Variance Risk Premiums and the Forward Premium Puzzle*

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Abstract

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JEL Classification: G12, G15, F31.
Keywords: Foreign exchange return predictability, world currency variance risk premium, stock variance risk premium, forward premium puzzle, local and global uncertainties, currency crash risk.

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Abstract

We provide new empirical evidence that world currency and U.S. stock variance risk premiums have nonredundant and significant predictive power for the appreciation rates of 22 currencies with respect to the U.S. dollar, especially at the 4-month and 1-month horizons, respectively. These time variations in expected currency returns support a risk-based explanation of the forward premium puzzle. We rationalize these findings in a consumption-based asset pricing model with orthogonal local and global economic uncertainties characterized, respectively, by the stock and currency variance risk premiums. Global uncertainty is associated with currency crash risk.

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1 Introduction

This paper provides new empirical evidence that the time variation in expected currency returns are strongly related to the world currency variance risk premium and to the stock variance risk premium. The world currency variance risk premium is measured as an average of the variance risk premiums of 18 available currencies with respect to the U.S. dollar. Each currency-pair's variance risk premium is measured as the option-implied minus the realized variance of currency returns. The stock variance risk premium is measured alternatively as the U.S. stock variance risk premium or as a world average of major countries' variance risk premiums. We find that an increase in currency variance risk premium predicts a depreciation of foreign currencies with respect to the U.S. dollar, while an increase in stock variance risk premium predicts an appreciation of these currencies. Thus, currency and stock variance risk premiums seem to have different informational content for future exchange rate returns.

We set our empirical exercise against the background of pervasive violations in uncovered interest parity (UIP). For a large panel of 22 available currency rates against the U.S. dollar from 2000 to 2011, interest rate differentials are insignificant predictors for exchange rate returns, often with wrong negative signs and low R-squares of less than 1 percent for 1- to 4-month horizons. However, including the world currency variance risk premium increases the R-square to 2.2 percent at the 1-month horizon, 8 percent at the 4-month horizon, and 1.5 percent at the 12-month horizon. The slope coefficients associated with the world currency variance risk premium are uniformly negative and significant—a higher world currency variance premium indicates greater global uncertainty, hence higher U.S. dollar safety value for international investors. Including the stock variance risk premium increases the R-square to 5.3 percent at the 1-month horizon and almost zero at the 12-month horizon. The slope coefficients are, in this case, uniformly positive and significant for 1- to 6-month horizons—a higher stock variance risk premium indicates greater local uncertainty, hence higher return premium compensation for international investors.

The joint predictability of currency and stock variance risk premiums for exchange rate returns remains robust if we consider a pre-global financial crisis sample, if the realized variance is replaced with the expected variance from an AR(1) model (Drechsler and Yaron, 2011), or if the Black-Scholes implied variance is replaced with a model-free implied variance (Britten-Jones and Neuberger, 2000). Our main result also holds if we separate the sample countries into developed economies and emerging economies (Bansal and Dahlquist, 2000). Moreover, if we run the empirical tests for each of the 22 currencies individually, the findings remain intact except for a few outliers like Hong Kong and the Philippines. Interestingly, however, the predictive power of the world currency variance risk premium is more modest for the Japanese yen and the Swiss franc, two traditional funding currencies in carry-trade strategies. The predictability patterns for the currency variance risk premium are qualitatively the same for 1-, 3-, 6-, or 12-month maturities, although the 6-month currency variance risk premium produces the strongest finding, irrespective of the variance risk premium measure considered. For the stock variance risk premium, it makes no material difference if we use the U.S. option-implied variance or an equal-weighted or value-weighted average of major countries with available data for option-implied variance of stock returns.

To rationalize our new empirical findings, we introduce a two-country general equilibrium model where the consumption growth processes of both economies are exposed to global economic uncertainty. This uncertainty is, by construction, orthogonal to each country's purely domestic economic uncertainty and is therefore not priced by any of the country's domestic stock markets. But, the exposure to this global source of uncertainty varies across countries, which yields an asymmetric response of each country's currency to global uncertainty shocks. We also assume that global uncertainty is a currency-specific phenomenon. This assumption yields, in turn, that the currency variance risk premium reveals information about the currency-specific uncertainty that cannot otherwise be obtained from domestic stock and stock-options markets. Thus, on the one hand, the currency variance risk premium contains additional useful information to explain the time variation in appreciation rates. On the other hand, the informational content of stock variance risk premiums for exchange rate appreciations is similar to that for each country's stock market returns, in that each country's local economic uncertainty also contributes to the time variation in appreciation rates. To better understand the characteristics of our model's implied global uncertainty, we link the currency variance risk premium to a set of uncertainty- or currency-related variables. We find that the currency variance risk premium is associated with various tail risk measures, demand for safe assets, and, especially, currency crash risk.

Related literature

Recent literature focuses on the role of the volatility risk premium in explaining the time variation in currency returns. Della Corte, Sarno, and Tsiakas (2011) provide empirical evidence that the volatility term premium is positive, time-varying, and predictable. In a related paper, Menkhoff, Sarno, Schmeling, and Schrimpf (2012) document the finding that global foreign exchange (forex hereafter) volatility risk is priced in currency markets (also see Bakshi and Panayotov, 2012). Chernov, Graveline, and Zviadadze (2012) find evidence that jump risk in currency variance may be priced in forex markets but is unrelated to interest rates or macroeconomic news. Using different methodologies, Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009); Jurek (2009); and Brunnermeier, Nagel, and Pedersen (2008) relate the high observed prices of currency options to the desire of agents to hedge rare and severe changes in exchange rate movements.[1] Finally, Mueller, Stathopolous, and Vedolin (2012) find that the forex correlation risk premium is also priced in currency markets. To the best of our knowledge, our paper is the first one to show that both currency and stock variance premiums provide useful information to explain exchange rate returns at medium and short horizons.

Our work is also intimately related to the early evidence that exchange rate volatility is time varying (Engle, 1982; Baillie and Bollerslev, 1989; Engel and Hamilton, 1990; Engle,

[1] The rare disaster model in Farhi and Gabaix (2011) aims to rationalize this empirical finding. Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) provide a related interpretation based on the peso problem.

Ito, and Lin, 1990; and Gagnon, 1993). However, we focus our attention on the unique information from the forex derivatives market not only to pin down the dynamics of forex volatility but also to show that the risk of this volatility is actually priced in forex markets. Graveline (2006) shows that the information from exchange rate options is valuable for the estimation of the exchange rate volatility that is much harder to identify using only time-series data. Bakshi, Carr, and Wu (2008) show that jumps are crucial in order to capture the currency return dynamics and to generate realistic currency option pricing behaviors. In fact, Bates (1996) and Guo (1998) provide evidence that the dollar/German mark variance risk premium is priced in the forex options market within a Heston (1993)-type model.

There is certainly a large amount of literature documenting the forward premium puzzle or the deviation from the uncovered interest parity (UIP). Early works by Hansen and Hodrick (1980); Fama (1984); Bansal (1997); and Backus, Foresi, and Telmer (2001); among others, find evidence that, as a consequence of this deviation, carry trade excess returns are large, on average positive, and predictable. Recent works by Lustig and Verdelhan (2007); Lustig, Roussanov, and Verdelhan (2012); and Verdelhan (2012) relate the cross-sectional evidence of carry trade strategies to fundamental risk factors (consumption, dollar, and carry-trade). Motivated by the recent finding that the stock variance premium can predict international stock market returns (Bollerslev, Marrone, Xu, and Zhou, 2012; and Londono, 2012), we investigate the role of currency and stock variance risk premiums in explaining this forward premium puzzle. Our contribution in this regard is to empirically document the different informational content of currency and stock variance risk premiums for explaining the predictable time variation in the forward premium.

The rest of the paper is organized as follows. In section 2, we introduce our currency and stock variance risk premium measures, and the data used to calculate them. In section 3, we summarize the main empirical findings for the predictive power of currency and stock variance risk premiums for forex appreciation rates. In section 4, we introduce a two-country general equilibrium model to understand our main empirical findings. Finally, section 5 concludes.

2 The currency and stock variance risk premiums

In this section, we introduce a measure for the world currency variance risk premium calculated as the equal-weighted average of the variance risk premiums of a total of 18 currencies with respect to the U.S. dollar. We also describe the stock variance risk premium, which is measured as the U.S. stock variance risk premium or as an average of the stock variance risk premiums of major countries with stock-options data available.

2.1 The world currency variance risk premium

Following the convention for the stock variance risk premium (Bollerslev, Tauchen, and Zhou, 2009; Drechsler and Yaron, 2011), we define the forex or currency variance risk premium (XVP hereafter) of the returns in U.S. dollars per unit of foreign currency as

$$XVP_t(h) \equiv E_t^Q \left(\sigma^2_{c,t,t+h}\right) - E_t^P \left(\sigma^2_{c,t,t+h}\right). \tag{1}$$

That is, the h-month ahead XVP equals the difference between the risk-neutral (Q) and the physical (P) expectation of the currency return variance between months t and $t+h$, $\sigma^2_{c,t,t+h}$. For the benchmark XVP measure in our empirical exercise in section 3, we substitute the risk-neutral expectation with the h-month ahead currency option-implied variance, using Black-Scholes at-the-money (ATM) options; and we substitute the physical expectation with the realized variance calculated as the sum of squared log daily currency returns between $t-h$ and t. We also assess the robustness of our results to two alternative variance risk premium measures; one where we use the model-free approach to measure the risk-neutral expected variance (Britten-Jones and Neuberger, 2000), and one where we replace the physical expectation by a forecast obtained from a VAR (Drechsler and Yaron, 2011). The world currency variance risk premium is calculated as an equal-weighted average of all countries' currency variance risk premiums.[2]

[2]In section 2.4, we summarize the results from a principal components analysis, which supports the election of the equal-weighted average to characterize the world currency variance risk premium, especially

2.2 The stock variance risk premium

Similar to the currency variance risk premium, we define the 1-month stock variance risk premium as

$$VP_t \equiv E_t^Q\left(\sigma^2_{r,t,t+1}\right) - E_t^P\left(\sigma^2_{r,t,t+1}\right), \tag{2}$$

where $\sigma^2_{r,t,t+1}$ is the stock return variance between months t and $t+1$. We calculate the stock variance risk premium as the difference between the (model-free) option-implied and the expected realized stock variance. As we did for the currency variance risk premium, we assume that the expected stock realized variance is given by $E_t(RV^2_{t+1}) = RV^2_t$, where RV^2_t is the realized variance of the stock index calculated using 1-month non-overlapping rolling windows of daily (log) stock returns. We consider the following three alternative measures of the world stock variance premium: the U.S. stock variance premium (VP_{US}), the equal-weighted average stock variance premium ($EW\ world\ VP$), and the value-weighted average stock variance premium ($VW\ world\ VP$). The average variance risk premiums are calculated using the variance risk premium for the headline stock indexes for the following countries: United States, Germany, Japan, and the United Kingdom.[3] The monthly value-weighted average VP is calculated following Bollerslev, Marrone, Xu, and Zhou (2012) using lagged total market capitalization for the four countries considered.

2.3 Data

Our sample runs from January 2000 to December 2011 and covers the exchange rate (with respect to the U.S. dollar) of the following countries (and their respective currencies in parenthesis): the Euro Area (EUR), Japan (JPY), Great Britain (GBP), Switzerland (CHF), Australia (AUD), Canada (CAD), Sweeden (SEK), New Zealand (NZD), South Korea (KRW), Singapore (SGD), Norway (NOK), Poland (PLN), South Africa (ZAR), Czech Republic

for the 6- and 12-month horizons.

[3]Considering alternative average variance premium measures including all other countries with model-free option-implied volatility data available has virtually no impact on the main results in our paper.

(CZK), Denmark (DKK), Thailand (THB), Taiwan (TWD), Hong Kong (HKD), Hungary (HUF), India (INR), Malaysia (MYR), and the Philippines (PHP). For 18 of these 22 currencies (excluding the HUF, INR, MYR and PHP), we can calculate the currency variance risk premium as the difference between the option-implied and the realized currency return variance. The ATM implied volatility for these 18 currency pairs is obtained from J.P. Morgan's over the counter (OTC) currency options database while the spot rates are obtained from Bloomberg.

The stock option-implied volatility and the daily spot price for the headline stock indexes of the United States, Germany, Japan, and the United Kingdom are obtained from Bloomberg. Monthly total market capitalizations for the four countries, which are used to calculate the value-weighted average VP, are obtained from Compustat.

Finally, we also calculate the interest rate differential between each country and the United States from h-month zero-coupon rates calculated by the Board of Governors of the Federal Reserve system using data from each country's central bank.

2.4 Summary statistics and stylized features

Table 1 reports summary statistics and average pair-wise correlations for 1-month currency appreciation rates with respect to the U.S.. The mean appreciation against the U.S. dollar ranges between -0.17 (KRW) and 0.44 (CZK) percent. Appreciation rates display a relatively high volatility (2.95 percent on average). The appreciation rate volatility is unusually low for the Hong Kong dollar, HKD (0.14 percent), most likely because this currency has been pegged to the U.S. dollar since 1983.[4] In contrast, the volatility is the highest for the South Korean won, KRW (5.12). Some currencies, other than the HKD, deviate from the normal distribution. In particular, kurtosis is relatively high for the SGD (7.22), ZAR (7.25), MYR (8.56) and PHP (7.64). Also, skewness is negative for all of the currencies in our sample

[4] The Hong Kong dollar has been pegged to the dollar at 7.8 since 1983. In 2005, the Hong Kong monetary authority also committed to keep the exchange rate with respect to the U.S. dollar between HKD 7.74 and HKD 7.85

except for the CHF and HKD. Skewness is particularly negative for the HUF (-1.21), SGD (-0.84), PLN (-0.89), and MYR (-0.85). It is particularly interesting to note that currency rates with respect to the U.S. dollar have a common component. The average pair-wise correlation for all currencies' appreciation rates with respect to the U.S. dollar is 0.48. Some currencies display relatively high average pair-wise correlations such as the EUR (0.60), SEK (0.60), SGD (0.58), and DKK (0.60). In contrast, the Japanese yen, JPY (0.19), and the Hong Kong dollar, HKD (0.16), have the lowest average pair-wise correlations with all of the other currencies considered.

Table 2 reports summary statistics for the 1-, 3-, 6-, and 12-month currency variance risk premiums (XVP) for the 18 countries in our sample with currency-options data available, in panels A, B, C, and D, respectively. In the first column of each panel, we also report summary statistics for the world XVP calculated as the equal-weighted average of all currencies' variance premiums. The world XVP series are also plotted in figure 1.

At the 1-month horizon, all XVPs except those of the CHF, AUD, SEK, NZD, and ZAR are, on average, positive. For nine currencies, the average XVP is significant at a 10 percent or higher significance level. The 1-month world XVP (XVP(1)), in panel A of figure 1, is, on average, positive (6.79) although insignificant. One-month XVPs display relatively large volatilities, ranging from 17.79 (SGD) to 326.88 (ZAR) percent, and deviate significantly from the normal distribution. In particular, 1-month XVPs have relatively large kurtosis, ranging from 7.25 (THB) to an impressive 118.94 (AUD). As is evident from figure 1, XVP(1) displays significant time variation, especially around the Lehman Brothers episode. Thus, XVP(1) turns out to have relatively large volatility (32.96 percent) and kurtosis (52.73), and is negatively skewed (-5.13).

At the 3-month horizon, we obtain positive and significant XVPs for seven currencies. The 3-month world XVP (XVP(3)) is also, on average, positive, although insignificant at any standard confidence level. As can be seen in panel B of figure 1, XVP(3) is also relatively volatile (49.36 percent) and deviates from the normal distribution (30.22 kurtosis and -4.31

skewness).

For the 6-month horizon, the currency variance risk premium is significant for seven currencies (EUR, GBP, AUD, SGD, DKK, THB, and TWD) at any standard confidence level. The 6-month world XVP (XVP(6)), in panel C of figure 1, is also, on average, positive and slightly more volatile than XVP(1) and XVP(3) (49.46 percent for the 6-month horizon to 32.96 and 49.36 percent for the 1- and 3-month horizon, respectively). The 6-month currency variance risk premium is particularly volatile for the AUD (160.97), KRW (125.04), and ZAR (182.89). The world XVP(6) also has a relatively large kurtosis (16.33), and, as with $XVP(1)$ and $XVP(3)$, is negatively skewed.

At the 12-month horizon, the currency variance risk premium is positive and significant for six currencies. The 12-month world XVP (XVP(12)) is also, on average, positive and more volatile than other-horizon currency variance risk premiums. The skewness and excess kurtosis of XVP(12) is comparable to those of other-horizon world XVPs (-2.62 and 13.32, respectively).

As the number of overlapped windows used to calculate the realized currency variance increases with the horizon, the persistence of all XVPs also increases with the horizon considered. Thus, 12-month XVPs are, on average, more persistent, with AR(1) coefficients ranging from 0.78 to 0.93. The AR(1) coefficient for the world XVP(12) is as high as 0.90 (significant at the 1 percent significance level), while those of XVP(6), XVP(3), and XVP(1) are 0.79, 0.50, and 0.10, respectively.

Another feature of XVPs is that their average pair-wise correlation also increases with the horizon, from 0.17 for XVP(1)s to 0.70 for XVP(12)s. To emphasize the differences in pair-wise correlations between all currencies, we perform a principal-components analysis. The first principal component of XVP(1)s only explains 28 percent of the total variation. This percentage increases to 37 percent for 3-month XVPs , 50 percent for 6-month XVPs, and 60 percent for 12-month XVPs. The evidence from the principal component analysis also supports the use of the equal-weighted average of currency variance risk premiums as a proxy for the world currency variance risk premiums, especially for the 6- and 12-month horizons for which the weights associated with all countries' variance risk premiums in the first principal component are positive for almost all countries and of a similar magnitude.[5]

Interestingly, the world currency variance risk premiums are poorly correlated with each other. For instance, the correlation between the world $XVP(12)$ with $XVP(1)$, $XVP(3)$, and $XVP(6)$ is, respectively, -0.24, 0.35, and 0.48. In the rest of the paper, we refer to $XVP(6)$ as the world currency variance risk premium (XVP) as we find that the currency variance risk premium at this horizon is a more powerful predictor of appreciation rates with respect to the U.S. dollar, irrespective of the variance risk premium measure considered. Nevertheless, the predictability patterns for the currency variance risk premium are qualitatively the same for 1-, 3-, 6-, or 12-month maturities.

Table 3 reports summary statistics for the 1-month stock variance risk premiums, while figure 2 shows their time series. Irrespective of the proxy used to measure the world stock variance risk premium, stock VPs are, on average, positive and significant at confidence levels above 10 percent. Stock VPs are also relatively volatile (418.9, 351.10, and 379.7 for VP_{US}, *EW world* VP, and *VW world* VP, respectively). Interestingly, although all stock variance risk premium measures are highly correlated with each other, as is also evident from the figure, their correlation with the world currency variance risk premium is moderate and negative (-0.17, -0.30, and -0.24 for VP_{US}, *EW world* VP, and *VW world* VP, respectively).

In the following section, we show that stock and currency variance premiums contain differential information to explain the time variation in forex returns. In section 4, we also provide some intuition for this empirical finding and for the poor correlation between currency and stock variance risk premiums. Specifically, we show that while the stock variance risk premium characterizes domestic uncertainty, the currency variance risk premium reveals information about an orthogonal source of global uncertainty.

[5] In unreported results, we show that the main empirical results in section 3 are virtually unchanged when we approximate the world currency variance risk premium as the first principal component of all countries' currency variance risk premiums.

3 The predictive power for forex appreciation rates

In this section, we conduct a comprehensive analysis of return predictability for the 22 currencies in our sample from the world currency and stock variance risk premiums. In the first part of the section, we provide the results for our benchmark panel-data regression setup. In the second part, we run a set of robustness tests. In the third part, we investigate whether our results depend on the type of foreign (other than the U.S. dollar) currency considered. In particular, we investigate whether our results hold when we classify currencies into those of advanced and emerging market economies. We also assess whether the predictability patterns differ substantially when we consider each individual currency's appreciation rate with respect to the U.S. dollar. In the following section, we propose a model to rationalize our empirical findings.

3.1 Panel data regressions

Our benchmark empirical regression setup for the predictive power of currency variance risk premium is

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{XVP}(h)XVP_t + u_{i,t+h}, \tag{3}$$

where s_i is the log of the exchange rate (in dollars per one unit of each one of the foreign currencies considered), $y_{US}(h) - y_i(h)$ is the interest rate differential for $h-$period zero-coupon bonds between the United States and the foreign country, and XVP is the 6-month world currency variance risk premium calculated as described in section 2.1. In unreported results, we show that, although the predictability patterns are very similar across XVPs at different horizons, the gains in predictive power for future appreciation rates with respect to the U.S. dollar are much higher for the 6-month currency variance risk premium than for XVPs at any other horizon.[6] The coefficients in equation 3 are estimated using ordinary

[6]The finding that XVP(6) is a more useful predictor of appreciation rates with respect to the U.S. dollar holds for alternative variance risk premium measures (see section 3.2 for a description of the alternative

least squares (OLS) where the coefficients associated with the interest rate differential and XVP are restricted to be homogeneous across currencies.[7].

Table 4 reports the predictive power of the world currency variance risk premium and the interest rate differentials for h-month ahead appreciation rates. Our results suggest that the currency variance risk premium plays a key role in predicting future appreciation rates. The statistical significance of XVP is above the 1 percent level for all horizons considered. Moreover, the estimated coefficient for the predictive power of XVP is economically meaningful—a one hundred units increase in the monthly XVP, which is equivalent to an increase of 1200 units in the observed XVP (see figure 1), corresponds to a 4-month ahead annual *depreciation* of 11.91 percent of the foreign currencies with respect to the U.S. dollar. The predictive power of the world currency variance risk premium is maximized at a medium 4- to 6-month horizon. The gains in predictive power with respect to the individual predictive power of the interest rate differential, $R^2 - R^2_y$, are considerable and are maximized at the 4-month horizon (8 percent).

Table 5 reports the results for the predictive power of the stock variance risk premium for forex returns. Our regression setup for the predictive power of the stock variance risk premium is similar to that in equation 3,

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{VP}(h)VP_t + u_{i,t+h}, \tag{4}$$

where VP is alternatively the U.S. stock variance premium (in panel A), the equal-weighted average stock variance risk premium (in panel B), or the value-weighted average stock variance premium (in panel C). The results in panel A suggest that the U.S. stock variance premium plays a key role in explaining the future appreciation rate for all currencies consid-

variance risk premium measures considered). The results for the predictive power of 1-, 3-, and 12-month currency variance risk premiums are omitted in order to save space and are available, upon request, from the authors.

[7] As pointed out by Bansal and Dahlquist (2000), a panel-data setup reduces imprecision in the estimation of currency-specific parameters (Baillie and Bollerslev, 2000).

ered, especially at the short 1- to 4-month horizon.[8] In particular, following an increase in the U.S. VP, the (1-month ahead) dollar tends to depreciate with respect to all currencies—a one hundred units increase in the monthly U.S. VP corresponds to a 1-month ahead annual *appreciation* of 2.10 percent of the foreign currencies with respect to the U.S. dollar. The statistical significance is above the 1 percent level for all currencies for horizons between 1 and 4 months. The predictive power of the stock variance premium over h-month ahead appreciation rates remains statistically significant, at almost the same levels, when equal- or value-weighted average VPs are considered instead of the U.S. VP.

Figure 3 shows the (additional) predictability patterns of the world currency and stock variance risk premiums for h-month ahead appreciation rates. Specifically, panel A displays the estimated coefficients from a multivariate regression, including the world currency and the U.S. stock variance risk premiums. Panel B reports the gains in R^2s from a regression where the interest rate differential and either XVP or VP_{US} are included (in tables 4 and 5 and repeated here again for completeness). Our results reveal that XVP has additional predictive power (after controlling for the U.S. stock variance risk premium) for forex returns for all horizons considered. In particular, the estimated $XVP(6)$ coefficient displays an inverted hump-shaped predictability pattern that peaks at the 3-month horizon (-10.99). VP_{US} also has additional predictive power for horizons between 1 and 6 months, and its estimated coefficient displays a decreasing pattern. The results in panel B suggest that adding XVP results in a hump-shaped pattern for the gains in R^2s, while the gains in R^2s for a regression including only VP_{US} are maximized at the 1-month horizon and are almost null for horizons longer than 6 months.[9]

[8]Zhou (2009) provides evidence that the U.S. stock variance risk premium has predictive power for 1-month dollar/EUR and dollar/GBP returns. Aloosh (2012) also finds some positive evidence of 1-month ahead currency return predictability from the stock variance premium differential between the United States and other countries. Interestingly, Londono (2012) finds that the U.S. stock variance risk premium is also a useful predictor for international stock returns, and Rapach et al. (2013) find that the U.S. lagged stock return is a main driver for predicting international stock returns.

[9]The decreasing predictability pattern of the stock variance premium is robust to considering the EW or the VW world stock variance risk premiums. These results are omitted in order to save space and are available, upon request, from the authors.

We now discuss the predictive power of the more traditional interest rate differential between each country and the United States in tables 4 and 5. The (lack of) predictive power of the interest rate differential allows us to examine the forward premium puzzle or the deviations from the uncovered interest-rate parity (UIP). UIP predicts that the expected *appreciation* of the foreign currency must equal the difference between domestic and foreign interest rates, such that an investor is indifferent between holding a domestic or a foreign bond. However, vast empirical evidence since Fama (1984) shows exactly the opposite—an increase in the domestic interest rate corresponds rather to a *depreciation* of the foreign currency. The UIP violation is especially challenging at short horizons (Hodrick, 1987).

Our results are in line with deviations from the UIP reported in the literature. That is, the interest rate differential is significantly different from one, and the estimated coefficient is even negative for the 1-month ahead appreciation rate. In unreported results, we show that the null hypothesis that the coefficients associated with the interest rate differential are homogeneous across countries and equal to 1 is rejected at the 10 percent confidence level for the 1-month horizon and at the 1 percent confidence level for horizons longer than 3 months. Finally, the R^2s in individual regressions for the predictive power of interest rate differentials are as low as 0.26 percent for the 1-month horizon and reach a maximum of 3.3 percent at the 12-month horizon.

3.2 Additional robustness checks

We investigate whether our benchmark results for the predictive power of currency and stock variance risk premiums hold for alternative regression specifications, subsamples, and variance risk premium measures. Some results in this section are left unreported, in order to save space, and are available, upon request, from the authors.

We first consider an alternative regression setup where the coefficient of interest rate differential is specific to each currency, while those of the world currency and stock variance risk premiums are homogeneous across currencies. This specification does not seem to have strong implications for the predictive power of currency or stock variance risk premiums. Specifically, in a setup with currency-specific b_{IR}, we find that the estimated coefficients associated with XVP are of a similar magnitude as in the benchmark setup and also display an inverted hump-shaped pattern. More importantly, XVP remains a useful predictor of future appreciation rates for all horizons considered. Similarly, VP also remains a useful predictor of future appreciation rates but with a positive sign and significant only for short horizons.

To verify the sensitivity of our results to large fluctuations in currency and stock variance risk premiums around the Lehman Brothers episode (see figure 1), in table 6, we show the results for our benchmark setup for a pre-June 2008 sample. For this subsample, our main results are almost unchanged, suggesting that the predictive power of world currency and stock variance risk premiums is not entirely driven by the global financial crisis. In particular, our main empirical findings do not seem to be affected considerably by large variance premium spikes observed around episodes of high economic uncertainty. For this subsample, the coefficient associated with the world currency variance risk premium is negative and significant for all horizons considered and the coefficient of the stock variance risk premium is positive and significant up to the 4-month horizon. If anything, the gains in predictive power when the world currency and stock variance risk premiums are added to the interest rate differential are slightly smaller than those for the full sample.

Finally, we investigate the sensitivity of our results for two alternative variance risk premium measures. In the first alternative measure, the expectation of the forex and stock return variance under the physical distribution is approximated using an AR(1) estimation of their respective realized variance as in Drechsler and Yaron (2011). In the second alternative measure, the expected forex return variance under the risk-neutral measure is approximated using a model-free measure similar to the one used to calculate the VIX.[10] Table 7 shows

[10] We follow the method in Bakshi and Madan (2000) and Bakshi, Kapadia, and Madan (2003) to calculate the risk-neutral distribution of each currency's appreciation rate with respect to the U.S. dollar using currency options at different degrees of moneyness. We thank Wenxin Du and Jesse Schreger for kindly providing the

the predictability of the alternative currency and stock variance premiums for forex returns. Our main result, that both currency and stock variance premiums are useful predictors of future appreciation rates against the U.S. dollar, holds for these alternative variance premium measures. For the first alternative measure (panel A), however, the predictability patterns are slightly changed. In particular, the currency variance risk premium is a useful predictor only at horizons between 1 and 4 months, while the stock variance risk premium becomes a useful predictor for all horizons considered.[11] The results for the second alternative measure are almost indistinguishable from those in our benchmark setup, which is not surprising, as the correlation between the alternative and the benchmark currency variance risk premium is 0.90. The result for the second alternative measure also suggests that there are little gains in using currency options at different degrees of moneyness instead of more simple ATM currency options to calculate the implied volatility of forex returns.

3.3 Alternative currency classifications

In the first part of this section, we find, in a panel-data setup, that an increase in the world currency variance risk premium predicts an appreciation of the U.S. dollar with respect to foreign currencies. We also find that the predictive power of the world currency variance risk premium is additional to that of the stock variance risk premium. These results are robust to alternative specifications, variance risk premium measures, and hold for a pre-global financial crisis sample. A natural question at this point is whether the predictive power of the currency variance risk premium depends on the type of foreign currency considered. To answer this question, in the rest of this section, we investigate up to what point our results are sensitive to classifying currencies into those of advanced and foreign economies and to considering each currency separately.

code to calculate these risk-neutral distributions.

[11] The first alternative measure differs from the benchmark measure especially around the Lehman Brothers episode. Specifically, this alternative measure is large and positive throughout most of the last quarter of 2008 while the benchmark measure displays a positive spike followed by a large negative spike in October 2008.

3.3.1 Developed and emerging economies

We classify the currencies in our sample into advanced and emerging market economies according to the IMF 2012's World Economic Outlook. According to this classification, the INR, PLN, ZAR, THB, HUF, MYR, and PHP are considered emerging economies' currencies. All other currencies are classified as those of developed economies.[12]

Table 8 reports the results for the predictive power of the world currency and the U.S. stock variance risk premium for forex returns for each group of currencies. The predictability patterns of currency and stock variance risk premiums are very similar whether we consider developed or emerging market economies' currencies. In fact, a formal test suggests that the regression coefficients for XVP and VP_{US} are statistically indistinguishable between the two groups of currencies.[13] Thus, irrespective of the type of economy considered, XVP's predictability displays an inverted hump-shaped pattern with gains in R^2s maximized at the 4-month horizon, while VP_{US}'s predictive power is larger at the 1-month horizon and disappears at medium-term horizons (after 5 and 4 months for developing and emerging economies' currencies, respectively).

Interestingly, the coefficients associated with the interest rate differential are negative and statistically different from 1, especially at short-term horizons, which suggests that UIP is violated for both groups of currencies. However, the estimated coefficients are systematically lower for developed economies' currencies. The average coefficient for the interest rate differential is about -0.61 for advanced economies versus -0.05 for emerging economies. In other words, the violation of UIP is *relatively* less severe in emerging economies, in line with Bansal and Dahlquist (2000), who find that the violations to the UIP is a phenomenon exclusive to the currencies of developed economies.

[12]This classification only affects the left-hand side of our regression setup, as we maintain the common-component nature of our variance risk premium measures.

[13]This formal test requires a panel data setup for all currencies where each variance risk premium is allowed to interact with a dummy for one group of currencies. We find that the estimated coefficients for the interaction terms are statistically insignificant for all horizons considered.

3.3.2 Individual-currency regressions

Table 9 reports the predictive power of XVP for individual currency appreciation rates. Our results reveal that the coefficient associated with XVP is significant at confidence levels above 10 percent for 18 of the 22 currencies considered at the 4-month horizon. At this horizon, the world XVP is not a useful predictor of appreciation rates for the following currencies: JPY, HKD, MYR and PHP.[14] The number of currencies where XVP is significant at any standard confidence level falls to 11 at the 12-month horizon. The individual-currency regression setup reveals that, except for the Japanese yen, a traditional *funding* currency, the gains in predictive power, $R^2 - R_y^2$, at the 4-month horizon are surprisingly high for almost all major currencies—the EUR (8.17), GBP (14.35), AUD (12.87), CAD (14.09). Gains in R^2s are also very high for other currencies such as the KRW (11.89), ZAR (13.11), and HUF (13.75), and are more modest for the CHF (4.53).[15]

Similarly, table 10 reports the currency-specific predictive power of the U.S. stock variance premium. In line with the results for the panel-data setup in table 5, VP_{US} is a useful predictor for 1-month-ahead appreciation rates for all currencies in our sample except for the EUR, HKD, INR, and PHP. At the 5-month horizon, the VP_{US} coefficient remains significant for 13 currencies for confidence levels above 10 percent, and at the 12-month horizon, the coefficient is insignificant for all currencies at any standard confidence level. The average gain in R^2 is maximized at the 1-month horizon (6.8 percent), and is almost null for horizons longer than 9 months.

[14] Interestingly, the Malaysian Ringgit, MYR, was pegged to the U.S. dollar between September 1998 and July 2005. On July 21, 2005, the Malaysian monetary authority announced the adoption of a managed float system. As mentioned before, the HKD is also pegged at 7.8 to the U.S. dollar but can trade between HKD 7.75 and HKD 7.85.

[15] In appendix B, we provide a tentative explanation for the lack of predictive power of the world currency variance risk premium for the yen/dollar exchange rate and for the modest gains in R^2 for the Swiss franc/dollar. Specifically, we find that the predictive power of the currency variance risk premium depends critically on the degree of heterogeneous exposure of economies to global uncertainty.

4 Currency variance risk premium and global economic uncertainty

In the previous section we find that world currency and stock variance risk premiums have predictive power for appreciations rates with respect to the U.S. dollar. To rationalize these empirical findings, in this section, we introduce a two-country consumption-based asset pricing model that links the currency variance risk premium to global economic uncertainty.

In our model, the consumption growth processes of both economies are exposed to global economic uncertainty. This uncertainty is, by construction, orthogonal to each country's purely domestic economic uncertainty and is therefore not priced by any of the country's domestic stock markets. But, the exposure to this global source of uncertainty varies across countries, which yields an asymmetric response of each country's currency to global economic uncertainty shocks. We also assume that global uncertainty is a currency-specific phenomenon. This assumption yields, in turn, that the currency variance risk premium reveals information about the global or currency-specific uncertainty that cannot otherwise be obtained from domestic stock and stock-options markets. Thus, the currency variance risk premium contains additional useful information to explain the time variation of appreciation rates.

In the first part of this section, we explain the model setup and its main implications and in the second part, we provide some intuition about the characteristics of our model's implied global or currency-specific uncertainty.

4.1 A model of global and domestic uncertainties

Our model extends the domestic framework in Bollerslev, Tauchen, and Zhou (2009) to an international setting. We also include a source of uncertainty common to the two economies. Specifically, we assume that the U.S. economy follows the process

$$g_{t+1} = \mu + \phi_l \sigma_{l,t} z_{g_l,t+1} + \phi_w \sigma_{w,t} z_{g_w,t+1}, \tag{5}$$

where the country's macroeconomic uncertainty, $\sigma_{l,t}$, is characterized by

$$\sigma^2_{l,t+1} = \mu_l + \rho_l \sigma^2_{l,t} + \rho_{lw}\sigma^2_{w,t} + \phi_{\sigma_l}\sqrt{q_t} z_{\sigma_l,t+1},$$

$$q_{t+1} = \mu_q + \rho_q q_t + \phi_q \sqrt{q_t} z_{q,t+1}.$$

Any other economy (foreign economy hereafter) follows a similar process, with parameters marked with *. Both countries are also exposed to global economic uncertainty characterized by

$$\sigma^2_{w,t+1} = \mu_w + \rho_w \sigma^2_{w,t} + \phi_{\sigma_w}\sigma_{w,t} z_{\sigma_w,t+1}.$$

We also assume that each country's representative agent is endowed with recursive preferences (Epstein and Zin, 1989). For simplicity, we assume that the parameters in the preference function are homogeneous across countries. Thus, for instance, the U.S. stochastic discount factor is given by

$$m_{t+1} = \theta \log \delta - \frac{\theta}{\psi} g_{t+1} + (\theta - 1) r_{t+1}, \tag{6}$$

where r_t is the return of an asset that pays the U.S. domestic production as dividends (stock return), $0 < \delta < 1$ is the time discount rate, $\gamma \geq 0$ is the risk aversion parameter, and $\theta = \frac{1-\gamma}{1-\frac{1}{\psi}}$ for $\psi \geq 1$ is the intertemporal elasticity of substitution.

To solve the model, as is standard in the literature, we log-linearize stock returns as

$$r_{t+1} = \kappa_0 + \kappa_1 z_{t+1} - z_t + g_{t+1},$$

where z_t is the price-consumption ratio. We conjecture a solution for the price-consumption ratio as a function of all state variables as

$$z_{t+1} = A_0 + A_{\sigma_l}\sigma^2_{l,t+1} + A_q q_{t+1} + A_{\sigma_w}\sigma^2_{w,t+1}. \tag{7}$$

To separate the sources of risk priced in domestic stock markets from those priced only if currency markets are added, we make two assumptions. First, we assume that $A_{\sigma_w} = A^*_{\sigma_w} =$

0. In other words, we assume that the global economic uncertainty is not priced in any of the stock markets (United States or foreign). Second, we assume that global uncertainty becomes priced once currency markets are made available to investors. Thus, when the currency market is added to both countries' stock markets, each country's stochastic discount factor is augmented to give an additional price of risk, λ (λ^* for the foreign economy), to global uncertainty, that is,

$$\widetilde{m}_{t+1} = m_{t+1} + \lambda. \tag{8}$$

Because of these two assumptions, in our model, global uncertainty is a currency-specific phenomenon.[16]

We present the detailed solution of the model in appendix A. In this section, we center our attention on assessing whether our model yields currency and stock variance risk premiums, and, more importantly, on whether the currency and stock variance risk premiums contain differential information to explain the appreciation rate of foreign currencies with respect to the U.S. dollar.

The expected variation in 1-period-ahead exchange rates of the foreign currency with respect to the U.S. dollar implied by our model is given by

$$E_t(s_{t+1}) - s_t = E_t(m_{t+1}) - E_t(m^*_{t+1}) + \frac{1}{2}Var_t(m_{t+1}) - \frac{1}{2}Var_t(m^*_{t+1}),$$

which is a function of the state variables,

$$E_t(s_{t+1}) - s_t = c_x + b_{x,\sigma_l}\sigma^2_{l,t} + b_{x,\sigma^*_l}\sigma^{*2}_{l,t} + b_{x,q}q_t + b_{x,q^*}q^*_t + b_{x,\sigma_w}\sigma^2_{w,t}, \tag{9}$$

where

$$b_{x,q} = (\theta - 1)A_q(\kappa_1\rho_q - 1) + \frac{1}{2}(\theta - 1)^2\kappa_1^2(A^2_{\sigma_l}\phi^2_{\sigma_l} + A^2_q\phi^2_q),$$

$$b_{x,\sigma_l} = (\theta - 1)A_{\sigma_l}(\kappa_1\rho_q - 1) + \frac{1}{2}\gamma^2\phi^2_l,$$

[16] The idea of a currency-specific uncertainty is closely related to the unspanned volatility literature initiated by Collin-Dufresne and Goldstein (2002) and to the more general concept of a hidden risk factor in Duffee (2011). The existence of a common factor and the idea of nearly unspanned sources of risk are also related to the intuition in Zapatero (1995).

and

$$b_{x,\sigma_w} = (\theta - 1)(\kappa_1 A_{\sigma_l}\rho_{lw} - \kappa_1^* A_{\sigma_l}^* \rho_{lw}^*) + \frac{1}{2}\gamma^2(\phi_w^2 - \phi_w^{*2}).$$

The variance risk premium of the U.S. stock market implied by our model can be found as the conditional covariance between the variance of stock returns and the domestic stochastic discount factor, that is,

$$VP_t = cov_t(\sigma_{r,t+1}^2, m_{t+1}),$$

where $\sigma_{r,t}^2$ is the conditional variance of stock returns, $var_t(r_{t+1})$. Thus, it can be shown that

$$VP_t = b_{vp,q} q_t, \tag{10}$$

where $b_{vp,q} = (\theta - 1)\kappa_1(A_{\sigma_l}\phi_l^2\phi_{\sigma_l}^2 + \kappa_1^2 A_q(A_{\sigma_l}^2\phi_{\sigma_l}^2 + A_q^2)\phi_q^2)$.

The expression for each country's stock variance risk premium (equation 10) is very similar to the model-implied stock variance risk premium in the domestic model in Bollerslev, Tauchen, and Zhou (2009). Because of our assumption that global uncertainty is a currency-specific phenomenon, the model-implied stock variance risk premium in both countries is a function of each country's domestic uncertainty. In particular, the stock variance risk premium is a function of each country's volatility of volatility, q_t. Therefore, following the intuition in Bollerslev, Tauchen, and Zhou (2009), the stock variance risk premium is positive as long as $\theta < 0$ and becomes a useful predictor of domestic stock returns for horizons for which q_t is the dominant source of variation in the equity premium. An extension of this intuition to our two-country model yields that, as the expected appreciation rate is also a function of q_t (equation 9) and this source of risk is isolated by the stock variance risk premium (equation 10), the stock variance risk premium should also be a useful predictor of the appreciation rate of the foreign currency with respect to the U.S. dollar.

The model-implied currency variance risk premium, from the point of view of an investor in the United States, can be found as

$$XVP_t = cov_t(\sigma_{c,t+1}^2, \widetilde{m}_{t+1}),$$

where $\sigma^2_{c,t} = var_t(c_{t+1})$, c_{t+1} is the 1-period log appreciation rate with respect to the U.S. dollar, which is obtained as the difference between the domestic stochastic discount factors $m_{t+1} - m^*_{t+1}$), and $\widetilde{m}_{t+1}$ is the currency-augmented stochastic discount factor needed to price sources of risk once currency markets are added to domestic stock markets. Therefore, it can be shown that

$$XVP_t = b_{xvp,q} q_t + b_{xvp,\sigma_w} \sigma^2_{w,t}, \tag{11}$$

where

$$b_{xvp,q} = (\theta - 1)\kappa_1 (A_{\sigma_l} \gamma^2 \phi_l^2 \phi^2_{\sigma_l} + A_q (\theta - 1)^2 \kappa_1^2 (A^2_{\sigma_l} \phi^2_{\sigma_l} + A_q^2 \phi_q^2) \phi_q^2),$$

and

$$b_{xvp,\sigma_w} = \lambda \gamma^2 (\phi_w - \phi^*_w)^2 \phi^2_{\sigma_w}.$$

Equation 11 suggests that our model's implied currency variance risk premium contains additional information to the stock variance risk premium as long as $\phi_w \neq \phi^*_w$ and $\lambda \neq 0$. The former condition implies that the exposure of the two economies to global uncertainty should be heterogeneous, while the latter implies that global uncertainty should have an additional price of risk once currency markets are added to the two countries' domestic stock markets. If these two conditions hold, the currency variance risk premium reveals information about the global or currency-specific uncertainty that can otherwise not be obtained from stock and stock-options markets. Therefore, the currency variance risk premium should contain additional useful information to explain the time variation in exchange rates.[17] The additional predictive power of the currency variance risk premium should become more relevant for horizons for which the global source of uncertainty dominates domestic sources of uncertainty in explaining the expected appreciation rate. In appendix B, we show that

[17] The relevance of having heterogeneous exposures to the common factor is acknowledged in Gourio, Siemer, and Verdelhan (2012); Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009); Backus, Foresi, and Telmer (2001); Lustig, Roussanov, and Verdelhan (2011); and, in a no-arbitrage setting, in Lustig, Roussanov, and Verdelhan (2012). The global-uncertainty component in Bansal and Shaliastovich (2010) and Du (2011) cancels out in the expression for the expected appreciation rate precisely because of the homogeneous exposure of both countries to this factor.

our model is able to qualitatively replicate the predictability patterns documented in section 3. We also investigate the sensitivity of the model-implied predictability patterns to two key parameters in the model, namely the degree of heterogeneous exposure to global economic uncertainty and the additional price of risk of this uncertainty.

4.2 Understanding the global or currency-specific uncertainty

Our model suggests that the currency variance risk premium reveals information about global uncertainty, which is orthogonal to the information revealed by the stock variance risk premium about domestic uncertainty. Therefore, in our model, global uncertainty is a currency-specific phenomenon. In this section, we provide more intuition about the characteristics of global or currency-specific uncertainty, which, in turn, helps to understand the predictive power of currency variance risk premium for appreciation rates. To do so, we select a set of variables that have been related to uncertainty or to currency-specific phenomena in previous literature, such as carry-trade strategies, international fund flows, and crash risk. Appendix C gives a detailed description of all variables considered, including the data source and availability.

We divide the set of variables potentially related to currency-specific uncertainty into four groups. The first group contains tail or crash risk measures from stock markets. Specifically, we include four variables that contain information about the shape of the tail of the risk-neutral distribution of stock returns to assess how much agents are willing to pay to hedge the risk of extreme fluctuations in stock markets (Bollerslev and Todorov, 2011). The variables in the second group contain information about flows to and from equity and bond funds in different regions of the world. The variables in this second group allow us to assess whether global uncertainty is related to investors' decision to demand safer assets by changing their positions in equities and bonds or to invest more in regions considered to be safer. The variables in the third group contain information about the attractiveness of carry-trade strategies (Lustig and Verdelhan, 2007; Lustig et al., 2012; and Verdelhan, 2012). In particular, we assess the informational content of interest rate differentials and carry-to-risk ratios for currency-specific uncertainty. Finally, in the fourth group, we collect information about currency crashes—how much agents are willing to pay to hedge the risk of large fluctuations in exchange rates (Farhi et al., 2009 and Farhi and Gabaix, 2011).

Table 11 summarizes the results from associating these variables—carry-trade strategies, international fund flows, and crash risk in stock and currency markets—to the world currency variance risk premium. To be consistent with our model-based interpretation discussed previously, we also control for the U.S. stock variance risk premium as a proxy for domestic uncertainty. Our results suggest that, after controlling for the stock variance risk premium, the slope coefficients associated with all stock market tail risk measures are positive and significant—an increase in stock tail risk is accompanied by an increase in global uncertainty. Within this group of variables, the VIX not only has the largest associated coefficient but also has the highest explanatory power for the world variance risk premium.[18] Our results also suggest that an increase in currency variance risk premium goes hand in hand with a reduction in flows to stock funds. However, the coefficient associated with stock funds is significant only for the United States and other advanced economies, not for emerging economies.[19] For bond funds, our evidence also suggests that investors demand safer assets when global uncertainty increases. In particular, our results show that the coefficient associated with bond funds investing in the United States is positive and significant, while the coefficients associated with bonds in emerging markets are negative and significant—around episodes of higher global uncertainty, flows to bond funds investing in the U.S. increase while flows to bond funds in emerging markets decrease. We also find that average interest rate differentials with respect to the United States are negatively related to the world currency variance risk premium. Moreover, this relationship holds after we control for the implied volatility, as can be seen from the estimated coefficients associated

[18] The variables have been standardized to facilitate the interpretation of their explanatory power.

[19] Section 3.3 describes our classification of economies into advanced and emerging markets.

with the carry-to-risk ratios. The results for the carry-trade related variables are in line with the finding in Menkhoff, Sarno, Schmeling, and Schrimpf (2012) that high interest rate currencies are negatively related to the world currency volatility premium, measured as an innovation to currency volatility. Finally, we find that the coefficients associated with currency tail risk measures are all positive and significant. More importantly, the coefficients are considerably larger than those associated with all other variables and the R-squares are the highest, suggesting that global uncertainty is closely related to currency tail risk or the increasing desire of agents to hedge against currency crashes.

In sum, we confirm that currency variance risk premium—as a proxy for global uncertainty—is associated with stock tail risk, demand for safe assets, carry-trade strategy, and, more prominently, currency tail risk or currency crash hedging.

5 Conclusion

The pervasive violations of UIP documented in Fama (1984) imply that there is a time-varying predictable component in the currency risk premium. In this paper, we provide empirical evidence that the currency and stock variance risk premiums are useful predictors of future appreciation rates with respect to the U.S. dollar for 22 currencies.

We propose a measure for the world currency variance risk premium as the average of 18 currencies' variance risk premiums. We show that the world currency variance risk premium predicts currency depreciation against the U.S. dollar, especially at the medium within-year horizon. The estimated world currency variance premium coefficient displays an inverted hump-shaped predictability pattern that peaks at the 3-month horizon, and the gains in predictive $R-squares$ reach a maximum of 8 percent at the 4-month horizon. We also document a finding that the stock variance risk premium can predict the appreciation rates for the 22 currencies considered, especially at the 1-month horizon, where the gains in predictive $R-squares$ are maximized at 5.3 percent. Interestingly, currency and stock variance risk premiums have different informational content for the future exchange rate return and are not highly correlated with each other. The predictability of the currency and stock variance risk premiums are robust to considering alternative regression setups, variance premium measures, and currency classifications, and hold for a pre-global financial crisis sample.

Such a clear time-varying component of currency risk premium helps to provide a risk-based interpretation of the forward premium puzzle. We rationalize these empirical findings in a two-country consumption-based model with both economies exposed to global and local economic uncertainties. Thus, on the one hand, the informational content of stock variance risk premiums for exchange rate appreciations is related to each country's local economic uncertainty. On the other hand, the currency variance risk premium, as a characterization of global economic uncertainty, contains unique useful information to explain the time variation in appreciation rates. As expected, the currency variance risk premium is related to various crash risk measures, especially currency crash risk.

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APPENDIX

A Detailed solution of the two-country model

As is standard in the literature, we solve the model in section 4 by log-linearizing domestic stock returns following Campbell and Shiller (1988) as

$$r_{t+1} = \kappa_0 + \kappa_1 z_{t+1} - z_t + g_{t+1}. \tag{A.1}$$

We then propose a process for the log of the wealth-consumption ratio of the asset that pays the consumption endowment in terms of the state variables (equation 7 written here again for completeness), that is,

$$z_{t+1} = A_0 + A_{\sigma_l}\sigma^2_{l,t+1} + A_q q_{t+1} + A_{\sigma_w}\sigma^2_{w,t+1}.$$

Finally, we impose the general equilibrium condition, $E_t(r_{t+1}+m_{t+1})+\frac{1}{2}Var_t(r_{t+1}+m_{t+1}) = 0$. The solution yields

$$A_0 = \frac{\theta\log\delta + \theta\kappa_0 + (1-\gamma)\mu + \theta\kappa_1(A_{\sigma_l}\mu_l + A_q\mu_q + A_{\sigma_w}\mu_w)}{\theta(1-\kappa_1)},$$

$$A_{\sigma_l} = \frac{(1-\gamma)^2\phi_l^2}{2\theta(1-\kappa_1\rho_l)},$$

$$A_q^{\pm} = \frac{(1-\kappa_1\rho_q) \pm \sqrt{(1-\kappa_1\rho_q)^2 - \theta^2\kappa_1^4\phi_q^2\phi_{\sigma_l}^2A_{\sigma_l}^2}}{\theta\kappa_1^2\phi_q^2},$$

and

$$A_{\sigma_w}^{\pm} = \frac{(1-\kappa_1\rho_w) \pm \sqrt{(1-\kappa_1\rho_w)^2 - 2\kappa_1^2\phi_{\sigma_w}^2(\theta\kappa_1A_{\sigma_l}\rho_{lw} + \frac{1}{2}(1-\gamma)^2\phi_w^2)}}{\theta\kappa_1^2\phi_{\sigma_w}^2}.$$

To avoid the load of time-varying domestic volatility of volatility, q_t, and common volatility, $\sigma_{w,t}$, from growing without bounds, it only makes sense to keep A_q^- and $A_{\sigma_w}^-$. Positive roots are discarded as they are explosive in ϕ_q and ϕ_{σ_w}, respectively. That is, $\lim_{\phi_q\to 0} A_q^+\phi_q \neq 0$ and $\lim_{\phi_{\sigma_w}\to 0} A_{\sigma_w}^+\phi_{\sigma_w} \neq 0$. A_q^- and $A_{\sigma_w}^-$ will be solutions to the model as long as $(1-\kappa_1\rho_q)^2 \geq \theta^2\kappa_1^4\phi_q^2\phi_{\sigma_l}^2A_{\sigma_l}^2$ and $(1-\kappa_1\rho_w)^2 \geq 2\kappa_1^2\phi_{\sigma_w}^2(\theta\kappa_1A_{\sigma_l}\rho_{lw} + \frac{1}{2}(1-\gamma)^2\phi_w^2)$, respectively. It is easy to show from these expressions that A_{σ_l}, A_q, $A_{\sigma_w} \leq 0$ as long as $\theta < 1$.

B Model-implied predictability patterns

In this appendix, we calibrate the model in section 4 to illustrate its ability to generate predictability patterns that are qualitatively comparable to those suggested by the empirical evidence in section 3. In particular, we show that the model-implied slope coefficients for the predictive power of stock and currency variance risk premiums for appreciation rates and the (univariate-regression) coefficients of determination linked to these variance risk premiums qualitatively match the observed patterns.

The h-horizon model-implied slope coefficients for stock and currency variance risk premiums are given by

$$\beta_{c,VP}(h) = \frac{cov(s_{t+h} - s_t, VP_t)}{var(VP_t)}, \tag{B.1}$$

and

$$\beta_{c,XVP}(h) = \frac{cov(s_{t+h} - s_t, XVP_t)}{var(XVP_t)}, \tag{B.2}$$

respectively. The coefficients of determination are given by

$$R^2_{c,VP}(h) = \frac{cov(s_{t+h} - s_t, XVP_t)^2}{var(XVP_t)var(s_{t+h} - s_t)}, \tag{B.3}$$

and

$$R^2_{c,XVP}(h) = \frac{cov(s_{t+h} - s_t, XVP_t)^2}{var(XVP_t)var(s_{t+h} - s_t)}, \tag{B.4}$$

for a regression where either the stock or the currency variance risk premium is considered, respectively.

We now describe how to obtain the components of equations (B.1) to (B.4). The model-implied h-period ahead exchange rate return can be approximated by the compound return based on monthly appreciation rates as follows:

$$\begin{aligned} s_{t+h} - s_t &\simeq \frac{1}{h}\sum_{j=1}^{h}(s_{t+j} - s_{t+j-1}) \\ &= \frac{1}{h}[b_{x,\sigma_l}(\frac{1-\rho_l^h}{1-\rho_l})\sigma^2_{l,t} + b_{x,\sigma_l^*}(\frac{1-\rho_l^{*h}}{1-\rho_l^*})\sigma^{*2}_{l,t} \\ &\quad +b_{x,q}(\frac{1-\rho_q^h}{1-\rho_q})q_t + b_{x,q^*}(\frac{1-\rho_q^{*h}}{1-\rho_q^*})q_t^* \\ &\quad +(\frac{b_{x,\sigma_l}\rho_{lw}}{\rho_l - \rho_w}(\frac{1-\rho_l^h}{1-\rho_l} - \frac{1-\rho_w^h}{1-\rho_w}) + \frac{b_{x,\sigma_l^*}\rho^*_{lw}}{\rho_l^* - \rho_w}(\frac{1-\rho_l^{*h}}{1-\rho_l^*} - \frac{1-\rho_w^h}{1-\rho_w}) + b_{x,\sigma_w}(\frac{1-\rho_w^h}{1-\rho_w}))\sigma^2_{w,t} \\ &\quad +f_c(z_{y,t+1}, ..z_{y,t+h})], \end{aligned}$$

where $c_{c,h}$ is a constant term,

$$b_{x,\sigma_l} = (\theta - 1)b_{r,\sigma_l},$$

$$b_{x,\sigma_l^*} = -(\theta - 1)b_{r^*,\sigma_l^*},$$

$$b_{x,q} = (\theta - 1)b_{r,q},$$

$$b_{x,q^*} = -(\theta - 1)b_{r^*,q^*},$$

and

$$b_{x,\sigma_w} = (\theta - 1)(b_{r,\sigma_w} - b_{r^*,\sigma_w}),$$

where $b_{r,y}$ is the stock return load on the state variable y_t ($\sigma_{l,t}$, $q_{l,t}$, their foreign counterparts, and $\sigma_{w,t}$).

The model-implied 1-month ahead stock variance risk premium is defined in equation 10. From this expression, the components of $\beta_{c,VP}$ and $R^2_{c,VP}$ are given by

$$cov(\frac{1}{h}\sum_{j=1}^{h}(s_{t+j} - s_{t+j-1}), VP_t) = \frac{1}{h}b_{vp,q}b_{c,q}(\frac{1-\rho_q^h}{1-\rho_q})var(q_t),$$

and

$$var(VP_t) = b^2_{vp,q}var(q_t).$$

The T-month ahead currency variance risk premium is given by

$$XVP_t(T) = [b_{xvp,q}q_t(\frac{1-\rho_q^T}{1-\rho_q}) + b_{xvp,\sigma_w}\sigma^2_{w,t}(\frac{1-\rho_w^T}{1-\rho_q}) + f_{xvp}(z_{t+1,..}z_{t+T})],$$

where $b_{xvp,q}$ and b_{xvp,σ_w} are defined in equation 11. Therefore, the components of $\beta_{c,XVP}$ and $R^2_{c,XVP}$ are given by the following expressions:

$$cov(\frac{1}{h}\sum_{j=1}^{h}(s_{t+j} - s_{t+j-1}), XVP_t(T)) = \frac{1}{h}[b_{c,q}b_{xvp,q}(\frac{1-\rho_q^h}{1-\rho_q})(\frac{1-\rho_q^T}{1-\rho_q})var(q_t)$$

$$+b_{xvp,\sigma_w}(\frac{1-\rho_w^T}{1-\rho_q})(\frac{b_{c,\sigma_l}\rho_{lw}}{\rho_l-\rho_w}(\frac{1-\rho_l^h}{1-\rho_l}-\frac{1-\rho_w^h}{1-\rho_w})+\frac{b_{c,\sigma_l^*}\rho_{lw}^*}{\rho_l^*-\rho_w}(\frac{1-\rho_l^{*h}}{1-\rho_l^*}-\frac{1-\rho_w^h}{1-\rho_w})+b_{c,\sigma_w}(\frac{1-\rho_w^h}{1-\rho_w}))var(\sigma^2_{w,t})],$$

and

$$var(XVP_t(T)) = [b^2_{xvp,q}(\frac{1-\rho_q^T}{1-\rho_q})^2var(q_t) + b^2_{xvp,\sigma_w}(\frac{1-\rho_w^T}{1-\rho_q})^2var(\sigma^2_{w,t})].$$

The unconditional variance of the h-month ahead appreciation rate is given by

$$var(\frac{1}{h}\sum_{j=1}^{h}(s_{t+j} - s_{t+j-1})) = \frac{1}{h^2}[h(var(c_{t+1})) + 2\sum_{j=1}^{h-1}(h-j)cov(c_{t+1}, c_{t+1+j})],$$

where

$$
\begin{aligned}
var(c_{t+1}) &= b_{x,\sigma_l}^2 var(\sigma_{l,t}^2) + b_{x,\sigma_l^*}^2 var(\sigma_{l,t}^{*2}) \\
&+ b_{x,q}^2 var(q_t) + b_{x,q^*}^2 var(q_t^*) + b_{x,\sigma_w}^2 var(\sigma_{w,t}^2) \\
&+ \gamma^2 \phi_l^2 E(\sigma_{l,t}^2) + (\theta-1)^2 \kappa_1^2 (A_{\sigma_l}^2 \phi_{\sigma_l}^2 + A_q^2 \phi_q^2) E(q_t) \\
&+ \gamma^2 \phi_l^{*2} E(\sigma_{l,t}^{*2}) + (\theta-1)^2 \kappa_1^{*2} (A_{\sigma_l}^{*2} \phi_{\sigma_l}^{*2} + A_q^{*2} \phi_q^{*2}) E(q_t^*) \\
&+ (\theta-1)^2 (\kappa_1 A_{\sigma_w} - \kappa_1^* A_{\sigma_w}^*)^2 \phi_{\sigma_w}^2 E(\sigma_{w,t}),
\end{aligned}
$$

and

$$
\begin{aligned}
cov(c_{t+1}, c_{t+1+j}) &= b_{x,\sigma_l}^2 \rho_l^j var(\sigma_{l,t}^2) + b_{x,\sigma_l^*}^2 \rho_l^{*j} var(\sigma_{l,t}^{*2}) + b_{x,q}^2 \rho_q^j var(q_t) + b_{x,q^*}^2 \rho_q^{*j} var(q_t^*) \\
&+ b_{x,\sigma_w} (b_{x,\sigma_l} \rho_{lw} (\frac{\rho_l^j - \rho_w^j}{\rho_l - \rho_w}) + b_{x,\sigma_l^*} \rho_{lw}^* (\frac{\rho_l^{*j} - \rho_w^j}{\rho_l^* - \rho_w}) + b_{x,\sigma_w} \rho_w^j) var(\sigma_{w,t}^2) \\
&+ (\theta-1) \kappa_1 A_{\sigma_l} b_{x,\sigma_l} \phi_{\sigma_l}^2 \rho_l^{j-1} E(q_t) + b_{mr} \kappa_1 A_q b_{x,q} \phi_q^2 \rho_q^{j-1} E(q_t) \\
&- (\theta-1)^* \kappa_1^* A_{\sigma_l}^* b_{x,\sigma_l^*} \phi_{\sigma_l}^{*2} \rho_l^{*j-1} E(q_t^*) - (\theta-1)^* \kappa_1^* A_q^* b_{x,q^*} \phi_q^{*2} \rho_q^{*j-1} E(q_t^*) \\
&+ (\theta-1)(\kappa_1 A_{\sigma_w} - \kappa_1^* A_{\sigma_w}^*)(b_{x,\sigma_l} \rho_{lw} (\frac{\rho_l^{j-1} - \rho_w^{j-1}}{\rho_l - \rho_w}) + b_{x,\sigma_w} \rho_w^{j-1} + ... \\
& b_{x,\sigma_l^*} \rho_{lw}^* (\frac{\rho_l^{*j-1} - \rho_w^{j-1}}{\rho_l^* - \rho_w})) \phi_{\sigma_w}^2 E(\sigma_{w,t}^2).
\end{aligned}
$$

Finally, the unconditional first and second order moments of the state variables can be found as follows:

$$
E(q_t) = \frac{\mu_q}{1-\rho_q}; E(q_t^*) = \frac{\mu_q^*}{1-\rho_q^*};
$$

$$
E(\sigma_{w,t}^2) = \frac{\mu_w}{1-\rho_w}; E(\sigma_{l,t+1}^2) = \frac{\mu_l + \rho_{lw} E(\sigma_{w,t}^2)}{1-\rho_l}; E(\sigma_{l,t+1}^{*2}) = \frac{\mu_l^* + \rho_{lw}^* E(\sigma_{w,t}^2)}{1-\rho_l^*};
$$

$$
var(q_t) = \frac{\phi_q^2 E(q_t)}{1-\rho_q^2}; var(q_t^*) = \frac{\phi_q^{*2} E(q_t^*)}{1-\rho_q^{*2}}; var(\sigma_{l,t+1}^2) = \frac{\rho_{lw}^2 var(\sigma_{w,t}^2) + \phi_{\sigma_l}^2 E(q_t)}{1-\rho_l^2};
$$

$$
var(\sigma_{l,t+1}^{*2}) = \frac{\rho_{lw}^{*2} var(\sigma_{w,t}^2) + \phi_{\sigma_l}^{*2} E(q_t^*)}{1-\rho_l^{*2}}; var(\sigma_{w,t}^2) = \frac{\phi_{\sigma_w}^2 E(\sigma_{w,t}^2)}{1-\rho_w^2}.
$$

The numerical values for the components of the model-implied slope coefficients and coefficients of determination depend upon the values of the parameters that characterize the local and foreign economic growth processes (equation 5 and its foreign counterpart) and the parameters of the preference function (equations 6 and 8). We calibrate the parameters for the consumption growth processes to mimic the U.S. economy and the German economy. In particular, we assume $\mu = 0.18$ percent and $\mu^* = 0.125$ percent, equivalent to the average monthly industrial production growth for each country, respectively, for a sample period running from 1970 to 2011. We assume that ϕ_w and ϕ_w^* are proportional to each other with $\phi_w = 1$ and $\phi_w^* = w\phi_w$. Thus, parameter w controls the heterogeneous exposure to global/currency-specific uncertainty. For simplicity, we assume that all other parameters driving the consumption growth volatility in each country are homogeneous. Therefore, w also controls the cross-country difference in total consumption growth volatility. To calibrate the parameters driving the dynamics of local uncertainties, we follow Bollerslev, Tauchen, and Zhou (2009) and set $\rho_l = \rho_l^* = 0.979$. We calibrate ρ_{σ_l} and $\rho_{\sigma_l}^*$ so that the condition for global uncertainty not to be priced by the two countries' stock markets holds (that is, $A_{\sigma_w} = A_{\sigma_w}^* = 0$).[20] We also set $\phi_{\sigma_l} = \phi_{\sigma_l}^* = 0.2 < 1$ to reduce the chance of finding nonreal solutions for the model (see appendix A). To calibrate the parameters driving the dynamics of the volatility of volatility, we also follow Bollerslev, Tauchen, and Zhou (2009) and set $\rho_q = \rho_q^* = 0.80$, $\mu_q = \mu_q^* = 1\text{x}10^{-6}(1-\rho_q)$, and $\phi_q = \phi_q^* = 0.001$. We calibrate the parameters driving the process for the global uncertainty (μ_w, ρ_w, and ϕ_{σ_w}) to match three unconditional moments for the dollar/EUR exchange rate appreciation: its unconditional mean, $E(c_t)$; its average first difference, $E(c_{t+1}-c_t)$; and its unconditional volatility, $var(c_t)$. Specifically, we find μ_w, ρ_w, and ϕ_{σ_w} that minimize the average of the squared moment conditions defined as the difference between the observed moments in our sample and those implied by our model. Following this simple procedure, we obtain the following calibrated values: $\mu_w = 5\text{x}10^{-13}$, $\rho_w = 0.98$, and $\phi_{\sigma_w} = 0.63$. Finally, to calibrate the preference-function parameters, we follow Bansal and Yaron (2004) and Bollerslev, Tauchen, and Zhou (2009) and set $\delta = 0.997$, $\gamma = 10$, and $\psi = 1.5$.[21]

We center the attention on the predictive power of currency variance risk premium for appreciation rates. This model-implied predictability pattern depends critically on the degree of heterogeneous exposure to global uncertainty, driven by variable ω, and the additional price of risk of global uncertainty in currency markets, λ as can be seen in figure B.1. As shown in panel A, when the exposure to global uncertainty is homogeneous, that is,

[20]This condition holds if

$$\phi_w^2 = -\frac{\kappa_1 \phi_l^2}{(1-\kappa_1\rho_l)}\rho_{lw}.$$

In other words, if the effect of global uncertainty on the local consumption growth, ϕ_w^2, is compensated by a decrease in the effect of this uncertainty on the conditional expectation of the country-specific uncertainty, ρ_{lw}. See appendix A.

[21]Following Londono (2012), we calibrate the Campbell and Shiller's constants to match the unconditional mean of the price-dividend ratios for these two countries. Thus, we fix $\kappa_0 = 0.13$, $\kappa_1 = 0.97$, $\kappa_0^* = 0.12$, and $\kappa_1^* = 0.97$. Restricting the Campbell and Shiller's constants to these values allows us to center the attention on the impact of the key parameters in our model (in principle, these constants depend upon the other parameters in the model).

$\phi_w = \phi_w^*$, an increase in the dollar/EUR variance risk premium predicts a depreciation of the U.S. dollar, in contrast to our empirical evidence for most currencies except perhaps for the yen, the Philippine peso, and other hard-pegged currencies. However, as long as $\omega > 1$ and $\phi_w > \phi_w^*$, an increase in the dollar/EUR variance risk premium predicts an appreciation of the U.S. dollar for all horizons considered. This finding suggests that, as the U.S. economy is less exposed to global or currency-specific uncertainty, an increase in currency variance risk premium reflects an increase in global uncertainty and should be accompanied by a higher demand to hold foreign currency. The higher demand for foreign currency will make the U.S. dollar value relatively low today. As shown in panel B, if U.S. investors are indifferent to global uncertainty, that is, $\lambda = 0$, the dollar/EUR currency variance risk premium has no predictive power for the appreciation rate between these currencies. But, as U.S. investors become more concerned about global uncertainty, the regression coefficient becomes more negative. Thus, again, a shock to global uncertainty increases the dollar/EUR variance risk premium, if agents are not indifferent to this source of risk, and makes the value of the U.S. dollar relatively low with respect to other currencies. Therefore, an increase in the dollar/EUR currency variance risk premium predicts a future appreciation of the U.S. dollar with respect to the euro.

C. List of variables related to XVP

Variable	Source	Description	Available
Stock market tail risk			
10% COI drop	FRB	Cost of insurance against a 30-day 10% drop in the S&P 500	1/31/2000
10% COI increase	FRB	Cost of insurance against a 30-day 10% increase in the S&P 500	1/31/2000
VIX	Chicago FED	S&P 500 options-implied volatility	1/31/2000
World IV	Authors	Equal-weighted average of 8 countries' VIX-type options IV	1/31/2000
Fund flows			
Equity US	EPFR	Net equity fund flows in USD per country/region	11/30/2000
Equity AFE	EPFR	Advanced economies except for the U.S.	11/30/2000
Equity EMASIA	EPFR	Emerging market economies in Asia	11/30/2000
Equity LATAM	EPFR	Emerging market economies in Latin America	11/30/2000
Bonds US	EPFR	Net bond fund flows in USD per country/region	1/30/2004
Bonds AFE	EPFR	Advanced economies except for the U.S.	1/30/2004
Bonds EMASIA	EPFR	Emerging market economies in Asia	1/30/2004
Bonds LATAM	EPFR	Emerging market economies in Latin America	1/30/2004
Carry-trade strategies			
World IRDIFF(6)	FRB	Equal-weighted average of 6-month interest rate differentials between all currencies in our sample and the U.S.	1/31/2000
AFE IRDIFF(6)	FRB	Equal-weighted average for advanced economies ouside U.S.	1/31/2000
EME IRDIFF(6)	FRB	Equal-weighted average for emerging market economies	1/31/2000
World carry (6)	FRB, Morgan markets (MM)	Equal-weighted average of carry-to-risk ratios for all currencies, calculated as (interest rate differential)/(ATM currency-options IV)	1/31/2000
AFE carry (6)	FRB, MM	Equal-weighted average for advanced economies outside U.S.	1/31/2000
EME carry (6)	FRB, MM	Equal-weighted average for emerging market economies	1/31/2000
Currency tail risk			
World XIV(6)	MM	Equal-weighted average of ATM currency IV for all currencies	1/31/2000
AFE XIV(6)	MM	Equal-weighted average for advanced economies outside U.S.	1/31/2000
EME XIV(6)	MM	Equal-weighted average for emerging market economies	1/31/2000
World 10 RR(6)	Bloomberg	Equal-weighted average of risk reversal for all currencies, calculated using 10% OTM (ITM) puts and calls (risk of appreciation of USD)	10/31/2003
AFE 10 RR(6)	Bloomberg	Equal-weighted average for advanced economies outside U.S.	10/31/2003
EME 10 RR(6)	Bloomberg	Equal-weighted average for emerging market economies	10/31/2003

FRB stands for Federal Reserve Board and FED stands for Federal Reserve Bank.

Table 1: 1-month currency appreciation rates with respect to the U.S. dollar, summary statistics

This table reports the summary statistics for the time series of 1-month fluctuations of the logarithm of foreign exchange rates with respect to the U.S. dollar. The appreciation rates are expressed in percent. The exchange rates are quoted in units of U.S. dollar per one unit of foreign currency—a positive sign corresponds to a appreciation of the foreign currency with respect to the U.S. dollar. We also report the average pair-wise correlation between each currency and all other currencies considered.

	EUR	JPY	GBP	CHF	AUD	CAD	SEK	NZD	KRW	SGD	NOK
Mean	0.20	0.23	−0.03	0.40	0.33	0.24	0.18	0.31	−0.17	0.19	0.23
Median	0.26	0.28	−0.02	0.14	0.53	0.27	0.16	0.88	−0.06	0.23	0.29
St. Dev.	3.22	2.81	2.64	3.34	4.04	2.80	3.61	4.07	5.12	1.71	3.44
Skew.	−0.21	−0.30	−0.32	0.07	−0.76	−0.61	−0.10	−0.52	−0.59	−0.84	−0.55
Kurt.	3.89	3.41	4.83	4.51	5.14	6.30	3.33	4.50	3.47	7.22	4.51
AR(1)	0.02	−0.04	0.10	−0.08	0.06	−0.06	0.06	0.06	0.05	−0.09	0.07
Avg. Corr.	0.60	0.19	0.45	0.54	0.59	0.45	0.60	0.54	0.39	0.58	0.56

	PLN	ZAR	CZK	DKK	THB	TWD	HKD	HUF	INR	MYR	PHP
Mean	0.14	−0.02	0.44	0.20	0.12	0.01	0.00	0.06	−0.14	0.13	−0.05
Median	0.47	0.20	0.75	0.20	0.28	−0.02	0.00	0.61	0.03	0.00	0.02
St. Dev.	4.32	3.54	3.87	3.20	1.75	1.46	0.14	4.47	1.94	1.42	2.03
Skew.	−0.89	−0.27	−0.40	−0.20	−0.29	−0.01	0.99	−1.21	−0.62	−0.85	−1.09
Kurt.	4.85	7.25	3.51	3.89	3.73	3.94	9.52	6.57	5.79	8.56	7.64
AR(1)	0.13	−0.05	0.04	0.03	0.13	0.21**	0.00	0.07	0.18*	−0.09	0.06
Avg. Corr.	0.55	0.49	0.57	0.60	0.45	0.47	0.16	0.56	0.43	0.48	0.34

Table 2: Currency variance risk premiums, summary statistics

This table reports the summary statistics for the variance risk premiums of all available currencies with respect to the U.S. dollar. The currency variance risk premiums are expressed in annualized squared percent. We also report the summary statistics for the world currency variance risk premiums, calculated as the equally weighted average of all currencies' variance risk premiums, for the 1-, 3-, 6-, and 12-month horizons in panels A, B, C, and D, respectively. Our sample runs from January 2000 to December 2011. Each currency's variance risk premium, $XVP_{i,t}(h)$, is measured as the difference between the square of the h-month (ATM) forex option-implied volatility and the realized variance of the exchange rate appreciation. The forex return realized variance is calculated using h-month lagged non-overlapping rolling windows of daily (log) appreciation rates between each currency and the U.S. dollar. *,** and *** represent the usual 10, 5, and 1 percent significance levels. To assess the significance of the mean $XVP_t(h)$, the standard errors are corrected by Newey-West with 3 lags. We also report the average correlation between each currency's and all other currencies' variance risk premiums.

A. $XVP(1)$

	World $XVP(1)$	EUR	JPY	GBP	CHF	AUD	CAD	SEK	NZD
Mean	6.79	13.87***	16.65***	9.17***	−8.01	−28.46	3.89	−0.82	−3.05
Median	9.01	8.94	13.63	7.64	0.88	5.71	8.75	0.12	16.79
St. Dev.	32.96	48.47	43.95	33.82	99.89	262.96	46.21	68.69	108.12
Skew.	−5.13	2.55	1.47	1.34	−5.92	−10.38	0.40	−2.40	−4.23
Kurt.	52.73	18.78	12.11	8.15	49.22	118.94	23.19	19.63	32.11
AR(1)	0.10	0.04	0.19**	0.16*	0.42***	0.13	−0.04	0.13	0.11
Avg. Corr.	0.17	0.16	0.21	0.11	0.10	0.15	0.22	0.13	0.22

	KRW	SGD	NOK	PLN	ZAR	CZK	DKK	THB	TWD
Mean	48.10**	7.84***	1.72	19.49*	−17.22	5.56	14.06***	29.48***	10.75***
Median	19.77	5.67	3.16	22.74	27.67	−1.44	7.82	12.79	7.80
St. Dev.	290.70	17.79	66.43	144.81	326.88	93.94	49.75	58.48	19.02
Skew.	1.32	−0.35	−1.48	2.24	−9.36	2.68	2.51	1.30	−0.05
Kurt.	41.76	8.71	11.23	30.25	103.60	21.32	18.75	7.25	8.36
AR(1)	0.03	0.42***	0.07	0.26***	0.15*	0.33	0.07	0.61***	0.37***
Avg. Corr.	0.16	0.18	0.27	0.26	0.16	0.31	0.16	0.00	0.10

Table 2: Currency variance risk premiums, summary statistics (continued)

B. $XVP(3)$

	World $XVP(3)$	EUR	JPY	GBP	CHF	AUD	CAD	SEK	NZD
Mean	0.83	14.93***	11.26**	10.65***	−6.71	−39.75	0.43	−5.96	−10.07
Median	5.45	8.02	15.54	6.94	0.01	−1.47	5.10	3.33	7.70
St. Dev.	49.36	38.96	49.83	30.50	77.39	206.59	30.48	71.62	93.27
Skew.	−4.31	2.64	−3.23	1.94	−4.32	−6.68	−1.84	−1.71	−4.33
Kurt.	30.22	18.52	22.19	14.38	30.51	50.49	10.43	10.32	29.28
AR(1)	0.50***	0.38***	0.41***	0.51***	0.70***	0.68***	0.48***	0.69***	0.52***
Avg. Corr.	0.25	0.28	0.34	0.32	0.15	0.23	0.39	0.30	0.33

	KRW	SGD	NOK	PLN	ZAR	CZK	DKK	THB	TWD
Mean	16.54	9.80***	−0.70	5.28	−39.03	−5.18	14.98***	28.71***	14.13***
Median	12.60	5.76	0.61	11.61	12.04	0.38	7.64	15.34	9.22
St. Dev.	104.70	17.57	57.64	82.21	244.73	73.02	39.57	40.15	20.15
Skew.	−3.00	0.03	−1.57	−0.68	−6.32	0.84	2.71	1.26	1.63
Kurt.	21.41	7.78	9.06	11.75	48.32	19.51	19.15	4.64	7.10
AR(1)	0.44***	0.58***	0.66***	0.34***	0.59***	0.30***	0.39***	0.77***	0.76***
Avg. Corr.	0.24	0.17	0.39	0.27	0.27	0.34	0.27	−0.03	0.03

C. $XVP(6)$

	World $XVP(6)$	EUR	JPY	GBP	CHF	AUD	CAD	SEK	NZD
Mean	1.44	16.45***	9.65	13.24**	−7.39	−42.57*	0.06	−5.63	−12.34
Median	4.64	10.32	6.45	9.53	2.66	−8.36	2.16	2.62	0.80
St. Dev.	49.46	42.02	43.57	39.76	62.29	160.97	35.56	78.99	75.84
Skew.	−2.71	1.47	−1.10	0.61	−1.97	−4.43	−2.06	−2.36	−2.51
Kurt.	16.33	9.35	7.20	11.68	9.19	23.88	14.86	12.70	13.63
AR(1)	0.79***	0.67***	0.74***	0.77***	0.87***	0.87***	0.67***	0.83***	0.79***
Avg. Corr.	0.37	0.49	0.35	0.51	0.32	0.28	0.51	0.51	0.44

	KRW	SGD	NOK	PLN	ZAR	CZK	DKK	THB	TWD
Mean	2.78	12.15***	0.21	2.76	−42.45	−8.62	16.71***	30.15***	18.17***
Median	8.25	8.60	4.36	10.72	8.39	1.38	10.72	18.36	11.97
St. Dev.	125.04	18.56	65.07	92.14	182.89	66.46	42.66	36.21	23.10
Skew.	−4.59	1.47	−2.34	−1.41	−3.29	−2.19	1.53	1.17	2.08
Kurt.	29.63	9.20	12.23	8.93	15.58	11.47	9.52	3.84	8.41
AR(1)	0.71***	0.77***	0.81***	0.70***	0.78***	0.67***	0.67***	0.79***	0.84***
Avg. Corr.	0.38	0.24	0.54	0.44	0.30	0.46	0.48	−0.05	0.03

Table 2: Currency variance risk premiums, summary statistics (continued)

D. $XVP(12)$

	World $XVP(12)$	EUR	JPY	GBP	CHF	AUD	CAD	SEK	NZD
Mean	2.25	18.80***	8.60	15.41**	2.54	−41.07*	−5.48	19.14***	3.94
Median	5.71	9.53	3.11	13.05	1.34	−5.29	−2.19	10.25	7.21
St. Dev.	56.25	44.49	38.34	44.47	34.49	131.07	82.71	45.50	64.34
Skew.	−2.62	1.01	−0.37	0.67	−0.45	−3.29	−1.78	1.02	−2.08
Kurt.	13.32	6.75	3.93	9.54	4.81	13.90	9.64	6.56	10.97
AR(1)	0.90***	0.81***	0.83***	0.86***	0.78***	0.93***	0.88***	0.82***	0.87***
Avg. Corr.	0.70	0.60	0.44	0.63	0.55	0.51	0.67	0.59	0.69

	KRW	SGD	NOK	PLN	ZAR	CZK	DKK	THB	TWD
Mean	−9.27	13.10	−1.67	16.28***	33.16***	3.57	−36.59	2.61	−4.82
Median	2.33	20.31	3.87	10.19	23.00	4.08	−9.98	4.32	11.76
St. Dev.	67.83	128.53	76.13	20.70	33.47	15.64	154.42	37.18	144.41
Skew.	−2.61	−0.83	−1.84	2.79	1.42	0.01	−1.96	0.39	−3.39
Kurt.	12.87	9.81	10.47	12.66	4.45	2.86	8.54	11.88	16.21
AR(1)	0.88***	0.88***	0.89***	0.83***	0.79***	0.92***	0.89***	0.79***	0.89***
Avg. Corr.	0.64	0.61	0.66	0.41	0.06	0.18	0.51	0.60	0.62

Table 3: Stock variance risk premiums, summary statistics

This table reports the summary statistics for the stock variance risk premium calculated as the difference between the (model-free) option-implied and the realized stock return variance. The stock variance risk premiums are expressed in annualized squared percent. The stock variance premium is alternatively measured as the U.S. stock variance premium (VP_{US}), the equal-weighted average stock variance premium ($EW\ world\ VP$), and the value-weighted average stock variance premium ($VW\ world\ VP$). The average variance premiums are calculated using the variance premium for the following countries: United States, Germany, Japan, and the United Kingdom. For these four countries, the weights are calculated using lagged total market capitalization. We also report the correlation between the stock variance risk premium measures and the 6-month world currency variance risk premium, $corr(VP, XVP)$, as well as the cross-correlations among the three stock variance premiums.

	VP_{US}	$EW\ world\ VP$	$VW\ world\ VP$
Mean	88.69*	104.18***	100.36**
median	109.31	115.77	105.33
St. Dev.	418.86	351.10	379.72
Skew.	−4.32	−5.54	−5.16
Kurt.	32.97	53.04	46.26
AR(1)	0.32***	0.18**	0.28***
$corr(VP, XVP)$	−0.17	−0.30	−0.24

Correlations	VP_{US}	$EW\ world\ VP$	$VW\ world\ VP$
VP_{US}	1		
$EW\ world\ VP$	0.89	1	
$VW\ world\ VP$	0.98	0.96	1

Table 4: The predictive power of the world currency variance risk premium for exchange rate returns

This table reports the estimated coefficients for the following panel-data regressions:

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{XVP}(h)XVP_t + u_{i,t+h},$$

where $s_{i,t}$ is the dollar exchange rate of currency i (in units of U.S. dollar per unit of foreign currency), $y_{US,t}(h) - y_{i,t}(h)$ is the interest rate differential for $h-$month zero-coupon bond rates between the United States and country i, and XVP is the 6-month world currency variance premium calculated as the equal-weighted average of all available currencies' variance risk premiums (see Table 2). To facilitate the interpretation of the estimated coefficients, we divide XVP by 12 (equivalent to monthly XVP). The standard errors are corrected by panel-data Newey-West with h lags (standard deviations are reported in parenthesis). *,**, and *** represent the usual 10, 5, and 1 percent significance levels. The sample period runs from January 2000 to December 2011. The estimated regression currency-specific constants are left unreported, to save space. We report the R^2 of the regression and the gains in R^2s with respect to a univariate regression for the interest rate differential, $R^2 - R^2_y$.

h	1	2	3	4	5	6	9	12
$y_t(h) - y^*_t(h)$	−0.08	0.07	0.14	0.23	0.19	0.13	−0.02	−0.06
	(0.40)	(0.38)	(0.39)	(0.40)	(0.40)	(0.40)	(0.40)	(0.38)
XVP	−11.33***	−11.55***	−12.21***	−11.95***	−10.59***	−9.34***	−4.78***	−2.82***
	(1.70)	(1.35)	(1.19)	(1.19)	(1.07)	(0.93)	(0.66)	(0.57)
R^2	2.43	4.72	7.70	8.95	8.73	8.28	5.03	4.79
$R^2 - R^2_y$	2.16	4.22	6.95	8.00	7.57	6.94	2.86	1.51

Table 5: The predictive power of the stock variance risk premium for exchange rate returns

This table reports the estimated coefficients for the following panel-data regressions:

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{VP}(h)VP_t + u_{i,t+h},$$

where $s_{i,t}$ is the dollar exchange rate of currency i (in units of U.S. dollar per unit of foreign currency), $y_{US,t}(h) - y_{i,t}(h)$ is the interest rate differential for $h-$month zero-coupon bond rates between the U.S. and country i, and VP is the (1-month) stock variance premium. We consider three alternative measures for the stock variance risk premium: the U.S. stock variance premium (VP_{US}), the equal-weighted average stock variance premium (EW *world* VP), and the value-weighted average stock variance premium (VW *world* VP) (see table 3). To facilitate the interpretation of the estimated coefficients, we divide VPs by 12. The standard errors are corrected by panel-data Newey-West with h lags (the standard deviations are reported in parenthesis). *,**, and *** represent the usual 10, 5, and 1 percent significance levels. The sample period runs from January 2000 to December 2011. The country-specific estimated constants are left unreported, to save space. We report the R^2 of the regression and the gains in R^2s with respect to a univariate regression for the interest rate differential, $R^2 - R^2_y$.

A. VP_{US}

h	1	2	3	4	6	9	12
$y_t(h) - y^*_t(h)$	−0.39	−0.10	−0.07	0.01	0.05	−0.07	−0.11
	(0.39)	(0.38)	(0.38)	(0.39)	(0.41)	(0.40)	(0.39)
VP_{US}	2.10***	0.87***	1.07***	1.06***	0.42***	0.04	0.01
	(0.26)	(0.17)	(0.16)	(0.14)	(0.10)	(0.06)	(0.05)
R^2	5.57	2.21	4.58	5.39	2.26	2.19	3.28
$R^2 - R^2_y$	5.31	1.72	3.83	4.44	0.91	0.02	0.00

B. EW *world* VP

h	1	2	3	4	6	9	12
$y_t(h) - y^*_t(h)$	−0.20	0.00	0.02	0.10	0.07	−0.07	−0.11
	(0.40)	(0.39)	(0.39)	(0.39)	(0.41)	(0.40)	(0.39)
VP_{US}	1.48***	0.39**	1.02***	1.03***	0.45***	0.16**	0.09*
	(0.23)	(0.17)	(0.17)	(0.15)	(0.10)	(0.06)	(0.05)
R^2	2.11	0.74	3.19	4.00	2.16	2.34	3.37
$R^2 - R^2_y$	1.85	0.24	2.44	3.05	0.81	0.17	0.08

C. VW *world* VP

h	1	2	3	4	6	9	12
$y_t(h) - y^*_t(h)$	−0.28	−0.04	−0.02	0.06	0.06	−0.07	−0.11
	(0.39)	(0.38)	(0.39)	(0.39)	(0.40)	(0.40)	(0.39)
VP_{US}	1.96***	0.74***	1.11***	1.11***	0.47***	0.11*	0.05
	(0.26)	(0.18)	(0.17)	(0.15)	(0.10)	(0.06)	(0.05)
R^2	4.07	1.51	4.15	5.03	2.35	2.26	3.31
$R^2 - R^2_y$	3.81	1.01	3.40	4.08	1.00	0.09	0.03

Table 6: The predictive power of XVP and VP_{US} for exchange rate returns, pre-global financial crisis sample

This table reports the estimated coefficients for the panel-data regressions:

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{XVP}(h)XVP_t^* + b_{VP}(h)VP_{US,t}^* + u_{i,t+h},$$

where $s_{i,t}$ is the dollar exchange rate of currency i, $y_{US,t}(h) - y_{i,t}(h)$ is the interest rate differential for $h-$month zero-coupon bond rates between the United States and country i. The sample period considered runs from January 2000 to June 2008—a few months before the collapse of Lehman Brother in October 2008. To facilitate the interpretation of the estimated coefficients, we divide XVP and U.S. VP by 12. The standard errors are corrected by panel-data Newey-West with h lags (the standard deviations are reported in parenthesis). *,**, and *** represent the usual 10, 5, and 1 percent significance levels. The country-specific estimated constants are left unreported, to save space. We report the R^2 of each individual regression, and the gains in R^2s with respect to a univariate regression for the interest rate differential, $R^2 - R_y^2$.

h	1	2	3	4	6	9	12
$[y_t(h) - y_t^*(h)]$	-0.13	0.18	0.22	0.31	0.29	0.31	0.30
	(0.42)	(0.41)	(0.42)	(0.42)	(0.45)	(0.47)	(0.48)
VP_{US}	1.18^{***}	0.44^{**}	0.61^{***}	0.48^{***}	-0.17	0.27^{**}	0.64^{***}
	(0.26)	(0.20)	(0.18)	(0.17)	(0.12)	(0.11)	(0.11)
XVP	-11.54^{***}	-12.96^{***}	-12.63^{***}	-15.56^{***}	-19.00^{***}	-12.78^{***}	-14.17^{***}
	(2.10)	(1.73)	(1.47)	(1.80)	(1.96)	(1.94)	(1.75)
R^2	5.65	6.79	9.58	11.25	6.80	5.92	9.53
$R^2 - R_y^2$	5.27	6.15	8.64	9.96	4.96	2.87	4.83

Table 7: The predictive power of XVP and VP_{US} for exchange rate returns, alternative variance premium measures

This table reports the estimated coefficients for the panel-data regressions:

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{XVP2}(h)XVP_t^* + b_{VP}(h)VP_{US,t}^* + u_{i,t+h},$$

where $s_{i,t}$ is the dollar exchange rate of currency i, $y_{US,t}(h) - y_{i,t}(h)$ is the interest rate differential for $h-$month zero-coupon bond rates between the United States and country i. We consider two alternative variance risk premium measures (for VP^* and XVP^*). In panel A, $XVP2$ and $VP2_{US}$ are alternative measures for the world currency and U.S. stock variance risk premium where the expectation of the currency and stock return variance under the physical distribution, $E_t^P(\sigma_{c,t+1}^2)$ and $E_t^P(\sigma_{r,t+1}^2)$, is approximated using an AR(1) forecast of the realized variance. In panel B, $XVP3$ is an alternative world currency variance risk premium measure where the expectation of the currency return variance under the risk-neutral measure is approximated by a model-free measure using ATM and OTM option prices. The method to calculate this model-free measure is similar to that used to calculate the VIX, our proxy for the expectation of the stock return variance under the risk-neutral measure. To facilitate the interpretation of the estimated coefficients, we divide XVP and the U.S. VP by 12. The standard errors are corrected by panel-data Newey-West with h lags (the standard deviations are reported in parenthesis). *,**, and *** represent the usual 10, 5, and 1 percent significance levels. The sample period runs from January 2000 to December 2011. The country-specific estimated constants are left unreported, to save space. We report the R^2 of each individual regression, and the gains in R^2s with respect to a univariate regression for the interest rate differential, $R^2 - R_y^2$.

A. $XVP2$ and $VP2$ (AR(1) approximation of the physical variance)

h	1	2	3	4	6	9	12
$[y_t(h) - y_t^*(h)]$	−0.12	−0.10	0.01	0.32	0.45	0.32	0.22
	(0.42)	(0.41)	(0.42)	(0.43)	(0.46)	(0.46)	(0.44)
$XVP2$	−9.69***	−6.31***	−6.10***	−3.55***	0.08	2.10**	1.48
	(2.11)	(1.62)	(1.42)	(1.30)	(1.24)	(1.02)	(0.90)
$VP2_{US}$	3.88***	1.84***	2.06***	2.20***	1.58***	0.82***	0.57***
	(0.37)	(0.27)	(0.24)	(0.25)	(0.20)	(0.12)	(0.09)
R^2	7.78	4.14	6.99	7.90	5.49	4.49	4.98
$R^2 - R_y^2$	7.52	3.64	6.24	6.95	4.14	2.32	1.70

B. $XVP3$ (model-free approximation of the risk-neutral variance)

h	1	2	3	4	6	9	12
$[y_t(h) - y_t^*(h)]$	−0.16	0.27	0.39	0.61	0.85	0.85*	0.67
	(0.48)	(0.47)	(0.48)	(0.50)	(0.52)	(0.51)	(0.48)
$XVP3$	−8.90***	−11.88***	−11.41***	−10.70***	−8.84***	−4.46***	−2.18***
	(1.68)	(1.40)	(1.26)	(1.31)	(1.09)	(0.79)	(0.62)
VP_{US}	1.93***	0.51***	0.73***	0.66***	−0.04	−0.23***	−0.16**
	(0.28)	(0.19)	(0.17)	(0.15)	(0.12)	(0.08)	(0.07)
R^2	8.33	7.25	11.85	12.63	8.16	4.90	4.18
$R^2 - R_y^2$	8.07	6.75	11.09	11.68	6.81	2.73	0.90

Table 8: The predictive power of XVP and VP_{US} for exchange rate returns, developed and emerging economies

This table reports the estimated coefficients for the panel-data regression setup including the interest rate differential, the 6-month world currency variance risk premium, and the U.S. stock variance risk premium (see tables 6 and 7 and figure 3). We classify the currencies into two groups: developed and emerging economies. This classification is done according to the IMF's 2012 World Economic Outlook. The standard errors are corrected by panel-data Newey-West with h lags (the standard deviations are reported in parenthesis). *,**, and *** represent the usual 10, 5, and 1 percent significance levels. The sample period runs from January 2000 to December 2011. The country-specific estimated constants are left unreported, to save space. We report the R^2 of each individual regression, and the gains in R^2s with respect to a univariate regression for the interest rate differential.

A. Developed economies

h	1	2	3	4	5	6	9	12
$[y_t(h) - y_t^*(h)]$	−0.93	−0.52	−0.54	−0.37	−0.32	−0.39	−0.67	−0.92
	(0.62)	(0.63)	(0.65)	(0.67)	(0.70)	(0.72)	(0.70)	(0.69)
XVP	−9.64***	−11.61***	−11.80***	−11.39***	−10.60***	−9.51***	−5.08***	−2.89***
	(2.19)	(1.72)	(1.47)	(1.43)	(1.30)	(1.18)	(0.97)	(0.89)
VP_{US}	1.99***	0.59***	0.76***	0.68***	0.26**	0.08	−0.13	−0.09
	(0.34)	(0.21)	(0.16)	(0.14)	(0.11)	(0.11)	(0.09)	(0.08)
R^2	7.03	5.94	10.08	11.33	9.55	8.89	5.96	6.02
$R^2 - R_y^2$	6.73	5.38	9.22	10.27	8.23	7.27	3.04	1.43

B. Emerging economies

h	1	2	3	4	5	6	9	12
$[y_t(h) - y_t^*(h)]$	−0.25	−0.07	−0.05	−0.02	0.00	−0.04	−0.05	0.04
	(0.54)	(0.50)	(0.49)	(0.49)	(0.49)	(0.50)	(0.51)	(0.49)
XVP	−8.99**	−10.46***	−10.93***	−10.29***	−10.01***	−9.03***	−5.64***	−4.12***
	(3.52)	(3.02)	(2.64)	(2.54)	(2.33)	(2.03)	(1.33)	(1.08)
VP_{US}	1.83***	0.75**	1.02***	0.96***	0.50	0.30	−0.08	−0.09
	(0.50)	(0.34)	(0.37)	(0.36)	(0.32)	(0.27)	(0.17)	(0.13)
R^2	5.77	5.07	9.42	10.35	8.14	7.11	4.39	4.43
$R^2 - R_y^2$	5.63	4.78	8.99	9.81	7.51	6.40	3.26	2.63

Table 9: The predictive power of XVP for exchange rate returns, individual-currency regressions

This table reports the estimated coefficients for the following individual-currency regressions:

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{i,IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{i,XVP}(h)XVP_t + u_{i,t+h},$$

where $s_{i,t}$ is the dollar exchange rate of currency i, $y_{US,t}(h) - y_{i,t}(h)$ is the interest rate differential for $h-$month zero-coupon bond rates between the United States and country i, and XVP is the 6-month world currency variance premium (see table 2). To facilitate the interpretation of the estimated coefficients, we divide XVP by 12. The standard errors are corrected by Newey-West with h lags (the standard deviations are left unreported, to save space). *,**, and *** represent the usual 10, 5, and 1 percent significance levels. The sample period runs from January 2000 to December 2011. The estimated regression currency-specific constants are also left unreported, to save space. We report the R^2 of the regression and the gains in R^2s with respect to a univariate regression for the interest rate differential, $R^2 - R^2_y$.

	h	1	2	3	4	6	9	12
EUR	XVP	-10.67^{**}	-10.48^{***}	-12.10^{***}	-11.47^{***}	-9.42^{***}	-2.59^{**}	0.86
	R^2	1.89	3.54	7.29	8.21	8.71	1.11	0.20
	$R^2 - R^2_y$	1.88	3.53	7.27	8.17	8.69	1.11	0.19
JPY	XVP	5.23	1.71	-0.30	-2.00	-2.18	0.31	0.88
	R^2	3.05	4.70	7.19	9.66	17.40	34.08	37.69
	$R^2 - R^2_y$	0.58	0.13	0.01	0.34	0.66	0.02	0.24
GBP	XVP	-11.88^{*}	-15.15^{***}	-15.76^{***}	-14.59^{***}	-9.52^{***}	-3.17^{*}	-1.11
	R^2	3.64	11.00	16.78	17.06	12.32	4.20	2.33
	$R^2 - R^2_y$	3.48	10.14	14.92	14.35	8.05	1.34	0.24
CHF	XVP	-5.97	-6.59	-8.02^{**}	-8.12^{**}	-5.66^{**}	-0.61	1.17
	R^2	0.86	2.16	4.14	5.22	5.76	3.16	4.28
	$R^2 - R^2_y$	0.54	1.44	3.46	4.53	3.99	0.09	0.47
AUD	XVP	-21.25^{***}	-20.47^{***}	-20.51^{***}	-19.70^{***}	-15.20^{***}	-9.14^{***}	-6.13^{**}
	R^2	4.76	7.99	11.66	13.13	11.28	6.23	4.51
	$R^2 - R^2_y$	4.72	7.99	11.66	12.87	10.61	6.13	4.51
CAD	XVP	-13.19^{*}	-13.23^{***}	-12.03^{***}	-12.44^{***}	-9.53^{***}	-6.15^{***}	-5.21^{***}
	R^2	4.04	8.51	10.80	15.05	11.77	7.61	8.09
	$R^2 - R^2_y$	3.79	8.06	10.20	14.09	11.08	7.43	8.07
HKD	XVP	-0.12	-0.13	-0.11	-0.06	-0.02	0.04	0.06
	R^2	1.65	1.31	1.02	0.88	0.13	0.77	2.12
	$R^2 - R^2_y$	0.12	0.28	0.33	0.16	0.03	0.24	0.79
SEK	XVP	-14.14^{*}	-15.40^{***}	-15.78^{***}	-16.53^{***}	-13.49^{***}	-5.78^{**}	-3.09
	R^2	2.62	5.79	8.93	11.67	10.24	2.87	1.87
	$R^2 - R^2_y$	2.62	5.78	8.91	11.64	10.22	2.84	1.26
NZD	XVP	-23.28^{***}	-24.20^{***}	-24.85^{***}	-23.90^{***}	-17.30^{***}	-10.02^{***}	-6.28^{***}
	R^2	5.61	11.30	17.80	18.67	13.96	7.48	4.56
	$R^2 - R^2_y$	5.52	11.12	17.44	18.17	13.10	6.54	3.84

Table 9: The predictive power of XVP for exchange rate returns, individual-currency regressions (continued)

	h	1	2	3	4	6	9	12
KRW	XVP	−19.39	−15.56***	−14.79***	−15.17***	−11.79***	−9.32***	−6.86***
	R^2	5.57	8.11	11.78	14.42	11.17	8.75	5.96
	$R^2 - R_y^2$	5.06	6.63	9.55	11.89	9.57	8.14	5.61
SGD	XVP	−4.83	−4.59*	−5.49***	−5.47***	−3.96***	−1.89*	−1.07
	R^2	2.00	4.05	8.63	9.92	9.37	8.32	10.25
	$R^2 - R_y^2$	1.35	2.66	6.24	7.58	6.23	2.25	1.10
NOK	XVP	−15.88***	−15.44***	−14.60***	−13.56***	−11.54***	−5.88***	−2.62**
	R^2	3.64	6.40	8.18	8.71	9.35	4.25	1.24
	$R^2 - R_y^2$	3.63	6.27	7.94	8.35	8.81	3.72	1.23
INR	XVP	−1.67	−4.58	−4.47	−4.18*	−4.11***	−3.88***	−3.61***
	R^2	8.60	16.36	21.51	24.47	24.24	22.22	18.82
	$R^2 - R_y^2$	0.12	1.52	2.09	2.22	3.09	3.85	4.37
PLN	XVP	−15.54	−15.89***	−19.33***	−20.64***	−17.26***	−8.16***	−4.05**
	R^2	2.71	4.82	9.26	11.73	10.76	4.77	3.33
	$R^2 - R_y^2$	2.17	3.89	8.05	10.60	9.68	3.49	1.58
ZAR	XVP	−31.93***	−29.09***	−27.57***	−24.75***	−16.39***	−11.36***	−9.92***
	R^2	8.20	13.29	17.95	18.71	17.03	22.04	24.00
	$R^2 - R_y^2$	6.66	10.26	13.25	13.11	8.18	6.34	6.16
CZK	XVP	−16.59**	−16.33***	−18.58***	−17.46***	−13.23***	−3.64	−1.39
	R^2	3.25	6.05	11.82	12.98	11.75	4.04	6.88
	$R^2 - R_y^2$	3.12	5.79	11.41	12.20	10.63	1.37	0.36
DKK	XVP	−11.14**	−10.83***	−12.45***	−11.86***	−9.67***	−2.66**	0.84
	R^2	2.03	3.76	7.68	8.79	9.14	1.18	0.20
	$R^2 - R_y^2$	2.03	3.74	7.64	8.68	9.08	1.17	0.18
THB	XVP	−4.13	−4.82**	−4.94***	−4.88***	−4.10**	−2.39**	−2.10**
	R^2	2.42	5.23	7.88	9.51	13.69	14.35	16.34
	$R^2 - R_y^2$	0.95	2.29	3.43	3.99	4.03	2.12	2.41
TWD	XVP	−3.77	−5.08**	−5.20***	−5.11***	−3.95***	−3.27**	−2.13
	R^2	1.15	3.42	5.11	6.15	5.54	6.38	4.09
	$R^2 - R_y^2$	1.14	3.42	5.11	6.14	5.49	6.00	4.00
HUF	XVP	−20.86**	−18.86***	−24.38***	−23.49***	−18.56***	−6.82***	−3.27
	R^2	4.40	6.42	13.37	14.59	13.37	3.00	1.73
	$R^2 - R_y^2$	3.44	5.08	12.38	13.75	12.60	2.88	1.20
MYR	XVP	−2.21	−2.60	−2.61	−2.81	−2.27	−2.07	−2.29*
	R^2	0.91	2.58	3.80	5.16	4.21	4.04	5.32
	$R^2 - R_y^2$	0.41	1.24	2.03	2.84	2.60	3.10	5.26
PHP	XVP	0.11	−0.15	−0.11	−0.46	−1.90	−2.58	−2.39*
	R^2	0.00	0.28	0.63	1.29	3.90	5.04	7.30
	$R^2 - R_y^2$	0.00	0.00	0.00	0.03	0.64	1.59	1.90
$Avg.R^2$		**3.32**	**6.23**	**9.69**	**11.18**	**10.69**	**8.00**	**7.78**
$Avg.(R^2 - R_y^2)$		**2.42**	**4.60**	**7.42**	**8.44**	**7.14**	**3.26**	**2.50**

Table 10: The predictive power of VP_{US} for exchange rate returns, individual-currency regressions

This table reports the estimated coefficients for the following individual-currency regressions:

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{i,IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{i,VP}(h)VP_{US,t} + u_{i,t+h},$$

where $s_{i,t}$ is the dollar exchange rate of currency i, $y_{US,t}(h) - y_{i,t}(h)$ is the interest rate differential for $h-$month zero-coupon bond rates between the United States and country i, and VP_{US} is the 1-month U.S. stock variance risk premium. To facilitate the interpretation of the estimated coefficients, we divide U.S. VP by 12. The standard errors are corrected by Newey-West with h lags (the standard deviations are left unreported, to save space). *,**, and *** represent the usual 10, 5, and 1 percent significance levels. The sample period runs from January 2000 to December 2011. The estimated regression currency-specific constants are also left unreported in order to save space. We report the R^2 of the regression and the gains in R^2s with respect to a univariate regression for the interest rate differential, $R^2 - R^2_y$.

	h	1	2	3	4	6	9	12
EUR	VP_{US}	1.94	0.12	0.48	0.64**	0.05	−0.19	−0.15
	R^2	4.46	0.04	0.83	1.83	0.04	0.41	0.39
	$R^2 - R^2_y$	4.45	0.03	0.81	1.79	0.01	0.41	0.37
JPY	VP_{US}	−1.49***	−1.10**	−0.60	−0.22	0.01	0.09	0.04
	R^2	5.91	8.50	8.96	9.62	16.74	34.19	37.48
	$R^2 - R^2_y$	3.44	3.93	1.77	0.30	0.00	0.13	0.04
GBP	VP_{US}	2.43***	1.51***	1.45***	1.28***	0.57**	0.08	0.13
	R^2	10.56	8.04	10.78	10.55	6.16	2.92	2.30
	$R^2 - R^2_y$	10.40	7.17	8.92	7.84	1.89	0.05	0.20
CHF	VP_{US}	2.26**	0.08	0.51	0.65**	0.16	−0.01	0.06
	R^2	5.90	0.74	1.67	2.76	1.99	3.07	3.90
	$R^2 - R^2_y$	5.58	0.02	0.99	2.07	0.22	0.00	0.09
AUD	VP_{US}	3.54**	1.49*	1.62***	1.34***	0.45	−0.17	−0.20
	R^2	9.44	3.04	5.25	4.50	1.27	0.24	0.33
	$R^2 - R^2_y$	9.40	3.03	5.25	4.24	0.60	0.14	0.33
CAD	VP_{US}	2.20**	1.02**	1.14***	0.95***	0.44*	−0.03	−0.08
	R^2	7.82	3.86	7.11	6.81	2.27	0.20	0.14
	$R^2 - R^2_y$	7.57	3.41	6.51	5.86	1.58	0.02	0.13
HKD	VP_{US}	0.00	−0.01	0.00	−0.01	−0.01	0.00	0.00
	R^2	1.55	1.13	0.70	0.82	0.45	0.53	1.35
	$R^2 - R^2_y$	0.02	0.10	0.00	0.10	0.35	0.00	0.01
SEK	VP_{US}	3.14***	1.66***	1.77***	1.73***	0.79***	0.17	0.18
	R^2	9.21	4.81	8.04	9.11	2.32	0.19	0.89
	$R^2 - R^2_y$	9.21	4.80	8.02	9.08	2.31	0.17	0.28
NZD	VP_{US}	4.29***	2.15***	2.29***	2.06***	0.83*	0.03	−0.07
	R^2	13.35	6.37	10.78	9.97	2.79	0.94	0.75
	$R^2 - R^2_y$	13.26	6.19	10.42	9.47	1.93	0.00	0.03

Table 10: The predictive power of VP_{US} for exchange rate returns, individual-currency regressions (continued)

	h	1	2	3	4	6	9	12
KRW	VP_{US}	3.18***	1.20	1.17***	1.24***	0.32	0.09	0.01
	R^2	10.14	4.28	6.47	8.08	2.06	0.66	0.35
	$R^2 - R_y^2$	9.63	2.80	4.23	5.54	0.46	0.05	0.00
SGD	VP_{US}	1.36*	0.33	0.62***	0.62***	0.27***	0.11**	0.08
	R^2	8.43	2.39	8.11	9.40	5.00	6.62	9.58
	$R^2 - R_y^2$	7.78	1.00	5.72	7.05	1.87	0.55	0.43
NOK	VP_{US}	2.79***	1.22**	1.11***	0.89***	0.23	−0.02	−0.11
	R^2	8.01	2.93	3.51	2.94	0.77	0.53	0.14
	$R^2 - R_y^2$	8.00	2.80	3.27	2.57	0.23	0.00	0.13
INR	VP_{US}	0.82	0.03	0.28	0.40	0.15	−0.08	−0.14
	R^2	10.65	14.84	20.04	23.73	21.40	18.48	14.92
	$R^2 - R_y^2$	2.17	0.00	0.62	1.49	0.26	0.11	0.47
PLN	VP_{US}	4.27***	2.70***	3.18***	3.09***	1.69***	0.39	0.21
	R^2	12.50	9.14	17.09	18.31	7.23	1.82	2.05
	$R^2 - R_y^2$	11.97	8.21	15.87	17.18	6.15	0.55	0.29
ZAR	VP_{US}	3.08**	1.53*	1.60***	1.03**	−0.03	−0.36	−0.25
	R^2	5.93	5.05	7.86	7.19	8.84	16.12	18.10
	$R^2 - R_y^2$	4.39	2.02	3.16	1.60	0.00	0.42	0.26
CZK	VP_{US}	3.34***	1.75***	1.96***	2.03***	0.78***	0.10	0.10
	R^2	9.20	5.07	9.51	12.65	3.53	2.74	6.66
	$R^2 - R_y^2$	9.07	4.80	9.10	11.88	2.41	0.07	0.14
DKK	VP_{US}	1.97*	0.10	0.47	0.63*	0.03	−0.20	−0.15
	R^2	4.51	0.04	0.82	1.82	0.07	0.45	0.40
	$R^2 - R_y^2$	4.51	0.02	0.78	1.71	0.01	0.45	0.38
THB	VP_{US}	1.06***	0.61***	0.57***	0.71***	0.43***	0.23**	0.18
	R^2	5.88	5.55	7.68	11.52	12.53	13.53	15.06
	$R^2 - R_y^2$	4.41	2.62	3.23	6.01	2.87	1.29	1.13
TWD	VP_{US}	1.11**	0.65**	0.70***	0.69***	0.34*	0.21	0.15
	R^2	7.13	4.04	6.53	8.02	2.75	2.08	1.45
	$R^2 - R_y^2$	7.12	4.04	6.53	8.01	2.70	1.70	1.36
HUF	VP_{US}	3.31**	1.66**	2.42***	2.55***	1.11***	0.06	0.06
	R^2	7.66	4.41	10.53	13.56	4.02	0.14	0.56
	$R^2 - R_y^2$	6.69	3.08	9.54	12.73	3.25	0.02	0.03
MYR	VP_{US}	1.23**	0.34	0.58***	0.57***	0.26*	0.16	0.05
	R^2	9.62	2.89	9.11	10.85	3.91	2.15	0.22
	$R^2 - R_y^2$	9.12	1.54	7.35	8.53	2.30	1.22	0.17
PHP	VP_{US}	0.40	0.00	0.22	0.28	0.30	0.18	0.11
	R^2	0.48	0.28	1.02	1.96	4.25	3.98	5.68
	$R^2 - R_y^2$	0.47	0.00	0.39	0.70	0.99	0.53	0.28
Avg.R2		**7.65**	**4.43**	**7.38**	**8.45**	**5.02**	**5.09**	**5.58**
Avg.(R2 − R2$_y$)		**6.76**	**2.80**	**5.11**	**5.72**	**1.47**	**0.36**	**0.30**

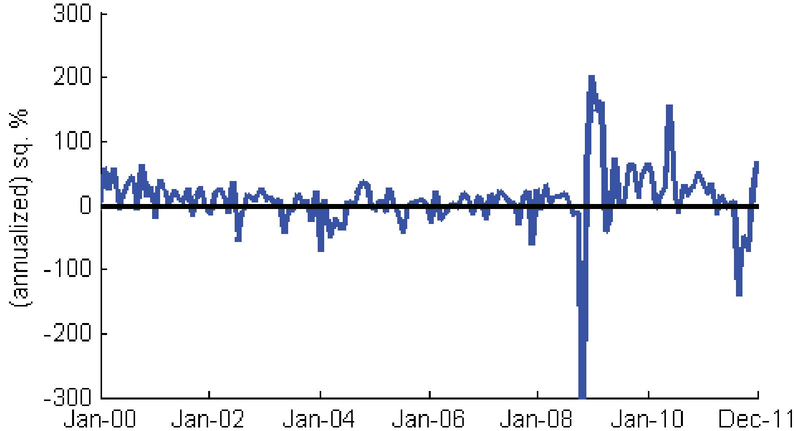
Table 11: Understanding global/currency-specific uncertainty, variables with explanatory power for XVP

This table reports the results for the following regression:

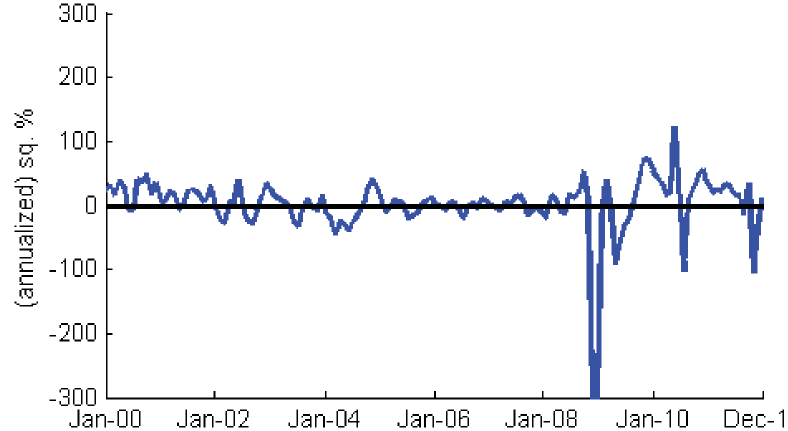
$$XVP_t = b_0 + b_x x_{i,t} + b_{VP} VP_{US,t} + b_{(-1)} XVP_{t-1} + u_t,$$

where x_i is each one of the variables in appendix C. We report the estimated coefficients associated with each variable and their standard deviations, in parenthesis. The standard errors are corrected by Newey-West with 3 lags. We also report the R^2 for a regression without control variables (that is, $XVP_{i,t} = b_0 + b_x x_{i,t} + u_t$).

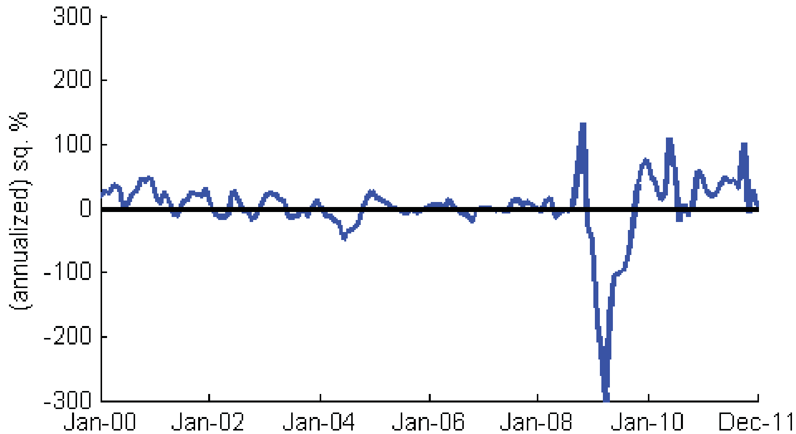
Variable	Coefficient	St. dev.	R^2
Stock market tail risk			
10% COI drops	14.40***	(6.48)	51.02
10% COI increases	13.12**	(7.45)	50.11
VIX	16.30***	(6.59)	56.28
World IV	11.64**	(5.79)	40.57
Fund flows			
Equity US	−5.82*	(3.55)	0.38
Equity AFE	−6.67***	(2.50)	4.65
Equity EMASIA	−5.05	(3.09)	1.85
Equity LATAM	−3.98	(3.45)	2.59
Bonds US	16.57***	(4.16)	1.85
Bonds AFE	−5.12	(5.39)	0.96
Bonds EMASIA	−13.41***	(3.81)	9.21
Bonds LATAM	−13.22**	(4.27)	12.38
Carry-trade strategies			
World IRDIFF(6)	−5.81***	(2.01)	14.40
AFE IRDIFF(6)	−5.06**	(1.84)	10.83
EME IRDIFF(6)	−6.48***	(2.23)	17.90
World carry (6)	−3.54**	(1.02)	4.00
AFE carry (6)	−3.59**	(1.13)	4.43
EME carry (6)	−2.61*	(1.33)	0.95
Currency tail risk			
World XIV(6)	38.86***	(7.10)	84.28
AFE XIV(6)	38.07***	(6.99)	83.44
EME XIV(6)	27.50***	(7.24)	76.05
World 10 RR(6)	33.33***	(7.83)	73.47
AFE 10 RR(6)	16.15***	(5.72)	42.23
EME 10 RR(6)	47.60***	(8.25)	82.89



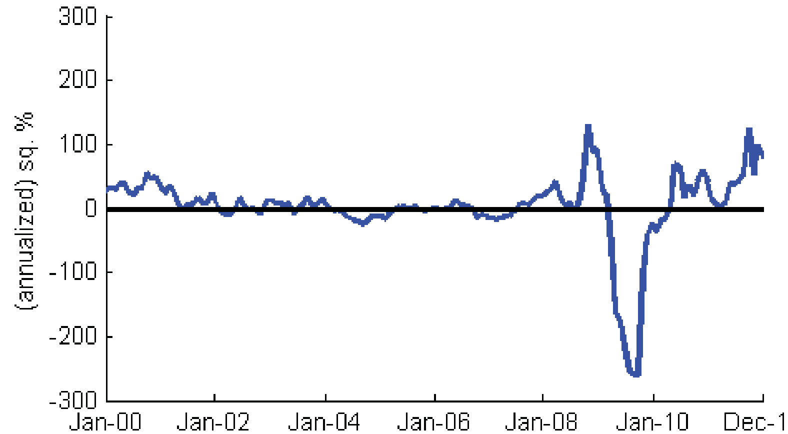
A. World XVP(1)



B. World XVP(3)



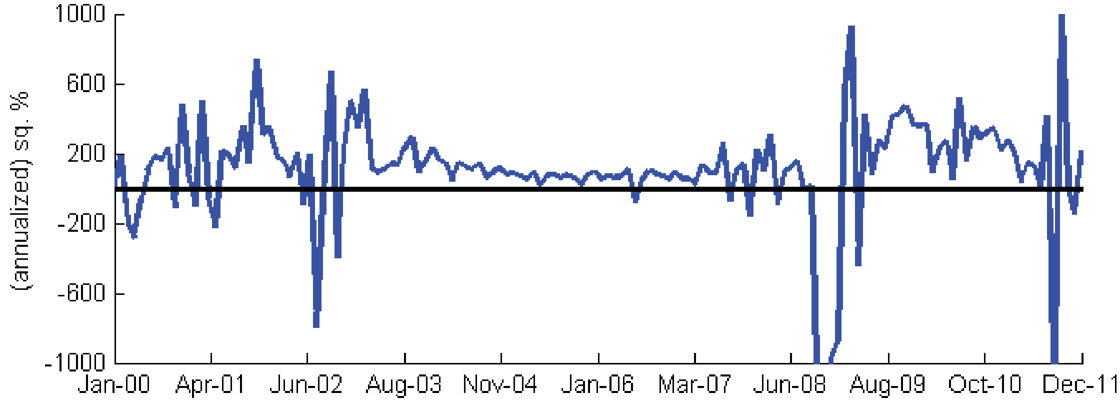
C. World XVP(6)



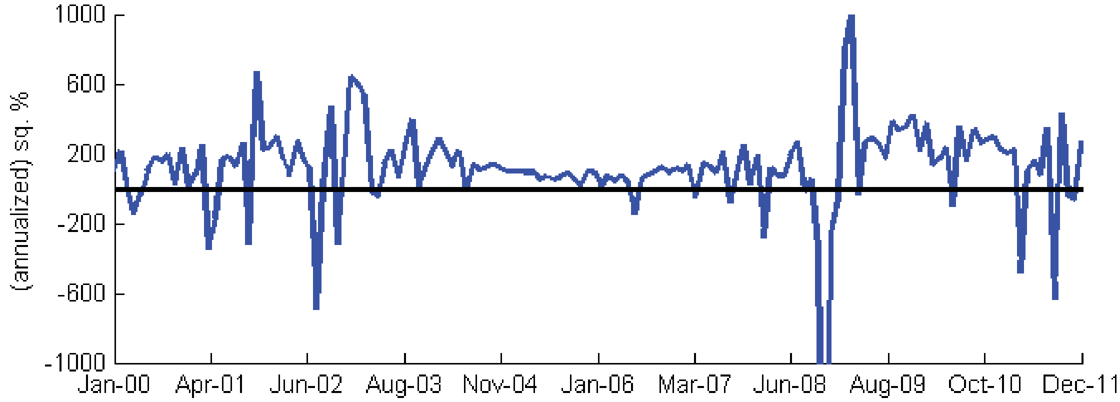
D. World XVP(12)

Figure 1: Currency variance risk premiums

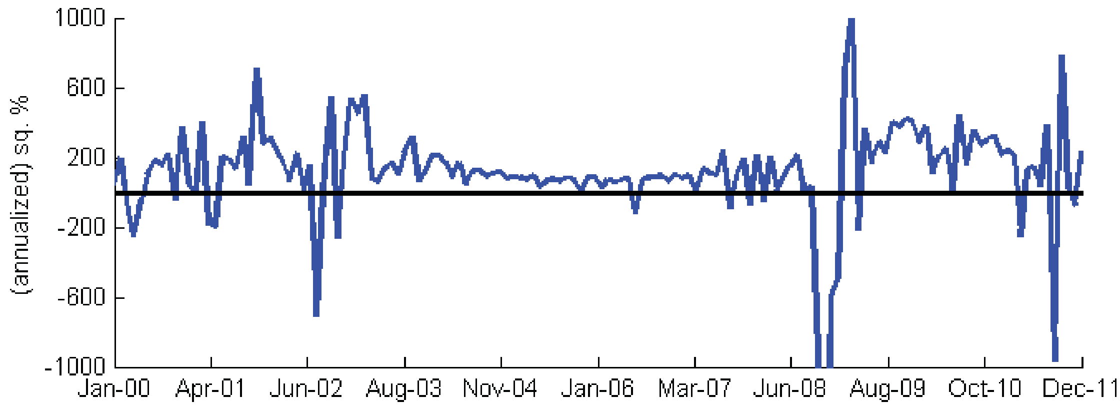
The figure shows the 1-, 3-, 6-, and 12-month world currency variance risk premium in panels A to D, respectively. The world currency variance risk premiums are calculated as the equal-weighted average of the variance risk premiums of 18 currencies with respect to the U.S. dollar (see table 2) at each horizon.



A. VP_{US}



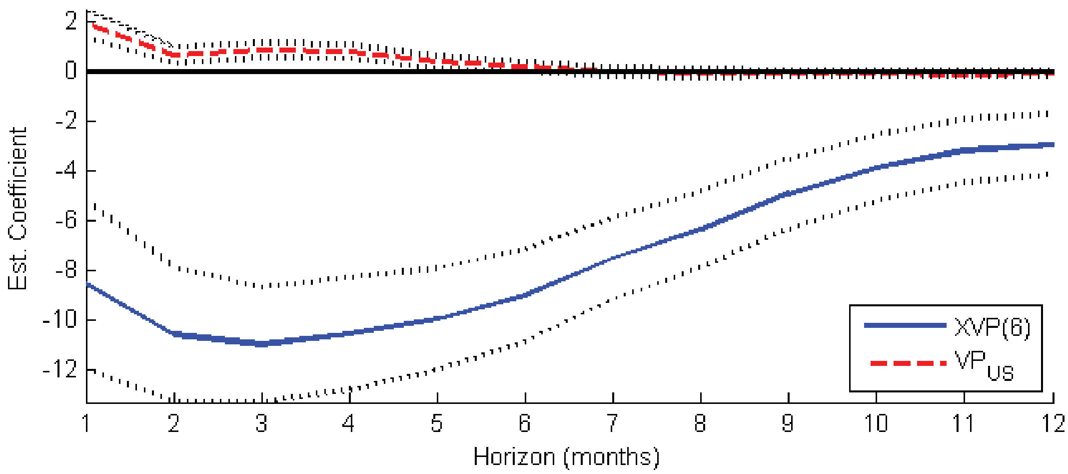
B. *EW world VP*



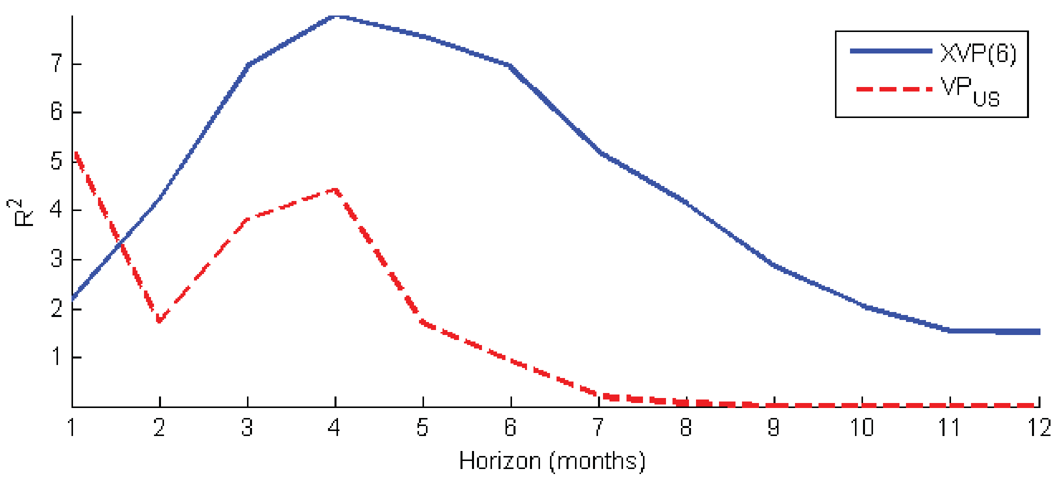
C. *VW world VP*

Figure 2: Stock variance risk premiums

The figure shows the stock variance risk premiums measured as the difference between the squared of the (model-free) implied volatility and the realized stock return variance. We report the U.S. variance risk premium and the equal- and value-weighted average variance risk premiums in panels A, B, and C, respectively (see table 3).



A. Estimated regression coefficients



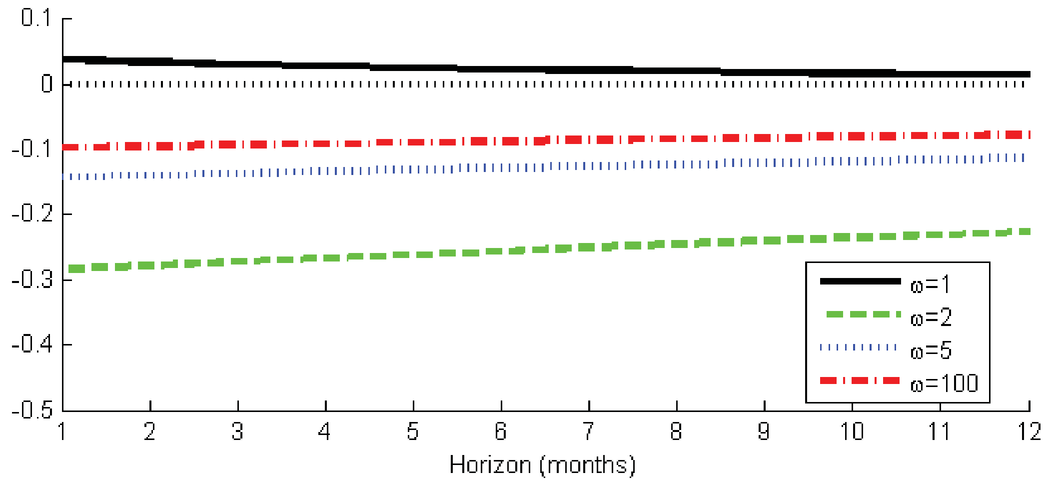
B. Gains in R^2

Figure 3: The predictive power of currency and stock variance risk premiums, predictability patterns

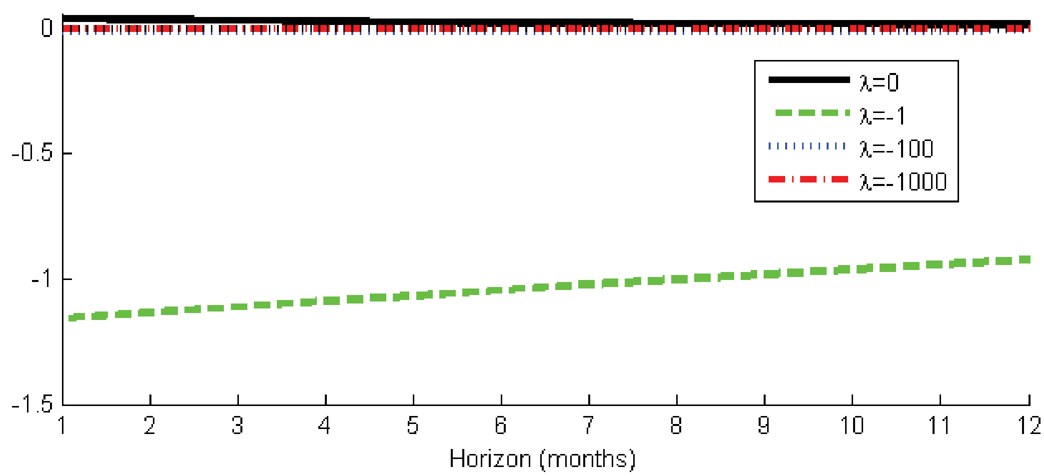
The figure shows a comparison between the predictive power for forex return of the world currency variance risk premium and that of the U.S. stock variance risk premium. Panel A shows the estimated coefficients associated with XVP (the bold line) and VP_{US} (the dashed line) in the following regression setup:

$$s_{i,t+h} - s_{i,t} = b_{i,0}(h) + b_{IR}(h)[y_{US,t}(h) - y_{i,t}(h)] + b_{XVP}(h)XVP_t + b_{VP}(h)VP_{US,t} + u_{i,t+h}.$$

In this panel, the dotted lines represent the 95 pecent confidence intervals for each estimated coefficient. Panel B compares the gains in R^2s from two separate regressions where the interest rate differential and either XVP (the bold line) or VP_{US} (the dashed line) are included.



A. ω



B. λ

Figure B.1: Sensitivity of the model-implied predictability of currency variance risk premium to ω and λ

The figure shows the regression coefficients for the predictive power of the dollar/EUR variance risk premium for the dollar/EUR appreciation rate implied by our model for alternative values of ω, the parameter driving the heterogeneous exposure of the U.S. and German economies to the global or currency specific uncertainty, and λ, the parameter driving the additional price of risk that U.S. investors give to the global or currency-specific uncertainty, in panels A and B, respectively. The predictability patterns are calculated using the parameters and expressions in appendix B.