant for five out of nine bilateral exchange rates against the US dollar. The relative level factor, by comparison, is statistically important in predicting risk premia for only three out of nine currency pairs. This confirms that the curvature factor may carry greater information for exchange rate risk premia than the other two Nelson-Siegel factors.[13]

6 Conclusion

We find that a single forecasting factor, a tick-shaped linear combination of sovereign bond yields which is strongly (negatively) correlated with the curvature factor in the Nelson-Siegel model, can predict risk premia in short-term money market rates with a

[12] We use Newey-West standard errors to control for serial correlation.

[13] We also run regressions of excess currency returns on each Nelson-Siegel factor separately. In this bivariate panel-level regressions the coefficients on both the level and slope factors turn out to be insignificant at all forecast horizons, while the curvature factor is statistically significant for in sample predictions up to 12 months. A detailed account of these results are available upon request.

remaining maturity of up to six months across across a large sample of major advanced economies. With surprises in short-term rates being a contemporaneous driver of currency risk premia, we show that the very same single forecasting factor predicts substantial variation in currency risk premia up to six months ahead for all G10 currencies, except one.

Our results are in line with the theory of uncovered interest rate parity to the extent that (relative) interest rate surprises are a key contemporaneous determinant of the exchange rate. From an empirical viewpoint, our findings suggest that the hump of the yield curve bears important information about future monetary policy. A relatively high curvature predicts a surprise monetary policy tightening, i.e. a rise in short-term interest rates beyond expectations, and, ceteris paribus, an appreciation of the home currency. Our findings provide support to recent interpretations of the curvature as an independent factor of the monetary policy stance, where the curvature signals the expected speed at which the short rate converges to the long rate.

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A Tables

A.1 Panel results

Table 1: Short-term interest rate risk premia and the yield curve—Panel estimates

	(1) 1-months	(2) 3-months	(3) 6-months	(4) 12-months
3-months yield	0.059***	0.118*	0.137	0.005
	(3.61)	(2.26)	(1.83)	(0.05)
2-year yield	-0.118***	-0.177**	-0.153*	-0.062
	(-4.87)	(-2.27)	(-1.65)	(-0.51)
10-year yield	0.053***	0.010	-0.035	0.271***
	(5.51)	(0.22)	(-0.71)	(4.79)
Constant	0.105***	0.414***	0.680***	-0.381**
	(8.65)	(5.43)	(6.75)	(-2.43)
Observations	2250	2250	2250	2922
No. of countries	10	10	10	10
R2	0.032	0.044	0.018	0.129

Robust standard errors.

Notes: Estimates of interest rate return-forecasting linear sport rate combination, $rx_{t+h}^{j,2h} = \alpha^j + \beta_1^h y_t^{j,3m} + \beta_2^h y_t^{j,2y} + \beta_3^h y_t^{j,10y} + \epsilon_{t+h}^j$ (see Equation (6)). The column headings refer to the return-forecasting horizon, h, of investments into money market instruments (bonds) with a remaining maturity that is equal to two times the return horizon (2h).

Table 2: Currency risk premia and interest rate risk premia —Panel estimates

	(1) 1-months	(2) 3-months	(3) 6-months	(4) 12-months
Relative interest rate risk premia	0.011**	0.032***	0.047***	0.029***
	(2.41)	(5.42)	(7.09)	(4.78)
Constant	-0.002***	-0.008***	-0.014***	-0.003
	(-4.39)	(-7.85)	(-10.77)	(-1.77)
Observations	1773	1773	1773	1773
R2	0.01	0.06	0.14	0.08

Robust standard errors.

Notes: Estimates of contemporaneous regression of currency risk premia on interest rate risk premia, $xr_{t+h}^{j/USD,h} = \alpha^{j,h} + \beta_1^h(rx_{t+h}^{j,2h} - rx_{t+h}^{US,2h}) + \epsilon_{t+h}^{j,h}$ (see Equation (7)). The column headings refer to the return horizon, h, of currency and interest rate investments.

Table 3: Currency risk premia and the yield curve—Panel estimates

	(1) 1-months	(2) 3-months	(3) 6-months	(4) 12-months
3-month rate diff	0.005**	0.014**	0.018**	0.023*
	(2.71)	(2.61)	(2.34)	(2.28)
2-year rate diff	-0.008***	-0.021***	-0.031***	-0.050***
	(-3.56)	(-3.42)	(-3.49)	(-4.70)
10-year rate diff	0.001*	0.002	0.005	0.016***
	(1.94)	(1.21)	(1.60)	(3.96)
Constant	-0.001	-0.003	-0.002	0.001
	(-1.49)	(-1.36)	(-0.64)	(0.20)
Observations	2712	2694	2667	2613
No. of currencies	9	9	9	9
R2	0.01	0.03	0.03	0.06

Robust standard errors.

Notes: Estimates of currency return-forecasting linear sport rate combination, $xr_{t+h}^{h,j/USD} = \alpha^{j,h} + \beta_1^h(y_t^{j,3m} - y_t^{US,3m}) + \beta_2^h(y_t^{j,2y} - y_t^{US,2y}) + \beta_3^h(y_t^{j,10y} - y_t^{US,10y}) + \epsilon_{t+h}^j$ *(see Equation (8)). The column headings refer to the return horizon, h, of currency investments.*

Table 4: Short-term interest rate risk premia and Nelson-Siegel factors - Panel estimates

	(1) 1-months b/t	(2) 3-months b/t	(3) 6-months b/t	(4) 12-months b/t
Level	-2.471	-42.561	-37.264	283.812***
	(-0.62)	(-1.73)	(-1.18)	(6.34)
Slope	1.859	-4.762	-33.369	8.419
	(0.43)	(-0.24)	(-0.91)	(0.22)
Curvature	-28.826***	-47.305**	-46.956*	3.782
	(-6.34)	(-2.26)	(-1.94)	(0.11)
Constant	0.081***	0.332***	0.569***	-0.541**
	(5.84)	(3.58)	(5.18)	(-2.69)
Observations	2250	2250	2250	2928
No. of countries	10	10	10	10
R2	0.029	0.038	0.011	0.139

Robust standard errors.

Notes: Estimates of interest rate return-forecasting Nelson-Siegel factors, $rx_{t+h}^{j,2h} = \alpha^{j,h} + \beta_1^h L_t^j + \beta_2^h S_t^j + \beta_3^h C_t^j + \epsilon_{t+h}^j$ *(see Equation (10)). The column headings refer to the return-forecasting horizon, h, of investments into money market instruments (bonds) with a remaining maturity that is equal to two times the return horizon (2h).*

Table 5: Currency risk premia and Nelson-Siegel factors - Panel estimates

	(1) 1-months b/t	(2) 3-months b/t	(3) 6-months b/t	(4) 12-months b/t
Relative level	-1.752***	-4.035**	-7.010***	-5.752
	(-3.69)	(-3.22)	(-3.37)	(-1.58)
Relative slope	-0.557	-1.754	-1.466	4.159
	(-0.93)	(-1.00)	(-0.48)	(0.82)
Relative curvature	-2.018***	-5.243***	-8.293***	-11.502***
	(-4.12)	(-4.04)	(-4.35)	(-4.61)
Constant	-0.001	-0.002	-0.003	0.002
	(-1.62)	(-1.53)	(-1.03)	(0.55)
Observations	2790	2772	2745	2691
No. of currencies	9	9	9	9
R2	0.01	0.03	0.04	0.05

Robust standard errors.

Notes: Estimates of currency return-forecasting Nelson-Siegel factors, $xr_{t+h}^{j/USD,h} = \alpha^{j,h} + \beta_1^h(L_t^j - L_t^{US}) + \beta_2^h(S_t^j - S_t^{US}) + \beta_3^h(C_t^j - C_t^{US}) + \epsilon_{t+h}^j$ *(see Equation (11)). The column headings refer to the return horizon,* h*, of currency investments.*

A.2 Results by currency

Table 6: One-month currency risk premia and the Nelson-Siegel factors

	(1) AUD b/t	(2) GBP b/t	(3) SEK b/t	(4) NOK b/t	(5) DEM b/t	(6) JPY b/t	(7) NZD b/t	(8) CHF b/t	(9) CAD b/t
Relative level	-0.589	1.372	-3.444**	-1.996**	-3.721	1.009	-2.676	-5.355	-3.329*
	(-0.28)	(0.46)	(-2.34)	(-2.34)	(-1.19)	(0.38)	(-1.05)	(-1.41)	(-1.70)
Relative slope	-3.150	-0.976	-2.425	-1.010	-1.750	3.518**	-0.757	1.648	-0.453
	(-1.22)	(-0.61)	(-1.54)	(-0.77)	(-0.98)	(2.55)	(-0.44)	(1.02)	(-0.49)
Relative curvature	-4.256***	-0.139	-4.383***	-1.975**	-3.422***	0.601	-1.965**	-0.992	-1.022
	(-3.15)	(-0.09)	(-4.25)	(-2.23)	(-3.24)	(0.62)	(-2.29)	(-0.92)	(-1.01)
Constant	-0.003	-0.002	0.001	-0.000	-0.004*	0.007	0.000	-0.007	0.001
	(-0.82)	(-0.99)	(0.68)	(-0.12)	(-1.73)	(1.05)	(0.12)	(-1.09)	(0.44)
Observations	310	310	310	310	310	310	310	310	310

Robust standard errors.

Notes: Estimates of currency return-forecasting Nelson-Siegel factors, $xr_{t+1}^{j/USD,1} = \alpha^{j,1} + \beta_1^1(L_t^j - L_t^{US}) + \beta_2^1(S_t^j - S_t^{US}) + \beta_3^1(C_t^j - C_t^{US}) + \epsilon_{t+1}^j$ *. The column headings refer to currency* j*.*

Table 7: Three-months currency risk premia and the Nelson-Siegel factors

	(1) AUD	(2) GBP	(3) NOK	(4) SEK	(5) DEM	(6) JPY	(7) NZD	(8) CHF	(9) CAD
Relative level	13.57	5.10	-51.30***	-27.45***	-17.50**	16.01***	-18.34+	-5.53	-21.51**
	(0.89)	(0.58)	(-4.88)	(-3.08)	(-2.25)	(2.84)	(-1.34)	(-0.61)	(-2.45)
Relative slope	-8.96+	-6.93+	-5.41+	-7.99*	-6.13	7.81**	-3.16	2.43	-15.84***
	(-1.50)	(-1.36)	(-1.43)	(-1.92)	(-1.04)	(2.19)	(-0.73)	(0.49)	(-2.61)
Relative curvature	-12.54***	-6.51**	-3.86*	-12.65***	-10.44***	1.65	-9.13***	-6.23*	-5.54**
	(-4.23)	(-2.24)	(-1.72)	(-4.47)	(-3.52)	(0.69)	(-3.92)	(-1.74)	(-2.28)
Constant	-0.02+	-0.00	-0.01*	-0.00	-0.01+	0.05***	0.02	-0.00	-0.01***
	(-1.34)	(-0.39)	(-1.88)	(-0.36)	(-1.46)	(3.99)	(1.27)	(-0.19)	(-2.91)
Observations	200	200	200	200	200	200	200	200	200
R^2	0.10	0.03	0.12	0.11	0.08	0.10	0.08	0.05	0.10

t statistics in parentheses
Robust standard errors.
$^{+}$ $p < 0.2$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: Estimates of currency return-forecasting Nelson-Siegel factors, $xr_{t+3}^{j/USD,h} = \alpha^{j,3} + \beta_1^3(L_t^j - L_t^{US}) + \beta_2^3(S_t^j - S_t^{US}) + \beta_3^3(C_t^j - C_t^{US}) + \epsilon_{t+3}^j$ *. The column headings refer to currency* j*.*

Table 8: Six-months currency risk premia and the Nelson-Siegel factors

	(1) AUD	(2) GBP	(3) NOK	(4) SEK	(5) DEM	(6) JPY	(7) NZD	(8) CHF	(9) CAD
Relative level	29.61	13.89	-91.43***	-44.67***	-35.34***	30.57***	-24.46	-9.31	-53.41***
	(1.25)	(0.85)	(-6.27)	(-3.40)	(-3.14)	(3.58)	(-1.14)	(-0.72)	(-4.40)
Relative slope	-13.40+	-11.86+	-6.10	-10.76*	-9.00	10.22**	-0.86	8.09	-30.51***
	(-1.64)	(-1.50)	(-1.03)	(-1.66)	(-1.05)	(2.00)	(-0.10)	(1.24)	(-3.32)
Relative curvature	-20.81***	-9.96**	-3.72	-19.22***	-17.04***	-0.44	-13.79***	-7.99*	-10.74***
	(-5.80)	(-2.56)	(-1.04)	(-4.43)	(-3.61)	(-0.13)	(-3.90)	(-1.68)	(-3.19)
Constant	-0.04*	-0.00	-0.02**	-0.00	-0.02**	0.10***	0.03	-0.01	-0.02***
	(-1.72)	(-0.62)	(-2.12)	(-0.38)	(-2.17)	(4.91)	(1.08)	(-0.31)	(-4.07)
Observations	197	197	197	197	197	197	197	197	197
R^2	0.13	0.04	0.15	0.11	0.11	0.14	0.07	0.07	0.20

t statistics in parentheses
Robust standard errors.
$^{+}$ $p < 0.2$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: Estimates of currency return-forecasting Nelson-Siegel factors, $xr_{t+6}^{j/USD,6} = \alpha^{j,6} + \beta_1^6(L_t^j - L_t^{US}) + \beta_2^6(S_t^j - S_t^{US}) + \beta_3^6(C_t^j - C_t^{US}) + \epsilon_{t+6}^j$ *. The column headings refer to currency* j*.*

Table 9: Twelve-months currency risk premia and the Nelson-Siegel factors

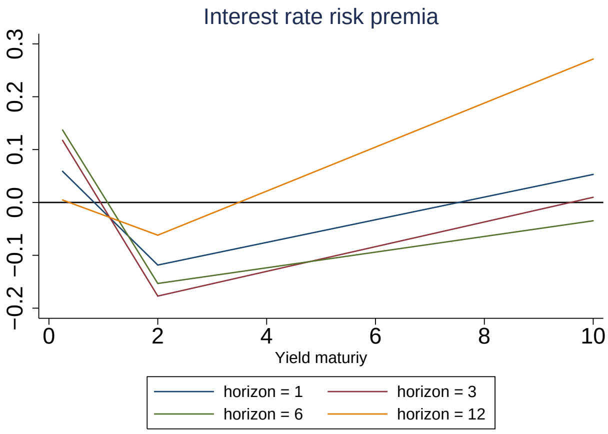
	(1) AUD	(2) GBP	(3) NOK	(4) SEK	(5) DEM	(6) JPY	(7) NZD	(8) CHF	(9) CAD
Relative level	54.72**	15.01	-124.90***	-55.64**	-83.21***	59.50***	-9.62	-24.62+	-90.53***
	(2.00)	(0.68)	(-5.19)	(-2.30)	(-5.35)	(5.34)	(-0.43)	(-1.50)	(-5.37)
Relative slope	19.81*	-4.15	-1.99	-0.44	-3.97	3.82	21.32*	19.39**	-31.11**
	(1.84)	(-0.47)	(-0.23)	(-0.05)	(-0.33)	(0.47)	(1.85)	(1.99)	(-2.18)
Relative curvature	-13.55**	-11.02**	-7.07	-22.38***	-22.35***	-12.47**	-8.71*	-7.04	-7.57
	(-2.23)	(-2.00)	(-1.28)	(-3.55)	(-3.31)	(-2.32)	(-1.68)	(-1.12)	(-1.25)
Constant	-0.03	0.00	-0.01	0.00	-0.03***	0.18***	0.01	-0.03	-0.04***
	(-1.17)	(0.45)	(-1.18)	(0.31)	(-3.43)	(7.43)	(0.19)	(-1.25)	(-4.90)
Observations	191	191	191	191	191	191	191	191	191
R^2	0.10	0.03	0.13	0.08	0.15	0.22	0.07	0.09	0.20

t statistics in parentheses
Robust standard errors.
$^{+}$ $p < 0.2$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: Estimates of currency return-forecasting Nelson-Siegel factors, $xr^{j/USD,12}_{t+12} = \alpha^{j,12} + \beta^{12}_1(L^j_t - L^{US}_t) + \beta^{12}_2(S^j_t - S^{US}_t) + \beta^{12}_3(C^j_t - C^{US}_t) + \epsilon^j_{t+12}$ *. The column headings refer to currency* j*.*

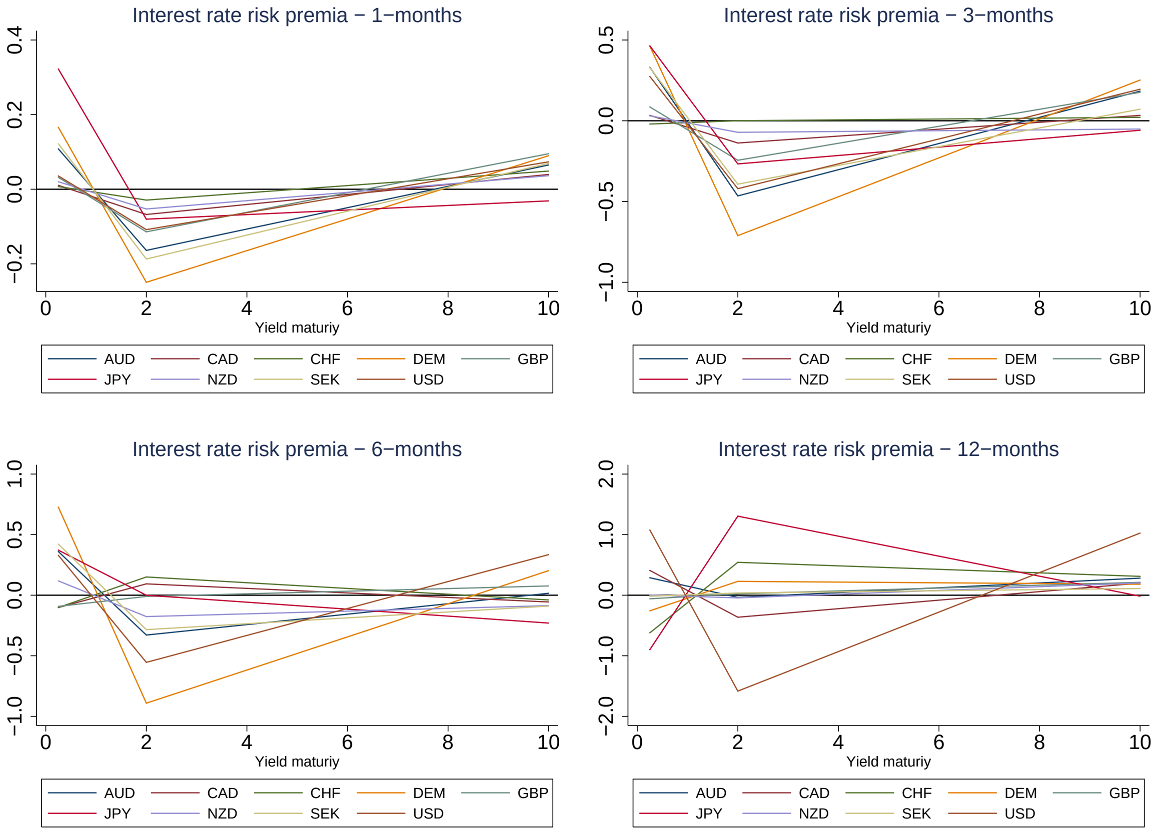
B Figures

Figure 1: Regression coefficients of interest rate risk premia on the yield curve



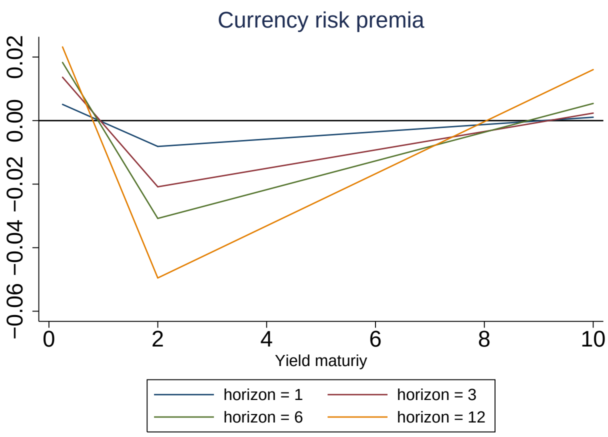
Notes: Slope coefficients of Equation (6), $rx^{2h}_{j,t+h} = \alpha^h_j + \beta^h_1 y^{3m}_{j,t} + \beta^h_2 y^{2y}_{j,t} + \beta^h_3 y^{10y}_{j,t} + \epsilon^h_{j,t}$*, as a function of yield maturity.*

Figure 2: Regression coefficients of interest rate risk premia on the yield curve—by currency



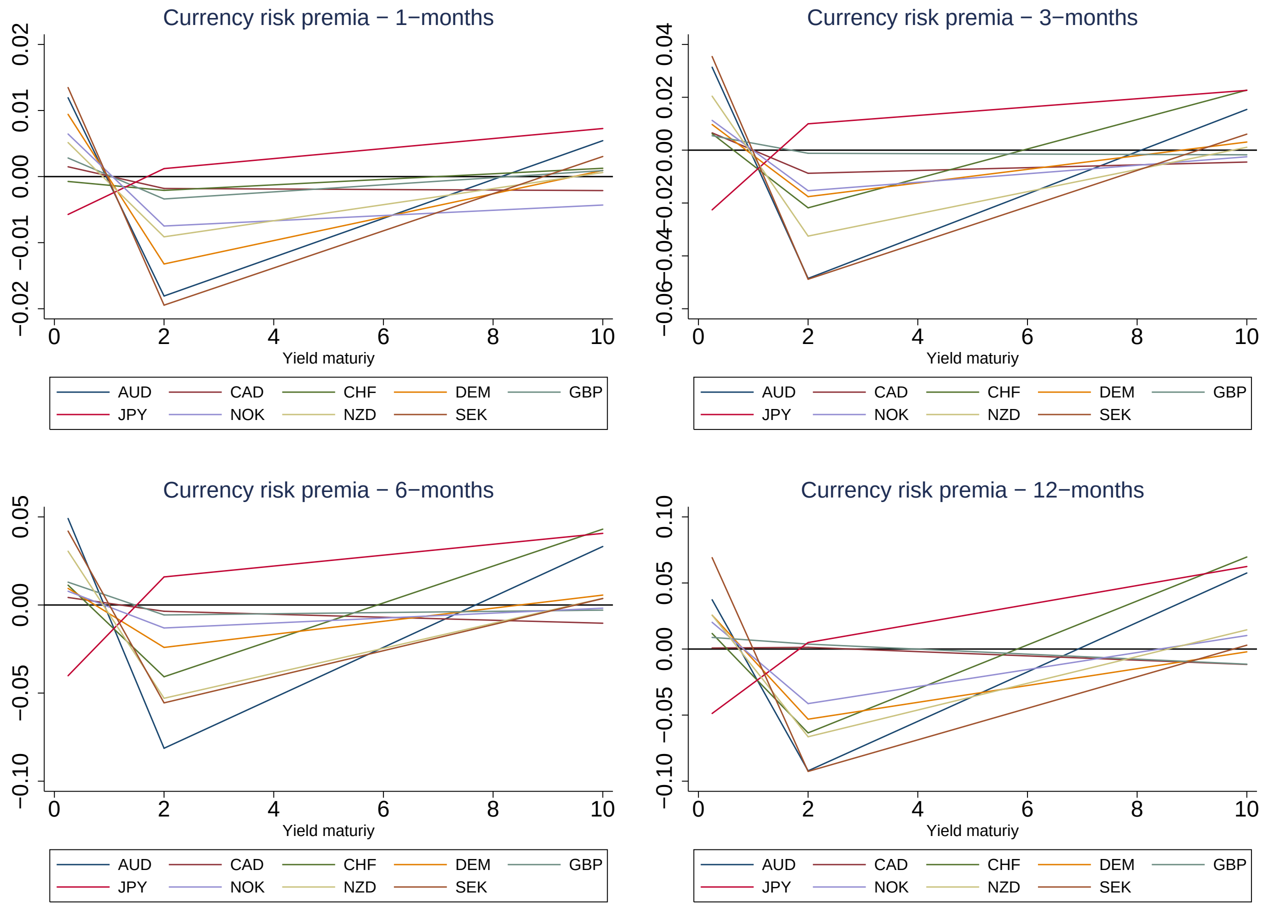
Notes: Slope coefficients of country-specific time series version of Equation (6) as a function of yield maturity.

Figure 3: Regression coefficients of currency risk premia on the yield curve



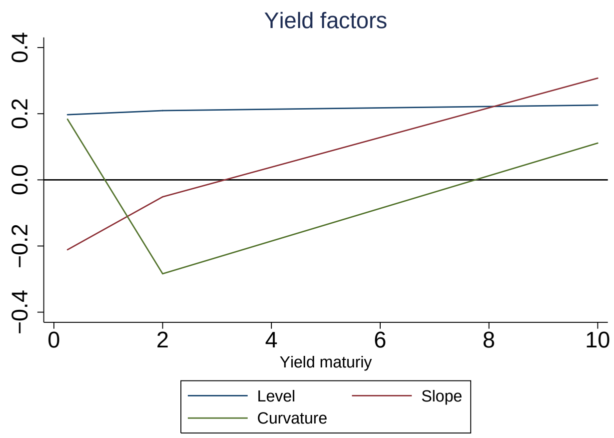
Notes: Slope coefficients of Equation (8), $xr_{t+h}^{h,j/USD} = \alpha_i^h + \beta_1^h(L_{j,t} - L_{US,t}) + \beta_2^h(S_{j,t} - S_{US,t}) + \beta_3^h(C_t^i - C_t^{US}) + \epsilon_{j,t+h}$*, as a function of yield maturity.*

Figure 4: Regression coefficients of currency risk premia on the yield curve—by currency



Notes: Slope coefficients of country-specific time series version of Equation (8) as a function of yield maturity.

Figure 5: Loading structure of approximated Nelson-Siegel factors on yields



Notes: Slope coefficients of three principal components as a function of yield maturity.