The Share of Systematic Variation in Bilateral Exchange Rates *

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Abstract

Changes in exchange rates are not random. Two economically motivated factors account for 20% to 90% of the daily, monthly, quarterly, and annual exchange rate movements in developed countries and in emerging and developing countries with floating exchange rates. The different shares of systematic variation across currencies are related to financial and macroeconomic measures of world integration. Across countries, the more integrated the equity and bond markets, the higher the share of systematic currency variation. These results have direct implications for asset managers, motivate further work on exchange rates, and offer new insights into international economics and finance models.

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Changes in exchange rates appear random to most investors, central bankers, and researchers alike, except perhaps at very high or very low frequencies. Hundreds of studies report low R^2s in regressions of changes in individual exchange rates on lagged or contemporaneous interest rate differences or other macroeconomic variables at monthly, quarterly, and annual frequencies. As a result, each individual exchange rate movement seems mostly idiosyncratic.

Recent research, however, has uncovered common risk factors in *portfolios* of currency excess returns sorted on interest rates. Unfortunately, currency portfolios by construction do not tell us much about the share of systematic versus idiosyncratic variation in *each* currency pair: portfolios of currencies are built in order to average out idiosyncratic components and to focus only on systematic risk. The key question now is: What share of individual bilateral exchange rate variances do common factors account for? In other words, do common factors explain much of the changes in the U.S. dollar / U.K. pound exchange rate, for example? This is the first question that this paper addresses.

Many economists would assume that common factors only account for a tiny share of the changes in bilateral exchange rates. Most previous research point in this direction. In the classic uncovered interest rate parity (UIP) tests, for example, monthly changes in bilateral exchange rates are regressed on a constant and the interest rate difference between two countries. R^2s on UIP regressions range from -0.5% to 1.7% on monthly series over the 1983–2010 period. Contemporaneous macroeconomic variables, like industrial production and inflation, generally do not fare better, leading to low or even negative adjusted R^2s over the same period.

In this paper, to the contrary, I find that two factors — the dollar and the carry factors — account for a substantial share of individual exchange rate time-series in developed countries. These two factors are constructed from portfolios of currencies. The dollar factor corresponds to the average change in the exchange rate between the U.S. dollar and all other currencies, while the carry risk factor corresponds to the change in exchange rates between baskets of high and low interest rate currencies. I augment the UIP regressions with additional explanatory variables, first adding the carry factor, and the same carry factor multiplied by the country-specific interest rate difference; the latter is referred to as the "conditional carry" factor. The dollar factor is the last additional explanatory variable. The change in bilateral exchange rate on the left hand side of these regressions is measured between t and $t+1$; on the right hand side, the carry and dollar factors correspond to changes between t and $t+1$ too, while the domestic and foreign interest rates correspond to risk-free loans over the same period and are thus known at date t. Importantly, the carry and dollar factors do not include the bilateral exchange rate that is the dependent variable.

The augmented-UIP regressions offer a novel picture of bilateral exchange rate movements. U.S.-based exchange rates tend to move in sync, and thus the dollar factor accounts for a large share of their time-series. Exchange rates also respond to the unconditional and conditional carry risk factors: the higher the interest rate, the higher the loading on the carry risk factor. Each of these factors raises the adjusted R^2s of the usual UIP or macroeconomic regressions by an order of magnitude. Adding the carry factors to the standard UIP regressions, the adjusted R^2s increases to 0% to 25%. With the dollar factor, R^2s increase further: as an example, the augmented-UIP regression for the U.S. dollar / U.K. pound exchange rate has an R^2 of 56%. Crucially, the augmented-UIP regressions uncover large differences in the shares of systematic variation: they range from 22% to 93% in developed countries and from 14% to 77% among developing countries with floating currencies.

The substantial R^2s of the augmented-UIP regressions do not imply that bilateral exchange rates are easy to forecast: the corresponding regressions use contemporaneous variables, not predictive ones. But if exchange rate movements were independent, the R^2s on the augmented-UIP regressions would be zero. In the data, they are significantly different from zero. They are also significantly higher than the expected R^2s obtained by regressing one currency on any other. In other words, the correlation between each currency movements and the carry and dollar factors is much higher than the average pairwise correlation. Moreover, the R^2s on the augmented-UIP regressions appear quite stable across frequencies; similar results appear at daily, monthly, quarterly, and annual frequencies.

The carry and dollar factor thus offer a powerful and intuitive description of individual currencies. The intuition comes from the risk-based approach to exchange rates: according to the risk logic, average currency excess returns should correspond to covariances between returns and risk factors. Previous research shows that the logic applies to the carry factor: its covariances with portfolios of currency excess returns sorted on interest rates account for the cross-section of average excess returns on those portfolios. Similarly, the dollar factor has a potential risk-based interpretation. Portfolios of countries sorted on their time-varying exposures to the dollar factor deliver a novel cross-section of currency excess returns. Conditioning on the average forward discount, covariances of the dollar factor with portfolio returns account for this new cross-section of average excess returns. Alternative interpretations of the carry and dollar factor remain possible, but this paper pursues the risk-based approach. If the carry and dollar factor measures risk, then what drives the large differences in systematic currency risk that the augmented-UIP R^2s uncover? This is the subsequent question that this paper addresses.

I find that the share of systematic risk in currency markets is related to world market integration. This finding is intuitive in a risk-based approach to exchange rates: in the class of no-arbitrage models, log changes in exchange rates correspond to the differences between domestic and foreign log pricing kernels (also known as stochastic discount factors or inter-temporal marginal rates of substitution). As a result, cross-country differences in currency R^2s come ultimately from differences in foreign pricing kernels, and thus should appear in other markets. This is indeed the case: the results show that, over the last ten years, countries with a high share of systematic equity risk also have a high share of systematic currency risk. Similarly, higher shares of systematic currency risk correspond to higher shares of fixed income risk. R^2s on currencies also appear related to macroeconomic measures of world integration, based on output and consumption growth rates. These findings highlight a novel link across asset markets. They also point towards currency markets as potential measures of world integration: unlike macroeconomic series, they are precisely estimated and available at high frequencies. Unlike equity returns, R^2s on currencies do not depend on the properties of the domestic and foreign dividend cash flows; they thus offer a more direct approach to international risk sharing and the properties of the one-period pricing kernels.

In the class of no-arbitrage models, the shares of systematic variation in currency markets depend on the relative importance of the global vs. domestic shocks in the pricing kernels. The intuition is simple. Without loss of generality, each pricing kernel can be decomposed into country-specific and world shocks. Bilateral exchange rates thus depend on (home minus foreign) differences in country-specific and world shocks. In large baskets of currencies, foreign country-specific shocks average out. As a result, the dollar factor (which is the average of all the domestic minus foreign pricing kernels) depends on both U.S.-specific and world shocks, but not on foreign-specific shocks. The carry factor, defined as a difference in baskets of exchange rates, is dollar-neutral and accounts for world shocks, provided that pricing kernels differ in their exposure to world shocks. Comparing UIP regressions with and without the carry and dollar factors is thus informative about the relative volatility of the country-specific and world components of the pricing kernel. If all shocks to the foreign pricing kernels were global, then the carry and dollar factors would perfectly account for all the changes in exchange rates. If all shocks to the pricing kernels were local, then the carry factors would be insignificant, the dollar factor would account for U.S.-specific shocks, and all the R^2s would be the same across countries. The data suggest otherwise, and augmented-UIP regressions offer a set of useful additional moments to match. They can help pin down hard-to-measure parameters (linked to, for example, the long run risk common component of stochastic discount factors or the time-varying world disaster probabilities), which are at the heart of recent models in international finance.

The findings in this paper are of importance for academics and practitioners alike. For researchers, they motivate the study of systematic components in exchange rates, since those components account for a large share of bilateral exchange rate movements. The augmented-UIP regressions are also of importance for international economists who want to link the deep characteristics of each economy to the behavior of its exchange rate. The heterogeneity and time-variation in loadings, along with the implied cross-country differences in predictability, offer new potential targets for future models in international economics. Finally, for macroeconomists, the augmented-UIP regressions suggest revisiting the links between monetary and fiscal policies and exchange rates. All the previous UIP regressions in the literature are misspecified and suffer from an omitted variable bias because the conditional carry and dollar risk factors comove with interest rate differences.

For practitioners, the results of the augmented-UIP regressions simplify portfolio allocation problems. As an example, a mean-variance investor allocating resources among, for example, 10 currencies would need to estimate the inverse of a three by three (instead of a 10 by 10) covariance matrix. More generally, the findings in this paper stress the need for currency risk management at the aggregate level. It would clearly be suboptimal to measure and hedge the risk of each individual currency in a world with large common variations across currencies. As an example, the results imply a clear difference between a basket of currency options and an option on a basket of currencies. The results are also relevant for asset managers of international stocks and bonds who do not hedge their returns for currency risk or who want to design the optimal currency hedge to their portfolios (see Campbell, de Medeiros, and Viceira, 2010). Many asset managers assume that changes in exchange rates are independent and random: under this assumption, then buying stocks in many different currencies would offer a simple diversification mechanism of currency risk. This paper, however, shows that such diversification is wishful thinking. Diversification only helps to accommodate a fraction of exchange rate variations. By considering the effect of the dollar, carry, and conditional carry factors on their portfolios, asset managers can better hedge their investments.

The paper is organized as follows. The rest of the introduction reviews the related literature. Section 1 reviews the related literature. Section 2 presents the data and common factors. Section 3 shows that the dollar and carry risk factors explain a large share of bilateral exchange rates. Section 4 compares the shares of currency systematic variations to measures of world market integration. Section 5 relates the previous findings to recent models in international finance. Section 6 considers several robustness checks and extensions. Section 7 concludes and ends with some suggestions for future research, building on the heterogeneity in exchange rate responses. These suggestions echo Cochrane (2011) who notes the need to study asset pricing not only at the portfolio-level but also at the asset-level. The carry and dollar factors are available online and thus the results in this paper can be easily checked.

1 Related Literature

Numerous studies in the 70s and early 80s report large R^2s in regressions of *levels* of exchange rates on various macroeconomic variables [see, for example, Frankel (1979) and Hooper and Morton (1982)]. But both sides of those regressions feature highly persistent variables, and in-sample fits do not lead to out-of-sample accurate predictions. Meese and Rogoff (1983) show that a large class of models fails to outperform the random walk in forecasting changes in exchange rates for individual currency pairs out-of-sample. Since Meese and Rogoff (1983), the standard view in international economics is that individual exchange rates follow random walks, with perhaps small departures from random walks at very high frequencies (Evans and Lyons, 2005). Engel and West (2005) show that exchange rates are very close to random walks when fundamentals are not stationary and risk premia are constant. The findings of this paper, which pertain to *changes* in exchange rates, are not inconsistent with the random walk view of exchange rates: the common shocks that account for each currency pair could be random walks. The dollar, conditional, and unconditional carry factors are not persistent variables. In other words, each currency pair may follow a random walk whose shocks are highly correlated across countries, thus explaining the comovement among currencies. Unlike the exchange rate regressions of the 70s and early 80s, the findings in this paper do not pertain to exchange rate levels and persistent regressors: the (absolute value of) first order auto-correlation of bilateral exchange rates is 0.06 on average among developed countries, while it is 0.9, 0.11 and 0.11 for the benchmark dollar, conditional carry, and unconditional carry factors.

This paper is related to principal component analyses of exchange rates: the dollar factor is close to the first principal component, although the carry factors are different from the other principal components. Early examples of principal component analyses include Diebold and Nerlove (1989) who propose a multivariate latent-variable model of seven currencies in which the common factor displays ARCH. Bollerslev (1990) estimate a GARCH model with constant conditional correlation on a set of five weekly exchange rates. More recently, Engel, Mark, and West (2009) propose a principal component decomposition of exchange rates and use the components to predict bilateral exchange rates. None of these papers reports the share of common variation of each currency pair. This paper focuses instead on two economically motivated factors, which account for the cross-section of currency excess returns and have a natural interpretation in any no-arbitrage model.

Although this paper builds on Lustig, Roussanov and Verdelhan (forthcoming), it is clearly distinct from it: Lustig et al. (forthcoming) never report any R^2s on any time-series regressions of bilateral exchange rates. They focus mostly on the dynamics of *portfolios* of currencies. As already noted, portfolios are by construction silent on the share of idiosyncratic risk in each currency pair. When they check their asset pricing results on bilateral exchange rates, Lustig et al. (forthcoming) report only measures of cross-sectional, not time-series, fit. More generally, this paper is part of a growing literature that focuses on currency portfolios following Lustig and Verdelhan (2005, 2007). DeSantis and Fornari (2008), Jurek (2008), Menkhoff, Sarno, Schmeling, and Schrimpf (forthcoming), Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009), Christiansen, Ranaldo, and Soderlind (2011), Galsband and Nitschka (2010), Gilmore and Hayashi (2011) study the properties of one-month interest rate-sorted portfolios of currency excess returns. Ang and Chen (2010), Kozak (2011), and Hu, Pan, and Wang (2010) consider new sorts, focusing on properties of the foreign yield curves at longer horizons or on liquidity risk. Lustig, Roussanov, and Verdelhan (2011) study the properties and predictability of the dollar risk factor.

Finally, the findings in this paper point to similar results obtained on equity and bond markets. Roll (1988) studies contemporaneous regressions of large individual U.S. stock returns on systematic risk factors and on the returns on other stocks in the same industry; he reports an average R^2 of about 35% on monthly data and 20% on daily data. Steeley (1990) and Litterman and Scheinkman (1991) uncover a clear factor structure in bond returns, where three factors account for more than 95% of the total return variance. Currency markets do not appear much different.

2 Data and Notation

I first describe the data set and introduce some notation before turning to the main result in the next section.

Data I start from daily spot and forward exchange rates in U.S. dollars and build end-of-month series from November 1983 to December 2010. These data are collected by Barclays and Reuters and available on Datastream. Spot and forward exchange rates correspond to midpoint quotes. The robustness section reports results on the changes in the bid-ask spreads.

The main data set contains at most 37 different currencies of the following countries: Australia, Austria, Belgium, Canada, Hong Kong, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, United Kingdom, as well as the Euro. The euro series start in January 1999. Euro area countries are excluded after this date; only the euro series remains.[1]

Some of these currencies have pegged their exchange rate partly or completely to the U.S. dollar over the course of the sample. They are in the sample because forward contracts were easily accessible to investors and their forward prices are not inconsistent with covered interest rate parity. Based on large failures of covered interest rate parity, however, the following observations are deleted from the sample: South Africa from the end of July 1985 to the end of August 1985; Malaysia from the end of August 1998 to the end of June 2005; Indonesia from the end of December 2000 to the end of May 2007; Turkey from the end of October 2000 to the end of November 2001; United Arab Emirates from the end of June 2006 to the end of November 2006.

[1]All the countries are included in the carry and dollar factors. To save space, some country-level results are not reported. Finland, Portugal, and Spain are left out because there are only 22 months of data for these countries. Belgium and the Netherlands are also left out because the sample contains already many European countries (results on these countries are very similar to those of France and Germany).

Notation The lower letter s denotes the log of the nominal spot exchange rate in units of foreign currency per U.S. dollar, and f the log of the one-month forward exchange rate, also in units of foreign currency per U.S. dollar. An increase in s means an appreciation of the home currency. In normal times, forward rates satisfy the covered interest rate parity condition; the forward discount is equal to the interest rate differential: $f_t - s_t \approx i_t^\star - i_t$, where $i^\star$ and i denote the foreign and domestic nominal risk-free rates over the maturity of the contract. Akram, Rime and Sarno (2008) study high frequency deviations from covered interest rate parity (CIP). They conclude that CIP holds at daily and lower frequencies.[2]

Portfolios of Currencies Following Lustig and Verdelhan (2005, 2007), Lustig et al. (forthcoming) focus on six *portfolios* of currencies instead of individual exchange rates. They sort countries each month according to their interest rates. Their six portfolios are re-balanced monthly and currencies switch frequently from one portfolio to another. By averaging out idiosyncratic risk and conditioning on interest rates, these portfolios deliver a cross-section of exchange rates and currency risk premia. The reader is referred to Lustig et al. (forthcoming) for a detailed description of the portfolio statistics.

Carry and Dollar Factors Lustig et al. (forthcoming) show that average currency excess returns on the interest rate-sorted portfolios correspond to the covariances between currency returns and two risk factors, as implied by the arbitrage pricing theory of Ross (1976). The two risk factors are the average return across all portfolios and the difference in returns between the last and first portfolio. The changes in exchange rates of these two risk factors are their key components; Lustig et al. (forthcoming) obtain similar asset pricing results when ignoring their interest rate components and focusing on exchange rates. They call the two factors respectively the "Dollar" and "Carry" factors.

The dollar factor is the average change in the dollar versus all the other currencies; it corresponds to the average change in exchange rate across all six portfolios at each point in time. The carry

[2] While this relation was violated during the extreme episodes of the financial crisis in the fall of 2008, including or excluding those observations does not have a major effect on the results.

factor is the average change in exchange rate between countries in the last portfolio (high interest rate countries) and those in the first portfolio (low interest rate countries). When built using all countries, the correlation between these two factors is less than 0.1.

Preliminary Notes Two important points need to be highlighted. First, note that for each currency put on the left hand side of a regression, that currency is excluded from any portfolio that appears on the right hand side. The objective is to prevent some purely mechanical correlation to arise. Excluding or not a single currency pair, however, has little impact on the properties of the factors because a large sample of countries is used to build them. This exclusion method is not perfect though: assume that two foreign countries A and B decide to peg their currency to each other, then excluding A from the dollar and carry portfolios does not matter much since the same information is available in the exchange rate between country B and the U.S. For this reason, all the countries in the euro area are excluded after January 1999, keeping only the Euro. But the objective of this paper is to highlight common components across currencies, so there would be no point in trying to exclude all the countries whose exchange rates might be correlated.

Second, portfolios always use the largest available sample of countries. Even when studying the bilateral changes in exchange rates of developed countries, portfolios and thus risk factors are derived from the large sample of developed and emerging countries.

After this brief description of the data set, I turn now to the first test results.

3 Measuring Currency Systematic Variations

This section shows that the dollar and carry risk factors explain a large part of each currency pair variations, uncovering cross-country differences in their shares of systematic risk. I start from the usual UIP regressions and progressively add risk factors as explanatory variables.

3.1 UIP and Augmented-UIP Tests

UIP According to the UIP condition, the expected change in exchange rates should be equal to the interest rate differential between foreign and domestic risk-free bonds. The UIP condition implies that a regression of exchange rate changes on interest rate differentials should produce a slope coefficient of one. Instead, empirical work following Tryon (1979), Bilson (1981) and Fama (1984) consistently reveals a slope coefficient that is smaller than one and very often negative. The international economics literature refers to these negative UIP slope coefficients as the UIP puzzle or forward premium anomaly.[3] Note that the UIP condition is equivalent to an Euler equation for risk-neutral investors.

Negative slope coefficients mean that currencies with higher than average interest rates tend to appreciate, not to depreciate as UIP would predict. Investors in foreign one-period discount bonds thus earn the interest rate spread, which is known at the time of their investment, plus the bonus from the currency appreciation during the holding period. As a result, the forward premium anomaly implies positive predictable excess returns for investments in high interest rate currencies and negative predictable excess returns for investments in low interest rate currencies. UIP regressions, however, do not uncover much predictability: R^2s are tiny and slope coefficients, although clearly different from one, are rarely statistically different from zero.

UIP Redux The left panel of Table 1 reports country-level results from the usual UIP tests:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i_t^\star - i_t$ is the interest rate difference. As in the rest of the literature, βs are always below one, and most of

[3]The UIP condition appears to be a reasonable description of the data only in four cases. Bansal and Dahlquist (2000) show that UIP is not rejected at high inflation levels, and likewise Huisman, Koedijk, Kool and Nissen (1998) find that UIP holds for very large forward premia. Chaboud and Wright (2005) show that UIP is valid at very short horizons but is rejected for horizons above a few hours. Meredith and Chinn (2005) find that UIP cannot be rejected at horizons above 5 years. Lothian and Wu (2005) find positive UIP slope coefficients for France/U.K. and U.S./U.K. on annual data over 1800-1999, because of the 1914-1949 subsample.

them are negative. Out of 13 countries, only three lead to positive βs, none of which is statistically significant. The adjusted R^2s on these regressions are tiny, often negative, with a maximum of 1.7%, and an average of -0.2%. Note that every R^2 reported in this paper is adjusted for the degrees of freedom.

UIP and the Carry Factor Let us now add the information contained in the carry trade factor. The right panel of Table 1 reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \varepsilon_{t+1},$$

where $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies. Each variable is expressed in percentage points; as a result, the slope coefficient on the conditional carry factor is 100 times larger than if all series were not in percentage points. Table 1 reports the constant α, the slope coefficients β, γ, and δ, as well as the R^2 of this regression (also in percentage points) and the number of observations. Standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The interest rate difference, the conditional carry, and the unconditional carry factors are correlated, and thus standard errors offer only a partial view of the significance of each coefficient. The standard errors for the R^2s are reported in parentheses; they are obtained by bootstrapping under the assumptions that changes in exchange rates are *i.i.d.*

All adjusted R^2s are positive. They are an order of magnitude higher than in classic UIP tests, ranging from -0.2% to 25.3%, with an average of 9.6%.

[Table 1 about here.]

UIP and the Carry and Dollar Factors I now turn to the main result of this section, by introducing jointly the carry and dollar factors. Table 2 reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. The loadings on the dollar factor are positive and statistically significant in all 13 countries, with values ranging from 0.4 to 1.5. The loadings on the dollar factor reflect the existence of a clear principal component in the dollar exchange rates. When the dollar appreciates, it does so against all developed currencies. This common component explains a large share of the variation in bilateral exchange rates. The adjusted R^2s are now all between 22% and 90%. The average R^2 among the 13 developed countries is 67%. Without the carry factors, the average R^2 is 60%; unsurprisingly, the difference in R^2s is particularly large for Australia and Japan (41% vs. 28% and 48% vs 30%). The dollar factor thus explains a large share of the systematic variation.

The conditional carry loadings (γ) are positive in 12 out of 13 countries (the only exception is Canada, where the coefficient is negative but insignificant). They are positive and statistically significant in 10 out of 13 countries. These findings are consistent with those of Lustig et al. (forthcoming): in their portfolios of currencies sorted on interest rates, the higher the interest rate (i.e., going from the first to the last portfolio), the larger the loading on the carry factor. Lustig et al. (forthcoming) show that the carry factor tends to pay badly in times of high equity volatility. As a result, portfolios of high interest rate currencies are riskier than portfolios of low interest rate currencies.

The sensitivity of each bilateral exchange rate to the carry factor depends on the conditional and unconditional carry factors. The unconditional carry loadings (δ) are all negative except for Australia and Canada. The unconditional and conditional carry factors are jointly statistically significant at the 1% confidence level in 12 out of 13 countries (the only exception is the U.K.).[4] For many countries, the estimation implies that the sensitivity to the carry factor switches sign

[4]At a daily frequency, the conditional and unconditional carry factors are jointly significant at the 1% level for all countries. Results are reported in the robustness Section 6.

along the sample. For example, the Swiss Franc used to depreciate in the 80s (a time of relatively high Swiss interest rates) when the carry factor paid badly; recently, it has appreciated.[5] The Japanese yen tends to appreciate when the carry factor tanks, while the Australian Dollar tends to depreciate. Such currency movement correspond to the funding and investment roles of these currencies that are commonly reported in press articles on carry trades.

[Table 2 about here.]

Emerging Markets I now turn to a set of 18 developing countries (using the same factors as for developed countries). Adjusted R^2s tend to be high for floating currencies. They are low for two pegged currencies: Hong Kong and the United Arab Emirates (6.0% and -1.0% respectively). Thailand and Malaysia, although they also experienced currency pegs, do not appear that much different from the other developing countries. Except for the two clear pegs (Hong Kong and the United Arab Emirates), R^2s range from 14% to 77%, almost as high as for developed countries. Loadings on the dollar are significantly positive for all countries, except Saudi Arabia and the United Arab Emirates. But loadings on the carry and conditional carry factors vary a lot and are less precisely estimated as those on developed countries. Out of 18 countries, 13 exhibit a positive loading on the conditional carry, eight of which are significant. Only two countries have a significantly negative loading on the carry factor (Hungary and Turkey). Note that the lack of significance might come from the much smaller samples available. Overall, developing countries with floating currencies seem to share the same factors as developed countries: they load positively on the dollar factor and tend to load positively on the conditional carry factor.

[Table 3 about here.]

How Large Are the R^2s? The augmented-UIP regressions deliver large R^2s compared to those of classic UIP regressions, but UIP tests might be too low a bar. Augmented-UIP R^2s, however, can also be favorably compared to those of simple pairwise currency regressions. For each currency

[5] This result is particularly clear for estimates based on rolling windows.

i, let us regress it on a constant and each currency j available in the sample ($i \neq j$):

$$\Delta s^i_{t+1} = \alpha + \beta \Delta s^j_{t+1} + \varepsilon^{i,j}_{t+1}.$$

Each regression delivers a pair-specific R-square, denoted $R^{2^{i,j}}$. Some currencies are highly correlated, and thus lead to high R^2s: the Australian and New Zealand Dollars offer one such example. But without knowing ex-ante the correlation matrix, one would expect, for each currency i, an R^2 that corresponds to the mean of all the estimates that involve currency i. For each currency i, the standard deviation of all the estimates $R^{2^{i,j}}$ gives a measure of the uncertainty around its mean R^2.

[Figure 1 about here.]

Figure 1 summarizes the findings, comparing R^2s obtained with the carry and dollar factors (vertical axis) to those obtained from random univariate regressions (horizontal axis). If the carry and dollar factors are of any help capturing exchange rate variation, all points in Figure 1 should be above the 45-degree line. it is clearly the case. It turns out that the augmented-UIP R^2s are, for all developed countries, at least one-standard deviation above the mean R^2 estimated from the pairwise univariate regressions above. The same is true for all developing countries, except two: Saudi Arabia and the United Arab Emirates, which are unsurprising outliers since they have pegged their currencies to the U.S dollar. For developed currencies, one can always handpick another developed currency that is highly correlated with the currency under study, and thus will lead to a high R^2. But there is no currency that delivers this feature for all exchange rates. The dollar and the carry factor, on the contrary, have the same economic interpretation for all currencies.[6] They deliver R^2s that are large, not only compared to those of UIP tests, but also to those of bivariate exchange rate regressions.

[6]The dollar and carry factors only differ across currencies because of the exclusion of the currency under study. This exclusion is meant to avoid mechanical correlations. But benchmark carry and dollar factors that use the whole sample produce similar results.

3.2 Dollar Risk

The augmented-UIP regressions rely on the carry and dollar factors in order to estimate the shares of systematic variation in bilateral exchange rates. Are these factors simply common characteristics or are they risk factors that are priced in currency markets? I rapidly review the evidence in favor of a risk-based interpretation of the two factors.

Lustig et al. (forthcoming) find that portfolios of countries sorted on interest rates tend to load monotonically on the carry factor: as already noted, the higher the portfolio interest rates, the larger the portfolio loading on the carry factor. Average excess returns on interest rate-sorted portfolios correspond to the covariances between returns and the carry factor, suggesting a risk-based explanation of those portfolios excess returns.

An alternative explanation of their findings is that the interest rate is simply one of the characteristics that determine returns. In this view, some currencies earn a lower risk premium than others because they have a lower interest rate, not because their exchange rates tend to comove with any risk factor. Based on their empirical evidence, Lustig et al. (forthcoming) cannot definitively rule out a characteristics-based explanation because interest rates and slope factor betas are very highly correlated in the data. However, they cannot rule out a characteristics-based explanation in model-generated data either, even though the true data generating process has no priced characteristics.

Portfolios of Countries Sorted on Dollar Exposures In this paper, I report additional evidence on the dollar risk, building on the work of Lustig, Roussanov, and Verdelhan (2011), who study the properties and predictability of the aggregate excess return on currency markets. Lustig, Roussanov, and Verdelhan (2011) show that the average forward discount of developed countries (i.e., the average interest rate difference between foreign and U.S. short term interest rates) predicts the returns on the dollar factor. They report a high average excess return and a high Sharpe ratio on a simple investment strategy that exploits this predictability by going long the aggregate currency market when the average forward discount is positive and short otherwise. The resulting excess return is the aggregate conditional dollar excess return.

I exploit the dollar predictability to build a new large cross-section of portfolio excess returns. The new portfolios are based on currencies' time-varying exposures to the dollar factor. At each date t, each currency i's change in exchange rate is regressed on a constant and the dollar and carry factors, as in the previous sectio, using a 60-month rolling window that ends in period $t-1$. Currency i's exposure to the *Dollar* factor is denoted τ_t^i; it only uses information available at date t. Currencies are then sorted into six groups at time t based on the slope coefficients τ_t^i. Portfolio 1 contains currencies with the lowest τs, while portfolio 6 contains currencies with the highest τs. At each date t and for each portfolio, the investor goes long if the average forward discount is positive and short otherwise.

The Price of Dollar Risk Panel I of Table 4 reports summary statistics on the portfolios of countries sorted on dollar exposures. Average log excess returns increase monotonically from the first to the last portfolio, from 0.3% to 7.7% on annual basis. Taking bid-ask spreads into account reduce the average excess returns (from -0.4% to 6.4%) but does not change the cross-sectional pattern. Mean excess returns on portfolios 2 to 6 are statistically different from zero (the standard errors are obtained by bootstrapping and thus take into account the sample size). Unsurprisingly, the volatility of excess returns increase from portfolio 1 to 6: the last portfolio contains more systematic variation than the first one by construction. Average forward discounts *do not* increase monotonically from portfolio 1 to portfolio 6. Sorts based on forward discounts and sorts based on dollar betas are clearly not the same.

[Table 4 about here.]

Average excess returns of the portfolios of countries sorted on dollar exposures correspond to the covariances between excess returns and a single risk factor, the aggregate conditional dollar excess return. Panel II of Table 4 reports GMM and Fama-McBeth asset pricing results. The market price of risk λ is positive, significant, and close to the mean of the risk factor, as implied by a no-arbitrage condition. The pricing errors are not statistically significant. Panel III of Table 4 reports OLS estimates of the factor betas. Betas increase monotonically from 0.06 to 1.58; they are precisely estimated. The alphas are not statistically different from zero. The dollar risk differs from the carry risk and the equity risk. The carry trade risk factor (which is dollar neutral) and the aggregate U.S. stock market excess returns cannot account for the excess returns of portfolios sorted on dollar exposures: for the CAPM, loadings tend to increase from portfolios1 to 6, but they are too small, implying a large market price of risk that is not in line with the mean U.S. stock market excess return. Sorts on dollar exposures thus reveal a novel cross-section of currency risk premia.

Figure 2 reports the realized and predicted excess returns. Each portfolio j's actual excess return is regressed on a constant and the conditional dollar excess return to obtain the slope coefficient β^j. Each predicted excess return then corresponds to the OLS estimate β^j multiplied by the mean of the conditional dollar excess return. Figure 2 clearly shows that predicted excess returns are aligned with their realized counterparts. An investor who takes on more dollar risk is rewarded by higher excess returns on average. The dollar risk is intuitive: Lustig, Roussanov, and Verdelhan (2011) show that the aggregate conditional dollar excess return compensates U.S. investors for taking on U.S. specific risk by shorting the dollar in U.S. recessions. When the U.S economy approaches a recession, U.S. short term interest rates tend to be low relative to other developed economies: the average forward discount is thus positive. If U.S. investors then buy a basket of currency forward contracts, they are long foreign currencies and short the U.S. dollar. They thus run the risk of a dollar appreciation during difficult times for them. The dollar appreciation is not unlikely: if markets are complete, the U.S. dollar should actually appreciate when marginal utilities of wealth are higher in the U.S. than abroad. Shorting the dollar is thus a risky strategy and risk-averse investors expect to be compensated for bearing that risk.

[Figure 2 about here.]

As a robustness check, I run country-level Fama and MacBeth (1973) tests, using country-level excess returns as test assets but currency portfolios to extract currency risk factors. The results are reported in the robustness section. The country-level results confirm the previous findings: the dollar risk is priced in currency markets, and the price of risk is not statistically different from the mean of the risk factor's excess return, as no-arbitrage implies.

Portfolios of countries sorted on dollar exposures and conditional excess returns at the country level thus offer additional evidence in favor of a risk-based explanation of exchange rates. Yet, the results in this paper do not depend on the outcome of the risk versus characteristics debate. I use the carry and dollar factors, focusing on their exchange rate component, but refraining from calling them *risk* factors: Section 5 offers a risk-based explanation of the empirical results in this paper, but it does not preclude other, more behavioral, explanations.

3.3 Comparison to the Literature

The large R^2s and significant loadings on the dollar and carry factors on augmented-UIP regressions are the first benchmark results of this paper. I now contrast these results to the previous literature on UIP tests and currency portfolios.

Omitted Variables The literature on exchange rates contains many estimations of the UIP condition. Twenty years ago, Froot and Thaler (1990) reported that, in a survey of 75 published estimates, the slope coefficient of the regression of changes in exchange rates on interest rate differences was always below unity (positive in a very few cases, and -0.88 on average). Many more papers have run similar tests since then and offered potential explanations. A simple search in *Scopus* returns 310 articles published since 1990 that mention "exchange rates" and either "uncovered interest rate parity" or "forward premium" or "carry trade" in their title, abstract or keywords. Engel (1996) and Chinn (2006) provide recent surveys.

This paper shows that all these UIP tests miss key explanatory variables. The conditional carry and dollar factors are jointly statistically significant for almost all currencies. These findings imply that all classic UIP tests suffer from an omitted variable bias. Slope coefficients (β) on interest rate differences vary when the carry, conditional carry and dollar factors are added as explanatory variables. They tend to increase from an average of -0.72 in UIP regressions to an average of -0.19 in the augmented-UIP regressions. Neither the former not the latter are significant. The latter still do not measure the interest rate sensitivities of exchange rate because the conditional carry and the dollar factor also respond to interest rate differences.

As a result, in order to study the reaction of exchange rates to monetary and fiscal policy shocks, it is necessary to consider the role of the carry and dollar factors. Without them, key shares of systematic variations are ignored. Further research should thus focus on the impact of monetary and fiscal policy shocks on the systematic components of exchange rates.

Bilateral Exchange Rates versus Portfolios of Exchange Rates What do the augmented-UIP regressions teach us that we did not know from the principal component decomposition of currency portfolios? These regressions show the importance of idiosyncratic risk at the country level. Idiosyncratic risk is one of the main reasons portfolios are commonly used in finance: by building portfolios of assets, one hopes that idiosyncratic risk averages out inside each portfolio. On the one hand, if idiosyncratic risk were to drive all of bilateral exchange rates, R^2s would be extremely low in the augmented-UIP regressions. On the other hand, if idiosyncratic risk were nonexistent, R^2s would be one. The results in this paper show that exchange rates are far from independent random walks, but also that the share of idiosyncratic risk varies notably from one country to another. I now explore these cross-country differences.

4 World Integration and Systematic Currency Variation

The previous section reports a large variation across countries in the levels of systematic currency risk. This section links such cross-country differences to measures of world integration. The link between the two arises naturally in a risk-based approach to exchange rates.

Exchange Rates under No Arbitrage If financial markets are complete, the change in the nominal exchange rate Δs between the home country and foreign country is equal to:

$$\Delta s_{t+1} = m_{t+1}^{\$} - m_{t+1}^{\pounds},$$

where $m^{\$}$ and $m^{£}$ denote the nominal pricing kernels of the domestic and foreign investor. Since all exchange rates are defined with respect to the U.S. dollar, $m^{\$}$ is a common component of all exchange rates. The absence of arbitrage then implies that shares of systematic risk vary across countries because the properties of foreign stochastic discount factors vary too. Such variation should affect other asset prices, for example, equity and fixed income markets, and it does. I first compare the cross-sectional variation in shares of systematic currency risk to the cross-sectional variation in shares of systematic equity and fixed income risk. The comparison links the vast literature on asset market integration to the study of exchange rates. I then turn to macroeconomic measures of world integration.

Systematic Equity Risk Comovements between stock returns across countries are the object of a large literature that is too wide to survey here. The reader is referred to a recent survey article by Lewis (2011) and recent evidence at the industry level by Bekaert, Hodrick, and Zhang (2009) and Bekaert, Harvey, Lundblad and Siegel (forthcoming).

I adopt a simple approach, focusing on the world capital asset pricing model (CAPM) and Fama and French (1993) factors. The share of systematic equity risk at the country-level corresponds to the share of each foreign country's equity returns explained by world equity factors, i.e. the R^2 of the following regression:

$$r_{t+1}^{m,\$} = \alpha + \beta r_{t+1}^{m,world,\$} + \gamma r_{t+1}^{hml,world,\$} + \varepsilon_{t+1},$$

where $r_{t+1}^{m,\$}$ denotes the returns on a given foreign country's MSCI stock market index, $r_{t+1}^{m,world,\$}$ is the MSCI world return equity index, and $r_{t+1}^{hml,world,\$}$ is the difference between the returns on the world MSCI value equity index and the world MSCI growth equity index (i.e., high minus low book-to-market equity returns). Equity indices correspond to country-level indices, and thus no additional local risk factor is used. Pukthuanthong and Roll (2009) argue in favor of similar R^2s to measure world market integration. As in Bekaert and Harvey (1995), Bekaert, Hodrick, and Zhang (2009), and Pukthuanthong and Roll (2009), all returns are expressed in U.S. dollars. Systematic equity risk is estimated on the same sample period as currency risk for each country. Adjusted R^2s range from 27% to 87% in developed countries, and from 26% to 67% in developing countries.

Equity versus Currency Figure 3 reports the share of systematic *currency* risk as a function of the share of systematic *equity* risk. Systematic risk is measured using the interest rate differences, carry, conditional carry, and dollar factors for exchange rates, and the world market and world value factors for equity. Standard errors on R^2s are obtained by bootstrapping, as in the rest of the paper. Figure 3 reports point estimates of R^2s as well as one-standard error confidence intervals on both sides of each point estimate. The estimation focuses on the 1999.1–2010.12 sub-sample, after the introduction of the euro. Over this sub-sample, the data set offers an (almost) balanced panel of both developed and emerging economies and one can thus compare countries over the same sample.[7] Over the last 10 years, the higher the share of systematic risk on equity markets, the higher the share of systematic risk on currency markets.

[Figure 3 about here.]

This result appears consistent with a simple risk-based definition of exchange rates. The intuition is as follows: the return on the world stock market depends only on world shocks, since country-specific shocks average out. The share of systematic equity risk thus increases with the relative volatility of world versus country-specific shocks to each stochastic discount factor: if all shocks were local (global), R^2s on equity returns would be zero (one). Likewise, the carry and conditional carry factors capture exposure to world shocks: if all shocks to the foreign stochastic discount factor were global (in addition to the U.S.-specific shocks), then the dollar and carry factors would account for them perfectly, and R^2s on exchange rates would be one. The currency R^2s are not one because changes in exchange rates also depend on foreign-specific shocks (e.g., U.K.-specific shocks to the U.K. stochastic discount factor) that are not spanned by the currency factors. As a result, high shares of systematic equity and currency risk can be interpreted as reflecting a large relative variance of world shocks in foreign stochastic discount factors.

[7] The whole sample, starting in 1983, offers a fuzzier picture as it mixes currency forward contracts defined on different time periods. Before the introduction of the euro, many European currencies exhibited high share of systematic currency risk (as they comoved a lot), but lower shares of equity risk.

Saudi Arabia (denoted SA) and Hong Kong (HK) appear as outliers on Figure 3: their share of systematic equity risk is much higher than their share of systematic currency risk, which are close to zero. This finding is not surprising: both countries have pegged their currencies to the U.S. dollar throughout the sample.

Among the developed countries, Canada and the U.K. exhibit higher shares of systematic equity risk than their currencies would suggest. How to interpret this finding? In any no-arbitrage model, exchange rates are informative about SDFs, whereas equity returns depend on both SDF and the properties of the dividend processes. Thus, one potential explanation is that Canadian and British firms (and thus their dividends) are more highly exposed to world shocks than their corresponding SDF would suggest, because of a higher leverage for example.

Overall, one cannot reject that the share of systematic currency risk increases across countries one for one with the share of systematic equity risk. Could this result be mechanical? If exchange rates drive most of the variation in equity betas, then both measures of systematic risk are equivalent. The literature on stock comovements use equity returns expressed in U.S. dollars: $r_{t+1}^{m,\$} = r_{t+1}^{m} - \Delta s$, where r_{t+1}^{m} denotes the return on country i's stock market, expressed in foreign currency. As a first approximation, the world equity return correspond to the average of the country-specific returns; likewise, the dollar risk factor is approximately the average change in exchange rates of the U.S dollar (ignoring capitalization weights for equity indices and portfolios for currencies). Tests of stock return comovements thus correspond to:

$$r_{t+1}^{m} - \Delta s = \alpha + \beta(\frac{1}{N}\sum_{i=1}^{N} r_{t+1}^{m,i} + Dollar_{t+1}) + \gamma(\frac{1}{N}\sum_{i=1}^{N} r_{t+1}^{hml,i} + Dollar_{t+1}) + \varepsilon_{t+1}.$$

If equity returns in local currencies are much less volatile than currency movements, the tests above boil down to measures of systematic currency risk using the dollar risk factor. This is, however, not exactly the case in the data. Exchange rates undoubtedly account for part of the correlations among equity returns converted in U.S dollars. But exchange rate conversions do not drive all the results: equity returns in local currencies deliver measures of systematic risk that do not differ much from our main estimates; the pattern observed in Figure 3 remains the same.

To push the comparison further and increase the sample size, I compare R^2s obtained on rolling windows. The methodology remains the same, but equity and currency regressions are now run on rolling windows of 60 months. Figure 4 reports the results for six countries: Australia, Canada, Japan, New Zealand, Switzerland, and the United Kingdom. In the first four countries, high R^2s on equity markets are associated with high R^2s on currency markets. But for Switzerland and the U.K., this relationship does not exist. The findings suggest that trading on the Swiss franc (or U.K. pound) is not linked to trading on the Swiss (U.K.) stock market. On the contrary, the integration of the Australian stock market appears highly correlated to the integration of the Australian dollar. Data on capital flows collected by the U.S Treasury are consistent with the finding. Capital flows linked to the sales and purchases of Swiss stocks and bonds account for less than 20% of the capital flows between the U.S. and Switzerland. But capital flows linked to the sales and purchases of Australian stocks and bonds account for more than 40% of the capital flows between the U.S. and Australia.

[Figure 4 about here.]

Fixed Income versus Currency I compare the shares of systematic risk on currency and fixed income markets. Adjusted R^2s on bond markets are derived from:

$$r^b_{t+1} = \alpha + \beta r^{m,world}_{t+1} + \gamma r^{b,world}_{t+1} + \varepsilon_{t+1},$$

where r^b_{t+1} denotes the returns in U.S. dollars on a foreign country's 10-year bond return index, $r^{m,world}_{t+1}$ corresponds to returns on the MSCI world equity index, and $r^{b,world}_{t+1}$ is the world bond return, obtained as the average of all the 10-year bond returns. Again, as Figure 5 shows, the more integrated the bond markets, the higher the share of systematic currency risk. Similar results appear with bond returns expressed in local currencies, except for three countries: the Czech Republic, Hungary, and Poland exhibit much lower R^2s in local currencies (in the 30% to 40% range instead of the 60% to 70% range reported in Figure 5). Yet, overall, even measured in local currencies, R^2s in fixed income markets increase with their currency counterparts.

[Figure 5 about here.]

The different shares of systematic currency risk across countries appear related to measures of world equity and fixed income market integration. A simple cross-country regression confirms the findings:

$$R_i^{2,FX} = \alpha + \beta R_i^{2,X} + \varepsilon_i,$$

where $R_i^{2,FX}$ denotes the share of systematic variation in the exchange rate of country i. $R_i^{2,FX}$ are obtained from UIP-augmented regressions using the carry and dollar factors. $R_i^{2,X}$ denotes the share of systematic variation measured with either equity or bond returns.

Table 5 reports the slope coefficients (β) on this cross-country regression. On the full sample period as on the post-1999, the slope coefficients are positive and significant for equity R^2s as well as for bond R^2s. On the post-1999 sample, shares of systematic equity or bond risk account for more than 70% of the cross-country differences in the shares of systematic currency risk. The slope coefficient are not statistically different from one. The link between measures of systematic risk is natural if exchange rates depend on pricing kernels.

[Table 5 about here.]

Macroeconomic Measures of World Integration In the international real business cycle literature, pricing kernels respond to shocks to fundamental macroeconomic variables. Thus, shares of systematic currency risk could be related to measures of world integration based on consumption growth for example. Adjusted R^2s on consumption growth rates are derived from:

$$\Delta y_{t+1} = \alpha + \beta \Delta y_{t+1}^{world} + \varepsilon_{t+1},$$

where Δy_{t+1} denotes the annual growth rate of real foreign consumption, Δy_{t+1}^{world} corresponds to the annual growth rate of the world consumption (measured as the sum of all OECD consumptions). Adjusted R^2s on GDP growth rates, which are available for more countries and on longer samples, are derived similarly. The GDP and consumption series, measured at purchasing power parity, come from the World Bank. They are only available at an annual frequency. The last two columns of Table 5 report cross-country regression results. Here again, the slope coefficient between different measures of systematic risk are positive and significant. Standard errors, however, are certainly underestimated. They do not take into account the uncertainty stemming from the estimation of each R^2 on bond, equity, currency, consumption, or output time series. Moreover, they pertain to a limited number of observations (one per country, subject to data availability). Yet, all estimates point in the same direction. And even if standard errors on equity and fixed measures were twice as high, slope coefficients would remain significant on the post-1999 sample. Overall, the cross-country regression results reported in Table 5 highlight a clear link among different measures of systematic risk. The findings in this paper thus point towards risk-based explanations of exchange rates.

5 A Risk-Based Interpretation of the Findings

In this section, I compare the key empirical results of this paper to existing models in international finance, starting with a review of the reduced-form model of Lustig et al. (forthcoming), which provides a simple interpretation of the dollar and carry factors. More generally, in the class of no arbitrage models of currency markets, the R^2s of augmented-UIP regressions are informative on the relative volatilities of the country-specific and world components of the pricing kernels. The findings in this paper thus provide useful additional moments to match.

5.1 A Reduced-Form Model

Complete Markets Lustig et al. (forthcoming) assume that financial markets are complete, but that some frictions in the goods markets prevent perfect risk-sharing across countries. As a result, the change in the real exchange rate Δq^i between the home country and country i is $\Delta q^i_{t+1} = m_{t+1} - m^i_{t+1}$, where q^i is measured in country i goods per home country good and m denotes the log stochastic discount factor (SDF) or pricing kernel. An increase in q^i means a real appreciation of the home currency. For any variable that pertains to the home country (the U.S.), the superscript is dropped.

Stochastic Discount Factors In this model, there are two sources of priced risk: country-specific and world shocks. Each type of risk has a different price. Lustig et al. (forthcoming) assume that the risk prices of country-specific shocks depend only on the country-specific factors, and that the risk prices of world shocks depend on world and country-specific factors. Let us consider a world with N countries and currencies. Lustig et al. (forthcoming) do not specify a full economy complete with preferences and technologies; instead they posit a law of motion for the SDFs directly. Building on Backus, Foresi and Telmer (2001), they assume that in each country i, the logarithm of the real SDF m^i follows a two-factor conditionally-Gaussian process:

$$-m_{t+1}^{i}=\alpha+\chi z_{t}^{i}+\sqrt{\gamma z_{t}^{i}}u_{t+1}^{i}+\chi z_{t}^{w}+\sqrt{\delta^{i}z_{t}^{w}+\kappa z_{t}^{i}}u_{t+1}^{w}.$$

To be parsimonious, they limit the heterogeneity in the SDF parameters to the different loadings, denoted δ^i, on world shocks (denoted u^w); all the other parameters are identical for all countries. Lustig et al. (forthcoming) show that the cross-sectional variation in δ is key to understanding the carry trade. The SDFs are heteroscedastic because, as Bekaert (1996), Bansal (1997), and Backus et al. (2001) have shown, expected currency log excess returns depend on the conditional variances of the home and foreign (lognormal) SDFs. If SDFs were homoscedastic, expected excess returns would be constant and the UIP condition would be valid.

Two minor comments are in order. First, all variables in the model are real: a law of motion for inflation can easily added, or the SDF can be reinterpreted as nominal variables. Second, there is no direct relation between the symbols in the model and the symbols previously used to describe the slope coefficients in the regressions of the previous sections. I choose to keep the same notation as in Lustig et al. (forthcoming) to help the reader familiar with their work.

In this model, there is a common global factor z_t^w and a country-specific factor z_t^i. The currency-specific innovations u_{t+1}^i (uncorrelated across countries) and global innovations u_{t+1}^w are $i.i.d$ gaussian, with zero mean and unit variance; u_{t+1}^w is a world shock, common across countries, while

u^i_{t+1} is country-specific. The country-specific and world volatility components are governed by autoregressive square root processes:

$$
\begin{aligned}
z^i_{t+1} &= (1-\phi)\theta + \phi z^i_t - \sigma\sqrt{z^i_t}u^i_{t+1}, \\
z^w_{t+1} &= (1-\phi)\theta + \phi z^w_t - \sigma\sqrt{z^w_t}u^w_{t+1}.
\end{aligned}
$$

Interest Rate Difference The same variables used in the augmented-UIP regressions can be obtained in closed forms in the model, starting with the forward discount between currency i and the U.S. In this model, it is equal to:

$$
r^i_t - r_t = \left(\chi - \frac{1}{2}(\gamma+\kappa)\right)(z^i_t - z_t) - \frac{1}{2}\left(\delta^i - \delta\right) z^w_t.
$$

If $\chi = 0$, the Meese-Rogoff hypothesis holds: the log of real exchange rates follows a random walk, and the expected log excess return is simply proportional to the real interest rate difference. This case is not supported by the data. In order to reproduce the UIP puzzle, Lustig et al. (forthcoming) and Verdelhan (2010) show that the precautionary savings effect must dominate on real interest rates. Here it means that interest rates decrease when volatility increases: $\chi - \frac{1}{2}(\gamma+\kappa) < 0$ and $\chi - \frac{1}{2}\delta^i < 0$. High interest rate currencies tend to have low loadings δ^i on common innovations, while low interest rate currencies tend to have high loadings δ^i.

Interpreting the Dollar Factor The dollar factor is also obtained in closed form. Recall that it corresponds to the average change in all exchange rates versus the U.S. dollar. In the following, a bar superscript ($\overline{x}$) denotes the average of any variable or parameter x across all countries. To build intuition, let us first focus on expected changes in exchange rates. As Lustig et al. (forthcoming) show, the expected dollar change in exchange rate is:

$$
E_t[Dollar_{t+1}] = E_t[\overline{\Delta q}_{t+1}] = \chi\left(\overline{z_t} - z_t\right).
$$

They assume that country-specific shocks average out within each portfolio. In this case, $\overline{z}$ is constant in the limit (when N is infinitely large, i.e., $N \to \infty$) by the law of large numbers. As a result, the expected dollar change in exchange rates only depends on the U.S.-specific market price of risk z_t. Hence its name as the dollar factor.

The realized dollar factor corresponds to the expected dollar factor above plus U.S specific and world shocks:

$$Dollar_{t+1} = \chi \left(\overline{z_t} - z_t \right) - \sqrt{\gamma z_t} u_{t+1} + (\overline{\sqrt{\delta^i z_t^w + \kappa z_t^i}} - \sqrt{\delta z_t^w + \kappa z_t}) u_{t+1}^w.$$

If one assumes that the average country's SDF has the same exposure to global innovations as the U.S., then the dollar factor only depends on the U.S. specific market price of risk z_t and U.S. shocks u_{t+1}. In this special case, $Dollar_{t+1} = \chi \left(\overline{z_t} - z_t \right) - \sqrt{\gamma z_t} u_{t+1}$.

Interpreting the Carry Factor The carry factor corresponds to the average change in exchange rates between high and low interest rate countries. Its expected value is:

$$E_t[Carry_{t+1}] = E_t[\Delta q_{t+1}^H - \Delta q_{t+1}^L] = \chi \left(\frac{1}{N_H} \sum_{i \in H} z_t^i - \frac{1}{N_L} \sum_{i \in L} z_t^i \right),$$

where N_H and N_L denote the number of currencies in the high (H) and low (L) interest rate portfolios. Again, with an infinite number of currencies per portfolio, the average z^i would be zero. But here sorting matters. The countries that end up in the first or last portfolios are not randomly chosen. As the closed form expression for interest rate differences show, these countries belong to those portfolios partially because of the values of their market prices of risk z^i. The realized carry factor corresponds to:

$$Carry_{t+1} = \chi \left(\frac{1}{N_H} \sum_{i \in H} z_t^i - \frac{1}{N_L} \sum_{i \in L} z_t^i \right) + \left(\frac{1}{N_H} \sum_{i \in H} \sqrt{\delta^i z_t^w + \kappa z_t^i} - \frac{1}{N_L} \sum_{i \in L} \sqrt{\delta^i z_t^w + \kappa z_t^i} \right) u_{t+1}^w.$$

Lustig et al. (forthcoming) present similar results on currency excess returns. The carry factor captures world shocks.

Finally, the change in bilateral exchange rates is:

$$\Delta q^i_{t+1} = \chi(z^i_t - z_t) + \sqrt{\gamma z^i_t}u^i_{t+1} - \sqrt{\gamma z_t}u_{t+1} + (\sqrt{\delta^i z^w_t + \kappa z^i_t} - \sqrt{\delta z^w_t + \kappa z_t})u^w_{t+1}.$$

Key Implications of the Augmented-UIP Regressions In contemporaneous regressions, the dollar factor picks up the U.S-specific shocks u_{t+1}, and possibly (if the U.S. does not have the average exposure to world shocks) part of the world shocks u^w_{t+1}. Interest rate differences at date t proxy for the spread in market prices of risk $z^i_t - z_t$. The unconditional and conditional carry factor appear as a convenient first-order approximation to the exposure of exchange rates to world shocks. The augmented-UIP regression tests are thus quite natural in this framework. They have two key implications. First, they highlight the difference between conditional and unconditional risk, and its consequence on the market price of risk. Second, they offer a measure of the relative importances of the global versus local shocks to the pricing kernels.

The empirical findings in this paper show that the market price of global risk in each country must depend on country-specific variables. In the language of the Lustig, Roussanov, and Verdelhan's model, the coefficient κ must be nonzero. If κ were zero, then the model would imply that slope coefficients on the conditional carry factor are zero. The result is apparent in the closed forms. If $\kappa = 0$, the carry factor and changes in exchange rates are:

$$\begin{aligned} Carry_{t+1} &= \chi\left(\frac{1}{N_H}\sum_{i\in H} z^i_t - \frac{1}{N_L}\sum_{i\in L} z^i_t\right) + \left(\frac{1}{N_H}\sum_{i\in H}\sqrt{\delta^i} - \frac{1}{N_L}\sum_{i\in L}\sqrt{\delta^i}\right)\sqrt{z^w_t}u^w_{t+1}, \\ \Delta q^i_{t+1} &= \chi(z^i_t - z_t) + \sqrt{\gamma z^i_t}u^i_{t+1} - \sqrt{\gamma z_t}u_{t+1} + (\sqrt{\delta^i} - \sqrt{\delta})\sqrt{z^w_t}u^w_{t+1}. \end{aligned}$$

In this special case, there is clearly no need for a conditional carry factor to capture the role of global shocks in the bilateral exchange rates. In the data, however, most slope coefficients on the conditional carry factor are statistically different from zero, and thus κ must be different from zero. Exchange rates do not respond to the carry factor simply because of some country's fixed effects; they respond more to the carry factor the higher their interest rates.

To study the relative importance of global and local shocks, I turn now to simulations.

Simulation The same regressions as in the first part of this paper can be run on simulated data. The model is simulated at monthly frequency using the calibration proposed in Lustig et al. (forthcoming) and the last 300 observations to build a sample of the same length as in the actual data. Table 6 reports the results.

Panel A focuses on standard UIP regressions. As in the data, UIP slope coefficients are negative. The Wald test cannot reject the null hypothesis that slope coefficients are zero (they are significantly negative in a long, but not in a short sample). As in the data, adjusted R^2s are small and less than 2%.

Panel B introduces the carry and conditional carry risk factors. As in the data, the higher the interest rate, the higher the exposure to the carry factor. This effect is highly significant, even in a short sample. The unconditional loading on the carry is negative for low delta countries and positive for high delta countries, but not always significant. The conditional loading, however, is so significant that the Wald test easily rejects the null hypothesis that all slope coefficients are zero. The adjusted R^2s of these regressions are much higher than for the standard UIP tests: R^2s are now in the 60% to 80% range. These R^2s are higher than in the data: the model implies that a too large share of bilateral exchange rates variations is explained by the carry factor and its interaction with interest rates.

Panel C uses the carry trade and dollar risk factors. The dollar slope coefficient is highly statistically significant and adjusted R^2s raise to the 80% to 90% range. In the actual data, R^2s are between 20% and 90%.

Overall, the model does a good job matching the UIP regressions. Its most glaring shortcoming resides in the high R^2s of the augmented-UIP regressions with carry factors. In the model, world shocks drive most of the variance in exchange rates. As a result, the carry factor, which captures those world shocks, accounts for a very large share of the changes in exchange rates. Its role is less preeminent in the data.

This finding does not imply a deep flaw in the model but highlights the usefulness of looking at new moments. Without them, one cannot pin down the share of systematic versus idiosyncratic risk. In order to match the share of exchange rates accounted for by the carry factor, one needs to increase the share of idiosyncratic shocks in the exchange rate volatility. Multiplying γ tenfold, for example, increases the volatility of exchange rates from 8.4% to 14% and reduces the R^2 in panel B to the 11% to 40% range, i.e., to levels closer to the data. A new complete calibration would require lowering slightly the exchange rate volatility.

[Table 6 about here.]

I turn now to recent advances in international finance and briefly sketch the use of augmented-UIP regressions.

5.2 Recent Macro-Finance Explanations of the UIP Puzzle

In order to account for the empirical findings in this paper, models need to deliver currency excess returns in the first place, and thus must be consistent with the failure of UIP. This is not an easy task, but a recent literature offers several potential explanations of the UIP puzzle. This literature can be divided into two groups that differ by their departure or not from rational expectations.

In the class of rational expectation frameworks, three general equilibrium models, through volatile stochastic discount factors, can replicate the UIP puzzle and are thus consistent with the most well-known stylized facts on exchange rates. I review them here rapidly in their chronological order of appearance and discuss their potential extensions. Verdelhan (2010), in a Campbell and Cochrane (1999) habit model, offers the first rational expectation model of the UIP puzzle. Bansal and Shaliastovich (2008), Colacito (2008), and Colacito and Croce (2011a) explain the UIP puzzle in a Bansal and Yaron (2004)'s long run risk model. Farhi and Gabaix (2008) build on the disaster risk model of Rietz (1988), Barro (2006), and Gabaix (2008). These models start from endowment economies. See Gourio, Siemer and Verdelhan (forthcoming) for an international real business cycle version of the disaster risk model.

These papers feature two-country models. They first need to be extended to several countries, while featuring a common risk factor. In the habit model, this necessary condition could be satisfied by the definition of habits over a global consumption growth rates. In the long-run risk model, the slow moving mean of consumption growth (i.e., its long-run risk component) is a natural candidate for the common component. Along this line, Colacito and Croce (2011b) show that highly correlated long-run risk components across countries deliver exchange rates that are as volatile as their empirical counterparts. They thus offer a solution to the puzzle described by Brandt, Cochrane and Santa-Clara (2006). In the disaster risk model, a world disaster whose probability is time-varying delivers a common source of risk (if the disaster characteristics were constant, risk premia would also be constant, and the model could not replicate the UIP puzzle). The findings in this paper imply restrictions in the calibrations of these models.

For long run risk models, augmented-UIP regressions are informative about the relative variance of the long run component of consumption growth relative to its temporary part. This is an interesting additional moment to consider because the long run component is difficult to pin down in the data. For disaster risk models, augmented-UIP regressions speak to the volatility of the world disaster probability, which is another component that is difficult to measure directly in the data.

There is a second set of potential explanations for the failure of UIP. Following Froot and Thaler (1990) and Lyons (2001), some authors depart from rational expectations in order to account for the forward premium puzzle. They assume that agents' expectations or beliefs are systematically distorted. See notably Gourinchas and Tornell (2004), Bacchetta and van Wincoop (2010) and Ilut (2010). It remains to be shown how these models could deliver the properties of currency portfolios (common factors across portfolios and large drops in carry trade excess returns when global volatility increases). Their extension to many countries seems also a worthwhile endeavor, left out for future research. The findings in this paper raise the bar for non-risk based explanations by uncovering new links in the shares of systematic variation across asset classes.

6 Robustness Checks and Extensions

I now consider several robustness checks to the main result. This section reports results obtained with other factors (like momentum, subsection 6.1), at daily, quarterly, and annual frequencies (subsection 6.2), with macroeconomic variables (subsection 6.3), in emerging and developing countries (subsection 3.1), and the dynamics of bid-ask spreads (subsection 6.4). I redo similar tests using different base currencies (subsection 6.5). I study the stability of the factor structure (subsection 6.6). Finally, I check that the carry and dollar factors are priced in country-level excess returns (subsection 6.7).

6.1 Other Factors

Momentum appears as a pervasive phenomenon in equity markets and seems also present in currency markets (see Asness, Moskowitz, and Pedersen, 2008). The equity literature has proposed many different ways to pick past winners and losers: for example, measuring returns over 1 to 12 months before sorting stocks, or adding lags of 1 to n months between the time stocks are sorted and the date portfolios are formed. I do not explore all the potential definitions, but conduct a simple experiment.

Momentum portfolios are formed by sorting countries on their past currency excess returns (measured over the previous month). The obtained cross-section of excess returns is partly explained by the carry and dollar factors. But a third potential factor emerges; it corresponds to the third component of the momentum-sorted portfolios. This momentum factor, however, does not add much explanatory power beyond the carry and dollar factors. It appears significant only for the U.K, but never in the other 12 countries. Similar results appear by sorting countries on their past three-month returns (instead of one-month returns). These negative results do not rule out the existence of an independent momentum factor in bilateral exchange rates as many other definitions of momentum can be tested.

Focusing on the currency market literature, another potential factor emerges: Ang and Chen (2010) show that sorting countries on the *changes* in short term interest rates also leads to a cross-section of currency excess returns. A potential factor could correspond to the following long-short strategy: long the last portfolio (larges changes in foreign interest rates) and short the first portfolio (small changes in foreign interest rates). This strategy delivers positive currency excess returns.

As for the carry factor, the focus is on the exchange rate components of these portfolios. In a similar set of augmented-UIP regressions, the additional factor appears significant for Denmark, Germany, Switzerland, and the U.K. but does not deliver significant increases in R^2s.

Again, these findings do not rule out the existence of other factors that account for bilateral changes in exchange rates. Future research will certainly uncover some new factors, but this study is limited to the potential factors already established by previous empirical and theoretical literature.

6.2 Daily, Quarterly, and Annual Changes in Exchange Rates

I now check the robustness of the main results at different frequencies, starting with daily data and then moving to quarterly and annual series.

Daily Data The carry and dollar factors are built from portfolios of daily changes in exchange rates by sorting countries on their one-month forward discounts. Although the forward rates are observed at daily frequencies, interest rate differences are quite persistent and thus the portfolio sorts are also persistent. Table 7 is the counterpart to Table 2: it reports similar regression results but at a daily frequency. The time windows are the same but the number of observations jumps from a maximum of 325 months to a maximum of 7048 days.

The similarity with monthly estimates is obvious. The adjusted R^2 still range from 20% to almost 90% even when looking at daily changes in exchange rates. The average adjusted R^2 is 61% among developed countries. The carry loadings are negative for 10 out of 13 countries (and positive for Australia, Canada, and New Zealand). The conditional carry loadings are positive in 11 out of 13 countries. They are negative for Japan and Canada (the two countries that did not have significantly positive loadings at the monthly frequency). They are now significantly different from zero for 12 out of 13 countries. The dollar loadings are quite similar to the monthly estimates too. They range from 0.5 (Canada, as on monthly data) to almost 1.5 (mostly scandinavian countries, again as on monthly data). R^2s and loading estimates thus appear very consistent across these two different frequencies.

[Table 7 about here.]

Quarterly and Annual Data Similar conclusions emerge at different frequencies. Overlapping series are built at quarterly and annual frequencies. The average shares of systematic currency risk increase from high to low frequencies. Among both developed and developing countries, the average R^2 is 50.5% at a daily frequency, 55.6% at a monthly frequency, 60.0% at a quarterly frequency, and 68.4% at an annual frequency. The relative ranking of each country is generally preserved across frequencies. The correlation between the monthly and daily R^2s is 0.95; it is 0.99 between the monthly and quarterly R^2s, and 0.94 between the monthly and annual R^2s.

6.3 Comparison to Macroeconomic Variables

For macroeconomic variables, capturing currency variations is even harder: while changes in exchange rates that drive the dollar and carry factors are measured precisely, growth rates of macroeconomic variables are not. I turn now to this issue, providing a quick comparison of the benchmark results to those obtained using macroeconomic variables.

At a monthly frequency, US industrial production growth rates and the foreign minus domestic growth rates of the consumer price index appear as natural candidates in order to measure currency risk. Table 8 reports the results. Many adjusted R^2s are negative, and the highest value is 2.5%. Using foreign minus domestic (instead of US) industrial production growth rates limits the sample in terms of countries and time windows and delivers similar results. The difference in industrial production appears significant only for Canada over the last 16 years. The adjusted R^2s are all below 3%. As with the usual UIP tests, such low R^2s led many people to think of exchange rates as independent random walks. Moreover, these macroeconomic variables are almost never significant. Even if one were to predict them perfectly, one would not beat the random walk at a monthly frequency.

This experiment does not mean that exchange rates are unrelated to macroeconomic variables. It simply highlights how difficult to uncover such links are. Yet, these links exist: they tend to appear more clearly at low frequencies (with quarterly, and mostly annual series), and on portfolios of currencies (instead of individual currency pairs). Lustig and Verdelhan (2007, 2011), for example, report that high (low) interest rate currencies tend to depreciate (appreciate) when annual and quarterly consumption growth is low. Further research will certainly explore many more potentially interesting macroeconomic series (notably the principal components of large data sets) in order to account for exchange rate comovements.

[Table 8 about here.]

6.4 Principal Components of Bid-Ask Spreads

Some authors argue that price pressure or other informational frictions (like moral hazard) are key mechanisms on currency markets. There is no formal empirical test of these mechanisms on currency markets, but the intuition suggests that they should affect the dynamics of bid-ask spreads.

Is there systematic variation in bid-ask spreads? Certainly, and the recent crisis offers a clear example, as many bid-ask spreads increased at the same time. But these bid-ask spreads are not strongly correlated with currency factors. In the data, the dollar and carry factors only explain a small fraction of the changes in bid-asks spreads. The average R^2 is less than 8% across developed countries. The carry, conditional carry, and dollar factors rarely appear significant. The most significant loadings are on interest rate differences. Overall, bid-ask spreads exhibit some comovement, but their variations are two orders of magnitude smaller than the changes in midquotes, and thus cannot infirm the benchmark results in this paper.

6.5 Other Base Currencies and Cross-Rates

All regressions so far pertain to exchange rates defined with respect to the U.S. Dollar. Similar results, however, emerge with other base currencies. I consider exchange rates defined with respect to the Japanese Yen, U.K. pound, and Swiss Franc. augmented-UIP tests, for example for pound-based exchange rates, are thus:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Pound_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.K. Pound and $Pound_{t+1}$ corresponds to the average change in exchange rates against the U.K. Pound. The *Carry* factor is not changed much as it is dollar-neutral. The shares of systematic risk range from 39% to 71% for pound-based currencies, from 65% to 82% for Yen-based currencies, and from 35% to 77% for franc-based currencies. In each case, a country-specific factor appears necessary to account for exchange rate variation.

The dollar factor is thus a basis factor, linked to the choice of the basis currency. The dollar factor, however, explains also part of some cross-rates changes (i.e. exchange rates not defined with respect to the U.S. dollar). The dollar factor is a significant factor of cross-rates for currencies that exhibit very different loadings on the dollar factor in their U.S. dollar based exchange rates in the first place. Going back to Table 2, the Yen/Dollar exchange rate, for example, has a loading of 0.98 on the dollar factor, whereas the Swiss Franc/Dollar has a loading of 1.36. As a result, the Swiss Franc/Yen exchange rate exhibits a large and positive loading on the dollar factor. The risk-based model of Lustig et al. (forthcoming) provides an intuition for this finding. Recall that the dollar factor captures U.S.-specific shocks to the U.S. pricing kernel as well as global shocks. In a no-arbitrage model, the Swiss Franc / Yen exchange rate depends on the Swiss and Japanese SDFs and there is thus no role for U.S.-specific shocks, but the Swiss Franc / Yen exchange rate also depends on global shocks that affect the dollar factor as well. Teasing out the global component of the dollar factor is no easy task because of its heteroscedasticity.

6.6 Stability of the Factor Structure

In order to study time-variation in currency R^2s and loadings, the same regressions as in Table 2 are run but on rolling windows of 60 months (5 years). There is no sign that the full sample corresponds to particularly high R^2s – higher values can be attained on shorter subsamples. For Japan, Switzerland, and the United Kingdom, the adjusted R^2s remain significantly above 0 throughout the sample. For Australia and New Zealand, some samples ending in the second half of the 90s lead to zero or negative adjusted R^2s. For Canada, R^2s are significantly different from 0 only over samples ending in the last ten years.

Mean Squared Errors The following experiment exploits the persistence of factor loadings. Assume that the carry and dollar factors are known one period in advance. Then expected changes in exchange rates are derived using the loadings estimated on past observations. These are *not* true forecasts since they assume that the factors are known one period in advance and thus perfectly predictable. This is a strong assumption given that these two factors are actually hard to predict, hence the *pseudo* characteristic of the predictability test. The pseudo-predicted change in exchange rate is thus:

$$\widehat{\Delta s_{t+1}} = \alpha_t + \beta_t(i_t^\star - i_t) + \gamma_t(i_t^\star - i_t)Carry_{t+1} + \delta_t Carry_{t+1} + \tau_t Dollar_{t+1},$$

where α_t, β_t, γ_t, δ_t, and τ_t are estimated on samples that end at date t. This exercise is in the same spirit as that of Ferraro, Rossi and Rogoff (2011) who show that exchange rate changes can be predicted by *contemporaneous* changes in a fundamentals-related variable (in their case, oil prices). It extends the seminal Meese and Rogoff (1983) experiment, which also assumes that macroeconomic variables are know one period in advance.

Table 9 reports the standard deviation of log changes in spot exchange rates and the square root of mean squared errors (RMSE) obtained in the experiment above. These RMSE are compared to those obtained by assuming that exchange rates are random walks with drifts (i.e., when only α_t is estimated). Standard deviations and RMSE are annualized (i.e., multiplied by $\sqrt{12}$) and reported in percentages. Compared to the random walk, the decrease in RMSE is large: the ratios range from 0.3 to 0.9 for developed countries.[8]

A quick comparison with the predictive power of macroeconomic variables puts the results above

[8]The literature relies on the Diebold and Mariano (1995) and Clark and West (2006) tests of equal predictive ability in order to assess small decreases in RMSEs.

into perspective. Cheung, Chinn and Pascual (2005) study five different models and test them on five currency pairs, two different samples, either in first-differences or in levels with cointegration, at one, four, and twenty-quarter horizons. Out of 216 estimations, only two outperforms significantly the random walk. Using the carry and dollar factors leads to large decreases in RMSE for the 13 developed countries in the sample.

A very large literature attempts to predict changes in exchange rates at the bilateral level (see Rossi (2011) for a survey). The experiment in this paper offers two insights to this literature. First, it gives a new benchmark. Table 9 shows that models in international economics and finance should seek to reduce the RMSE by 10% to 70% (depending on the currency) compared to a prediction based on a random walk. Additional pseudo-predictability might come from better predictions of the factor loadings and the discovery of new factors. Second, efforts should be focused on predicting the dollar and carry components in order to move beyond pseudo-predictability. These two components average out idiosyncratic changes in exchange rates and thus constitute better test assets for any model in international finance than individual exchange rates.

[Table 9 about here.]

Principal Components Obtaining large R^2s *per se* does not require portfolios of currencies in order to extract information. Large R^2s can be obtained by using a sufficient number of principal components, without forming any portfolio. Yet, the economic interpretation is quite different.

The first principal component of a large set of bilateral exchange rate changes is, unsurprisingly, highly correlated with the dollar factor; the correlation is 0.95. But the carry factor is different from the second principal component of unconditional changes in exchange rates. The correlation of the second principal component with the carry factor is only -0.38. The carry factor is close to the second principal component of portfolios of currencies sorted on interest rates, but not to the second principal component of a simple set of exchange rates. Conditioning on interest rate levels (as portfolios do) matters.

Focusing on the benchmark carry and dollar factors (instead of the principal components) has three advantages. First, the carry and dollar factors account for a large share of currency dynamics in a parsimonious way. Second, they are easily interpretable: they arise naturally in any no-arbitrage model of currency markets as Section section:models shows. Third, the loadings on the carry and dollar factors appear to be quite stable, while the loadings on the principal components are not. As a result, the RMSEs obtained in pseudo-predictable experiments are much higher than those obtained with the carry and dollar factors. As the last two columns of Table 9 shows, the first three principal components rarely beat the carry and dollar factors.

To sum up, robustness tests show that the large R^2s and significant loadings on the carry and dollar factors are pervasive and, unlike macroeconomic variables, point towards large comovement across currencies.

6.7 Country-Level Asset Pricing

Finally, I run country-level asset pricing tests in order to complement the evidence reported using currency portfolios and to check that the carry and dollar factors are priced risk factors.

Country-level asset pricing tests follow the Fama and MacBeth's (1973) procedure. The tests are similar to those reported in Lustig et al. (forthcoming), except that the average currency market excess return RX used in Lustig et al. (forthcoming) is replaced by its conditional counterpart, obtained as the dollar excess return multiplied by the sign of the average forward discount, $(\overline{i_t^i - i_t})RX$. This modification is key: the risk price of the former is not statistically significant, while the risk price of the latter is. This difference is consistent with the absence of arbitrage. No arbitrage implies that the market price of risk should be equal to the mean of the risk factor. The average currency market excess return RX is not statistically different from zero, while its conditional counterpart is. The Fama and MacBeth (1973) procedure is described in the notes to Table 10. To save space, I focus here on the results.

Unconditional country currency risk premiums Panel A of Table 10 reports the market prices of risk obtained on unconditional currency excess returns. They are positive and less than one standard error from the means of the risk factors, which are reported in Panel D of Table 10. The RMSE and the mean absolute pricing error are larger than those obtained on currency portfolios, but the null hypothesis that all pricing errors are jointly zero cannot be rejected. High beta countries tend to offer high unconditional currency excess returns.

Conditional country currency risk premiums I now turn to conditional risk premiums, first reporting results obtained with managed investments and then turning to time-varying factor betas. Investors can adjust their position in a given currency based on the interest rate at the start of each period to exploit return predictability. Such managed investment strategies correspond to *conditional* expected excess returns and complement the raw currency excess returns. For example, investors would invest more in high interest rate currencies in order to pocket the carry trade risk premium. Likewise, investors would go long all foreign currencies when the average forward discount is positive in order to pocket the dollar risk premium. To construct these managed positions, each currency excess return is thus multiplied by the appropriate beginning-of-month forward discount (normalized by subtracting the average forward discount across currencies and dividing by the cross-sectional standard deviation of forward discounts in the given period) or the sign of the average forward discount.

The Fama and MacBeth (1973) procedure applies to the large set of raw and managed currency excess returns. Panel B of Table 10 shows that the cross-sectional fit improves and the risk prices are more precisely estimated. Market prices of risk are positive and significant and in line with those obtained on the unconditional returns. The carry and conditional dollar risk factors are clearly priced in the cross-section of country-level currency excess returns.

Instead of enlarging the asset space to include managed returns, betas can be modeled as linear functions of the conditioning variables. In particular, it is natural to assume that each country's loading on the carry factor is a linear function of the country's forward discount. Likewise, each country's loading on the dollar factor is a linear function of the average forward discount. The results of the estimation are in Panel C of Table 10. This method produces very similar results to the managed returns approach, which provides further evidence for the role of forward discounts in capturing the currencies' dynamic exposures to common sources of risk.

Overall, the country-level results are thus fully consistent with the portfolio-level results and support the interpretation of the carry and dollar factors as risk factors.

[Table 10 about here.]

7 Conclusion

Two common components — a dollar and a carry components — account for 20% to 90% of bilateral exchange rates at daily, monthly, and quarterly frequencies. Cross-currencies differences in the shares of systematic variation appear related to financial and macroeconomic measures of world integration. The findings reported in this paper can be interpreted in a risk-based approach to currency markets, based on the assumption of no arbitrage.

I end this paper with a set of broader questions and a tentative research agenda. The results in this paper are very encouraging for future research in international finance. If a large share of the time-series variation in bilateral exchange rates were just noise, uncorrelated to anything, then the scope for future research would be very limited. One could at best hope to understand a small share of exchange rate dynamics. The results in this paper suggest otherwise. A large share of the exchange rate dynamics is accounted for by two common factors. This finding highlights a potential path for future research in two directions.

First, one could focus on common components. Are there other key common components? What are their drivers? Do they correspond to risk or characteristics? Would they arise under rational expectations and non-rational expectations alike? If they are risk factors, then what kind of risk do they capture? Macroeconomic risk? Liquidity risk? Are these factors predictable at short and long horizons?

Second, one needs to understand the heterogeneity across exchange rates. Lustig et al. (forthcoming) show that in any risk-based model pricing kernels must differ in the way they load on common shocks across countries. High interest rate countries must load less than low interest rate countries on common shocks. These loadings must also be time-varying. What is the source of heterogeneity in these loadings? Macroeconomics? Behavioral? What does explain the time-variation in these loadings? Is this source of heterogeneity enough to account for the difference in R^2s in the augmented-UIP regressions?

The large share of systematic risk in exchange rates makes these questions very relevant to researchers and practitioners alike.

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Table 1: Monthly UIP Tests With and Without the Carry Factor

	Panel I: UIP			Panel II: UIP with Carry					
Country	α	β	R^2	α	β	γ	δ	R^2	N
Australia	0.16	-0.88	**0.08**	0.00	-0.72	0.57	0.33	**14.52**	312
	(0.25)	(0.68)	[0.73]	(0.24)	(0.58)	(0.34)	(0.14)	[5.63]	
Canada	-0.03	-1.02	**0.21**	-0.14	-0.42	-0.51	0.25	**8.39**	312
	(0.14)	(0.74)	[0.78]	(0.13)	(0.63)	(0.44)	(0.07)	[5.03]	
Denmark	-0.21	-0.26	**-0.27**	-0.12	-1.36	1.30	-0.10	**6.31**	312
	(0.19)	(0.71)	[0.53]	(0.17)	(0.53)	(0.32)	(0.11)	[3.70]	
Euro Area	-0.18	-2.66	**0.55**	-0.18	-2.04	-0.47	0.04	**-0.22**	143
	(0.27)	(2.22)	[2.31]	(0.26)	(1.91)	(0.95)	(0.16)	[4.73]	
France	-0.19	-0.17	**-0.54**	-0.00	-1.82	1.60	-0.16	**11.11**	181
	(0.26)	(1.14)	[1.20]	(0.24)	(0.69)	(0.39)	(0.12)	[5.59]	
Germany	-0.23	0.43	**-0.43**	-0.30	-0.92	2.23	0.08	**25.29**	181
	(0.28)	(1.12)	[1.12]	(0.21)	(0.76)	(0.22)	(0.08)	[6.23]	
Italy	-0.12	0.40	**-0.45**	0.34	-0.82	1.01	-0.29	**5.72**	177
	(0.34)	(1.01)	[2.07]	(0.38)	(0.94)	(0.44)	(0.19)	[7.51]	
Japan	-0.91	-2.42	**1.71**	-0.91	-2.98	0.61	-0.29	**15.51**	325
	(0.26)	(0.90)	[1.59]	(0.26)	(0.88)	(0.38)	(0.11)	[4.95]	
New Zealand	0.21	-0.99	**0.91**	0.17	-1.13	0.42	0.20	**9.56**	312
	(0.25)	(0.49)	[1.44]	(0.24)	(0.45)	(0.32)	(0.15)	[4.35]	
Norway	-0.23	0.44	**-0.17**	-0.12	-0.45	0.63	0.03	**3.78**	312
	(0.22)	(0.89)	[0.93]	(0.20)	(0.64)	(0.21)	(0.11)	[3.42]	
Sweden	-0.04	-0.35	**-0.23**	0.02	-1.25	1.04	-0.01	**6.40**	312
	(0.21)	(0.99)	[0.78]	(0.19)	(0.61)	(0.39)	(0.11)	[4.20]	
Switzerland	-0.35	-0.53	**-0.19**	-0.48	-1.72	2.04	0.11	**13.15**	325
	(0.28)	(1.07)	[0.77]	(0.21)	(0.80)	(0.38)	(0.11)	[3.99]	
United Kingdom	0.22	-1.39	**0.43**	0.21	-1.60	1.08	0.05	**4.98**	325
	(0.23)	(1.24)	[1.43]	(0.21)	(0.97)	(0.88)	(0.17)	[3.96]	

Notes: The left panel of this table reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i_t^\star - i_t$ is the interest rate difference between the foreign country and the U.S. The right panel of this table reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \varepsilon_{t+1},$$

where $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies. The table reports the constant α, the slope coefficients β, γ, and δ, as well as the R^2 of this regression (in percentage points), and the number of observations. Standard errors in parentheses are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The standard errors for the R^2s are reported in brackets; they are obtained by bootstrapping. Data are monthly, from Barclays and Reuters (Datastream). All variables are in percentage points. The sample period is 11/1983–12/2010.

Table 2: Monthly Augmented UIP Tests in Developed Countries

Country	α	β	γ	δ	τ	R^2	$R^2_{\$}$	W	N
Australia	0.01	-0.19	0.86	0.19	0.91	**41.11**	28.32	***	312
	(0.22)	(0.56)	(0.32)	(0.12)	(0.11)	[5.90]	[6.27]		
Canada	-0.12	0.07	-0.50	0.21	0.41	**22.84**	17.04	***	312
	(0.11)	(0.64)	(0.39)	(0.06)	(0.08)	[6.66]	[5.07]		
Denmark	0.02	-0.38	0.58	-0.24	1.49	**89.60**	86.00	***	312
	(0.06)	(0.36)	(0.13)	(0.03)	(0.03)	[1.41]	[1.85]		
Euro Area	0.07	-0.60	0.11	-0.27	1.56	**83.19**	78.99	***	143
	(0.11)	(0.78)	(0.22)	(0.05)	(0.07)	[3.17]	[3.80]		
France	-0.14	-0.02	0.75	-0.10	1.30	**92.96**	90.36	***	181
	(0.06)	(0.30)	(0.15)	(0.03)	(0.03)	[1.23]	[1.65]		
Germany	-0.19	-0.09	0.86	-0.03	1.37	**92.06**	87.96	***	181
	(0.09)	(0.32)	(0.15)	(0.03)	(0.04)	[1.15]	[1.81]		
Italy	0.02	0.17	0.86	-0.21	1.22	**69.98**	64.55	***	177
	(0.19)	(0.52)	(0.24)	(0.09)	(0.09)	[5.14]	[6.30]		
Japan	-0.37	-1.01	0.18	-0.48	0.96	**47.62**	29.80	***	325
	(0.21)	(0.75)	(0.37)	(0.09)	(0.10)	[4.50]	[6.07]		
New Zealand	0.03	-0.30	0.95	-0.08	1.15	**46.86**	35.07	***	312
	(0.19)	(0.38)	(0.27)	(0.11)	(0.10)	[4.86]	[5.43]		
Norway	-0.07	0.29	0.39	-0.02	1.35	**73.48**	72.26	***	312
	(0.11)	(0.36)	(0.13)	(0.06)	(0.08)	[3.50]	[3.60]		
Sweden	0.06	-0.20	0.96	-0.09	1.40	**74.74**	69.82	***	312
	(0.09)	(0.30)	(0.18)	(0.04)	(0.06)	[2.66]	[3.61]		
Switzerland	-0.09	-0.25	0.78	-0.21	1.35	**81.45**	73.90	***	325
	(0.10)	(0.38)	(0.20)	(0.06)	(0.04)	[1.89]	[2.54]		
United Kingdom	0.02	0.02	0.68	-0.01	1.08	**56.43**	55.22		325
	(0.14)	(0.65)	(0.44)	(0.09)	(0.08)	[5.20]	[5.20]		

Notes: This table reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i_t^\star - i_t$ is the interest rate difference between the foreign country and the U.S., $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. The table reports the constant α, the slope coefficients β, γ, δ, and τ, as well as the R^2 of this regression (in percentage points) and the number of observations N. Standard errors in parentheses are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The standard errors for the R^2s are reported in brackets; they are obtained by bootstrapping. $R^2_{\$}$ denotes the R^2 of a similar regression with only the *Dollar* factor (i.e., without the conditional and unconditional *Carry* factors). W denotes the result of a Wald test: the null hypothesis is that the loadings γ and δ on the conditional and unconditional carry factors are jointly zero. Three stars (***) correspond to a rejection of the null hypothesis at the 1% confidence level; two stars and one star correspond to the 5% and 10% confidence levels. Data are monthly, from Barclays and Reuters (Datastream). All variables are in percentage points. The sample period is 11/1983–12/2010.

Table 3: Monthly Augmented UIP Tests in Emerging and Developing Countries

Country	α	β	γ	δ	τ	R^2	$R^2_{\$}$	W	N
China Hong Kong	-0.01	-0.15	0.06	0.00	0.02	**5.96**	5.06		325
	(0.01)	(0.09)	(0.04)	(0.00)	(0.01)	[3.46]	[3.23]		
Czech Republic	-0.11	-0.23	-0.03	-0.20	1.80	**68.88**	67.51	**	167
	(0.15)	(0.31)	(0.18)	(0.08)	(0.09)	[4.43]	[4.40]		
Hungary	0.31	-0.29	-0.55	0.39	1.82	**70.92**	69.67	***	158
	(0.37)	(0.55)	(0.18)	(0.15)	(0.13)	[4.72]	[4.67]		
India	0.30	-0.52	0.27	0.01	0.54	**34.47**	33.63		158
	(0.24)	(0.64)	(0.30)	(0.11)	(0.08)	[7.22]	[6.64]		
Indonesia	1.90	-2.37	1.00	0.35	1.83	**45.78**	22.92	***	90
	(0.87)	(0.78)	(0.25)	(0.48)	(0.64)	[11.97]	[5.78]		
Kuwait	-0.16	2.10	0.52	-0.10	0.22	**53.72**	45.26	***	167
	(0.03)	(0.19)	(0.08)	(0.02)	(0.04)	[11.32]	[9.45]		
Malaysia	0.11	0.10	0.21	0.14	0.49	**25.55**	21.48		230
	(0.13)	(0.59)	(0.18)	(0.09)	(0.08)	[5.20]	[4.96]		
Mexico	0.38	-0.39	-0.16	0.66	0.31	**36.51**	11.68	***	167
	(0.26)	(0.35)	(0.15)	(0.14)	(0.13)	[9.02]	[7.98]		
Philippines	0.22	-0.20	0.63	0.08	0.50	**42.64**	21.68	***	167
	(0.32)	(0.70)	(0.20)	(0.11)	(0.09)	[8.15]	[6.77]		
Poland	-0.12	1.32	1.23	0.03	1.82	**78.59**	75.43	***	106
	(0.19)	(0.69)	(0.29)	(0.08)	(0.11)	[4.96]	[5.34]		
Saudi Arabia	0.01	-0.42	0.23	-0.00	0.00	**12.36**	2.83	*	167
	(0.01)	(0.37)	(0.12)	(0.00)	(0.00)	[11.88]	[8.06]		
Singapore	-0.15	-0.25	0.21	0.06	0.54	**51.55**	50.94		312
	(0.10)	(0.59)	(0.14)	(0.03)	(0.04)	[4.07]	[4.28]		
South Africa	0.83	-0.72	0.32	0.31	1.15	**37.71**	29.79	***	324
	(0.44)	(0.67)	(0.40)	(0.27)	(0.14)	[5.04]	[5.71]		
South Korea	0.48	-1.19	1.38	-0.04	1.48	**61.06**	56.62	**	106
	(0.30)	(1.77)	(0.54)	(0.12)	(0.20)	[6.24]	[5.70]		
Taiwan	0.03	0.31	0.34	0.05	0.54	**38.94**	36.93	**	167
	(0.12)	(0.27)	(0.13)	(0.05)	(0.06)	[5.94]	[6.09]		
Thailand	-0.03	-0.95	1.10	0.02	0.78	**38.61**	21.87	**	167
	(0.18)	(1.09)	(0.50)	(0.13)	(0.16)	[6.94]	[5.94]		
Turkey	-0.71	0.63	-0.19	1.35	0.72	**52.15**	30.53	***	154
	(0.35)	(0.13)	(0.05)	(0.24)	(0.15)	[6.66]	[8.09]		
United Arab Emirates	0.00	-0.26	0.13	-0.00	0.00	**21.09**	3.33		162
	(0.00)	(0.16)	(0.09)	(0.00)	(0.00)	[20.36]	[13.06]		

Notes: This table reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i_t^\star - i_t$ is the interest rate difference between the foreign country and the U.S., $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. The table reports the constant α, the slope coefficients β, γ, δ, and τ, as well as the R^2 of this regression and the number of observations N. $R^2_{\$}$ denotes the R^2 of a similar regression with only the *Dollar* factor. W denotes the result of a Wald test on the joint significance of γ and δ. See Table 2 for additional information.

Table 4: Portfolios of Countries Sorted on Dollar Exposures

Panel I: Summary Statistics						
$Portfolio$	1	2	3	4	5	6
			Spot change: Δs			
$Mean$	0.21	-1.82	-2.85	-3.12	-4.86	-5.90
Std	2.76	5.09	6.23	8.42	10.11	10.86
			Forward Discount: $f-s$			
$Mean$	0.53	1.35	1.29	2.61	1.95	1.85
Std	0.51	0.95	1.17	1.49	0.70	0.60
			Excess Return: rx			
$Mean$	0.32	3.17	4.15	5.73	6.81	7.74
	[0.62]	[1.07]	[1.30]	[1.75]	[2.17]	[2.29]
Std	2.76	5.04	6.28	8.27	10.07	10.84
SR	0.12	0.63	0.66	0.69	0.68	0.71
Panel II: Risk Prices						
	$\lambda_{Cond.Dollar}$	$b_{Cond.Dollar}$	R^2	$RMSE$	χ^2	
GMM_1	4.26	0.86	98.68	0.28		
	[1.50]	[0.30]			96.36	
GMM_2	4.18	0.85	98.57	0.29		
	[1.35]	[0.27]			96.39	
FMB	4.26	0.86	98.88	0.28		
	[1.40]	[0.28]			93.31	
	(1.40)	(0.28)			93.79	
$Mean$	4.86					
Panel III: Factor Betas						
$Portfolio$	1	2	3	4	5	6
α	-0.66	-0.14	-0.62	-0.70	-0.72	-0.90
	[0.67]	[0.92]	[1.06]	[1.03]	[0.94]	[0.85]
β	0.06	0.43	0.66	1.06	1.37	1.58
	[0.02]	[0.06]	[0.06]	[0.07]	[0.06]	[0.04]
R^2	1.95	30.20	46.73	67.90	77.40	88.81

Notes: Panel I reports summary statistics on portfolios of currencies sorted on their exposure to the dollar factor. See Section 3.2 for details on the construction of these portfolios. The table reports, for each portfolio, the mean and standard deviations of the average change in log spot exchange rates Δs, the average log forward discount $f-s$, and the average log excess return rx without bid-ask spreads. All moments are annualized and reported in percentage points. For excess returns, the table also reports Sharpe ratios, computed as ratios of annualized means to annualized standard deviations. Panel II reports results from GMM and Fama-McBeth asset pricing procedures. The market price of risk λ, the adjusted R^2, the square-root of mean-squared errors $RMSE$ and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes the vector of factor loadings. The last row reports the mean of the risk factor. Excess returns used as test assets and risk factors take into account bid-ask spreads. All excess returns are multiplied by 12 (annualized). Shanken (1992)-corrected standard errors are reported in parentheses. The second step of the FMB procedure does not include a constant. Panel III reports OLS estimates of the factor betas. R^2s and p-values are reported in percentage points. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The alphas are annualized and in percentage points. Data are monthly, from Barclays and Reuters in Datastream. The sample period is 12/1988–12/2010.

Table 5: Cross-Country Differences in the Shares of Currency Systematic Variation

	Equity 11/1983–12/2010	Equity 1/1999–12/2010	Bonds 11/1983–12/2010	Bonds 1/1999–12/2010	GDP 1983–2010	Consumption 1983–2010
			Panel I: Constant R^2s, series in U.S. dollars			
β	0.69	0.65	0.93	0.66	0.61	0.52
s.e	[0.25]	[0.19]	[0.13]	[0.12]	[0.14]	[0.25]
R^2	19.79	31.86	78.30	72.54	41.86	14.30
N	33	28	17	13	29	27
			Panel II: Constant R^2s, series in P.P.P dollars			
β	0.51	0.50	0.87	0.38	0.60	0.55
s.e	[0.32]	[0.23]	[0.25]	[0.21]	[0.20]	[0.25]
R^2	7.75	15.54	44.83	22.04	23.62	16.10
N	33	28	17	13	30	27
			Panel III: Time-Varying R^2s, series in U.S. dollars			
β	0.42	0.34	0.74	0.55		
s.e	[0.06]	[0.10]	[0.08]	[0.09]		
s.e	(0.07)	(0.13)	(0.10)	(0.13)		
$trend$	-2.52	2.06	-4.55	4.91		
R^2	78.73	82.69	88.05	91.14		
N	5253	2915	3085	1578		
			Panel IV: Time-Varying R^2s, series in P.P.P. dollars			
β	0.22	0.30	0.33	0.08		
s.e	[0.07]	[0.10]	[0.09]	[0.10]		
s.e	(0.10)	(0.13)	(0.12)	(0.12)		
$trend$	-0.90	3.19	-1.10	5.29		
R^2	75.97	82.17	74.52	85.44		
N	5253	2915	3085	1578		

Notes: The first two panels of this table report results from the following cross-country regressions:

$$R_i^{2,FX} = \alpha + \beta R_i^{2,X} + \varepsilon_i,$$

where $R_i^{2,FX}$ denotes the share of systematic variation in the exchange rate of country i. $R_i^{2,X}$ are obtained in tests of world integration, using either equity returns, bond returns, GDP growth, or consumption growth. The last two panels of this table report results from the following cross-country panel regressions with country and time fixed effects:

$$R_{i,t}^{2,FX} = \alpha^i + \beta R_{i,t}^{2,X} + \gamma trend + \varepsilon_{i,t},$$

where $R_{i,t}^{2,FX}$ and $R_{i,t}^{2,FX}$ are estimated on rolling windows of 60 months. The first and third panels use financial and macroeconomic series expressed in U.S. dollars. The second and fourth panels use series expressed in purchasing power parity (P.P.P.) dollars. The table reports the slope coefficient β, the standard errors, the cross-sectional R^2 (in percentage points), as well as the number of observations N (i.e., countries, or country-month pairs). For the panel regressions, the table also reports the t-statistic on the common time trend. R^2s on financial markets (equity, bonds, and currencies) are obtained on monthly series. The sample periods are 11/1983–12/2010 and 1/1999–12/2010. R^2s on macroeconomic variables (consumption and output) are obtained on annual series. The sample period is 1983–2010. The standard errors (s.e.) in the panel regressions are obtained from the Newey-West autocorrelation consistent covariance estimator computed with a horizon of 60 months (reported between brackets) and from clustering by country (reported between parenthesis).

Table 6: Lustig et alii's (2010) Model: Augmented UIP Tests on Simulated Data

Country	α	β	γ	δ	τ	R^2
			Panel A			
Low Delta	0.57	−1.60				0.26
	[0.50]	[1.48]				
Med. Delta	−0.06	−2.12				1.31
	[0.11]	[1.21]				
High Delta	−0.18	−0.59				−0.23
	[0.54]	[1.39]				
			Panel B			
Low Delta	0.06	−0.12	2.38	−0.53		69.62
	[0.32]	[0.83]	[0.28]	[0.11]		
Med. Delta	−0.04	−0.36	3.17	0.10		65.27
	[0.07]	[0.62]	[0.16]	[0.02]		
High Delta	0.06	0.23	1.58	0.14		81.43
	[0.27]	[0.52]	[0.20]	[0.12]		
			Panel C			
Low Delta	−0.28	0.65	1.32	0.16	1.03	85.32
	[0.21]	[0.53]	[0.16]	[0.07]	[0.06]	
Med. Delta	−0.05	−0.40	2.00	0.22	0.81	81.46
	[0.05]	[0.41]	[0.14]	[0.02]	[0.05]	
High Delta	−0.05	0.03	1.14	0.04	0.78	89.04
	[0.19]	[0.41]	[0.16]	[0.08]	[0.08]	

Notes: This table reports results from the following set of regressions:

$$\Delta s_{t+1} = \alpha + \beta(i^\star_t - i_t) + \gamma(i^\star_t - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i^\star_t - i_t$ is the interest rate difference, $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. The table reports the constant α, the slope coefficients β, γ, δ and τ, and the adjusted R^2 of this regression. Standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The standard errors for the R^2s are reported in parentheses; they are obtained by bootstrapping. Data are simulated at monthly frequency. The sample corresponds to the last 300 months of the simulated series. Panel A focuses on the standard UIP tests; panel B introduces the carry trade risk factor; panel C introduces both the carry and dollar risk factors. In each case, we report results obtained on a low, medium, and high δ-country: δ measures the loading of the SDF on world shocks; it is the only source of heterogeneity in the model.

Table 7: Daily Augmented UIP Tests in Developed Countries

Country	α	β	γ	δ	τ	R^2	$R^2_{\$}$	W	N
Australia	-0.00	0.01	0.62	0.23	0.92	**36.57**	27.47	***	6776
	(0.01)	(0.03)	(0.10)	(0.03)	(0.03)	[1.79]	[1.39]		
Canada	-0.01	0.05	-0.37	0.20	0.47	**21.37**	17.31	***	6776
	(0.01)	(0.03)	(0.10)	(0.02)	(0.02)	[1.57]	[1.25]		
Denmark	-0.00	-0.01	0.52	-0.22	1.50	**83.53**	80.34	***	6776
	(0.00)	(0.01)	(0.05)	(0.01)	(0.02)	[0.55]	[0.66]		
Euro Area	0.00	-0.04	0.32	-0.25	1.52	**68.59**	64.47	***	3110
	(0.01)	(0.04)	(0.11)	(0.02)	(0.03)	[1.32]	[1.52]		
France	-0.01	0.01	0.66	-0.05	1.32	**85.55**	83.43	***	3937
	(0.00)	(0.02)	(0.08)	(0.02)	(0.02)	[0.90]	[1.04]		
Germany	-0.01	-0.00	0.77	-0.02	1.42	**88.89**	85.53	***	3937
	(0.00)	(0.02)	(0.05)	(0.01)	(0.01)	[0.52]	[0.67]		
Italy	0.00	-0.01	0.61	-0.17	1.25	**68.84**	66.14	***	3865
	(0.01)	(0.04)	(0.13)	(0.04)	(0.02)	[1.83]	[2.06]		
Japan	-0.01	-0.04	-0.04	-0.56	0.99	**43.42**	24.65	***	7048
	(0.01)	(0.03)	(0.11)	(0.04)	(0.03)	[1.29]	[1.70]		
New Zealand	-0.01	-0.00	0.44	0.28	0.97	**38.54**	26.88	***	6776
	(0.02)	(0.04)	(0.14)	(0.06)	(0.03)	[1.61]	[1.41]		
Norway	-0.00	0.02	0.46	-0.02	1.49	**70.39**	69.18	***	6776
	(0.01)	(0.02)	(0.05)	(0.02)	(0.02)	[1.31]	[1.44]		
Sweden	-0.00	0.01	0.41	-0.02	1.36	**60.37**	59.24	***	6776
	(0.01)	(0.02)	(0.06)	(0.02)	(0.02)	[1.22]	[1.27]		
Switzerland	-0.00	-0.01	0.58	-0.24	1.44	**76.55**	70.33	***	7048
	(0.01)	(0.02)	(0.07)	(0.02)	(0.02)	[0.73]	[0.94]		
United Kingdom	-0.00	0.03	0.47	-0.01	1.17	**57.12**	56.45	***	7048
	(0.01)	(0.03)	(0.09)	(0.03)	(0.02)	[1.19]	[1.22]		

Notes: This table reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i_t^\star - i_t$ is the interest rate difference between the foreign country and the U.S., $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. The table reports the constant α, the slope coefficients β, γ, δ, and τ, as well as the R^2 of this regression and the number of observations N. $R^2_{\$}$ denotes the R^2 of a similar regression with only the *Dollar* factor. W denotes the result of a Wald test on the joint significance of γ and δ. Standard errors in parentheses are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The standard errors for the R^2s are reported in brackets; they are obtained by bootstrapping. Data are daily, from Barclays and Reuters (Datastream). All variables are in percentage points. The sample period is 30/11/1983–31/12/2010.

Table 8: Monthly Augmented UIP Tests with Macroeconomic Variables

Country	α	β	γ	δ	R^2	N
Australia	0.24	-3.31	-5.37	81.59	2.04	312
	(0.27)	(1.83)	(10.62)	(79.86)	[3.27]	
Canada	-0.25	-2.16	-12.48	-67.84	0.75	312
	(0.23)	(1.40)	(8.85)	(59.33)	[1.71]	
Denmark	-0.18	-0.33	-3.65	-91.06	1.54	312
	(0.17)	(0.63)	(6.16)	(47.73)	[2.12]	
Euro Area	-0.27	-0.65	-0.93	-192.36	8.00	143
	(0.33)	(1.80)	(8.34)	(91.11)	[6.10]	
France	-0.09	-0.91	0.78	40.50	-1.64	107
	(0.28)	(0.85)	(10.56)	(88.83)	[2.96]	
Germany	-0.18	-0.00	-9.65	-15.22	-1.05	181
	(0.36)	(1.03)	(9.05)	(60.34)	[1.87]	
Italy	0.02	0.44	-6.55	35.18	-0.93	177
	(0.24)	(1.23)	(8.88)	(80.02)	[3.24]	
Japan	-1.40	-2.10	-13.46	-133.39	3.07	325
	(0.59)	(1.15)	(7.91)	(64.78)	[2.37]	
New Zealand	-0.13	0.65	-11.39	-40.94	-0.22	312
	(0.22)	(0.78)	(9.40)	(44.19)	[1.51]	
Norway	-0.02	-0.41	-6.77	-39.77	0.10	312
	(0.14)	(0.76)	(7.86)	(37.35)	[1.68]	
Sweden	-0.02	-0.92	-8.86	-84.85	2.76	312
	(0.16)	(0.73)	(7.16)	(34.31)	[2.31]	
Switzerland	-0.59	-0.87	-7.98	-68.13	0.82	325
	(0.30)	(0.71)	(6.52)	(53.33)	[1.66]	
United Kingdom	-0.19	-1.38	-11.68	-6.94	0.42	325
	(0.23)	(1.27)	(7.89)	(32.75)	[1.65]	

Notes: This table reports country-level results from the following regression:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma \Delta ip_{t+1} + \delta(\Delta cpi_{t+1}^\star - \Delta cpi_{t+1}) + \varepsilon_{t+1},$$

where where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i_t^\star - i_t$ is the interest rate difference between the foreign country and the U.S., Δip_{t+1} denotes the log difference in the industrial production index and $\Delta cpi_{t+1}^\star - \Delta cpi_{t+1}$ denotes the foreign minus domestic log difference in the consumer price indices. Changes in exchange rates and interest rate differences are expressed in percentage points. The table reports the constant α, the slope coefficients β, γ, δ, and τ, as well as the R^2 of this regression (in percentage points) and the number of observations. Standard errors in parentheses are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The standard errors for the R^2s are reported in brackets; they are obtained by bootstrapping. Data are quarterly, from Barclays and Reuters (Datastream). All variables are in percentage points. The sample period is 1983.11–2010.12.

Table 9: Pseudo-Predictability: Risk Factors vs Random Walk vs Principal Components

Country	$\sigma_{\Delta s}$	$RMSE$	$RMSE_{RW}$	$\frac{RMSE}{RMSE_{RW}}$	$RMSE_{PC}$	$\frac{RMSE_{PC}}{RMSE_{RW}}$
			Panel A: Developed Countries			
Australia	12.01	9.15	11.48	0.80	12.35	1.08
Canada	7.04	6.57	7.39	0.89	7.70	1.04
Denmark	11.06	3.87	10.76	0.36	11.27	1.05
Euro Area	10.73	4.34	11.05	0.39	11.86	1.07
France	11.20	3.31	10.66	0.31	10.94	1.03
Germany	11.72	3.75	10.90	0.34	11.12	1.02
Italy	11.30	7.71	11.14	0.69	11.28	1.01
Japan	11.50	8.82	11.30	0.78	12.41	1.10
New Zealand	12.18	8.78	11.26	0.78	11.69	1.04
Norway	10.99	5.88	10.88	0.54	11.34	1.04
Sweden	11.47	6.32	11.82	0.53	12.07	1.02
Switzerland	11.91	5.61	11.31	0.50	11.94	1.06
United Kingdom	10.52	7.08	9.89	0.72	10.18	1.03
			Panel B: Developing Countries			
Hong Kong	0.54	0.48	0.47	1.02	0.47	1.00
Czech Republic	13.13	7.69	13.17	0.58	13.87	1.05
Hungary	13.73	8.21	14.91	0.55	15.15	1.02
India	5.91	5.21	6.10	0.85	6.01	0.99
Indonesia	30.79	24.50	18.38	1.33	17.64	0.96
Kuwait	2.69	2.23	2.88	0.78	3.16	1.10
Malaysia	10.57	7.59	11.30	0.67	11.42	1.01
Mexico	9.36	7.26	9.02	0.80	9.38	1.04
Philippines	9.68	6.39	7.13	0.90	7.40	1.04
Poland	13.82	7.67	16.58	0.46	14.85	0.90
Saudi Arabia	0.35	1.30	0.39	3.37	0.69	1.78
Singapore	5.30	3.74	5.32	0.70	5.42	1.02
South Korea	15.47	11.86	13.97	0.85	14.14	1.01
South Africa	17.56	9.56	14.11	0.68	12.54	0.89
Taiwan	5.88	4.09	4.73	0.87	4.98	1.05
Thailand	12.85	8.53	7.00	1.22	7.36	1.05
Turkey	18.01	18.57	19.22	0.97	20.02	1.04
United Arab Emirates	0.18	1.39	0.27	5.09	0.84	3.09

Notes: This table reports the standard deviation of log changes in spot exchange rates (denoted $\sigma_{\Delta s}$), as well as the square root of mean squared errors ($RMSE$) obtained with the carry and dollar factors and with the first three principal components ($RMSE_{PC}$). These RMSE use the augmented-UIP slope coefficients obtained in the previous period. These RMSE do *not* correspond to out-of-sample predictions because the carry and dollar factors and the principal components are assumed to be known one period in advance. The table also reports the RMSE obtained by assuming that exchange rates are random walk with drifts (denoted $RMSE_{RW}$), as well as the ratio of RMSE obtained with factors or principal components to the random walk benchmark $RMSE_{RW}$. Data are monthly, from Barclays and Reuters (Datastream). Standard deviations and RMSEs are annualized (i.e multiplied by $\sqrt{12}$) and reported in percentages. The sample period is 11/1983–12/2010.

Table 10: Country-Level Asset Pricing

$\lambda_{HML_{FX}}$	$\lambda_{Cond.RX}$	$b_{HML_{FX}}$	$b_{Cond.RX}$	R^2	$RMSE$	$MAPE$	χ^2
			Panel A: Unconditional Betas				
3.22	3.13	3.48	6.05	50.12	2.63	1.68	
[2.52]	[1.85]	[3.15]	[3.94]				41.79
			Panel B: Raw and Managed Currency Excess Returns				
4.40	3.78	4.82	7.22	54.53	2.56	1.58	
[2.45]	[1.39]	[3.06]	[2.99]				43.29
			Panel C: Dynamic Betas using Forward Discounts				
5.72	3.97	6.42	7.41	41.05	2.62	1.88	
[2.22]	[1.34]	[2.74]	[2.83]				70.23
			Panel D: Risk Factors' Mean Excess Returns				
4.82	3.35						
[1.95]	[1.52]						

Notes: The table reports results from Fama-MacBeth asset pricing procedure using individual currency excess returns. The Fama and MacBeth procedure has two steps. In the first step, time-series regressions of each country i's currency excess return are run on a constant, the carry trade excess return HML_{FX}, and the conditional dollar excess return (obtained as the dollar excess return multiplied by the sign of the average forward discount, i.e. $Cond.RX = \overline{(i_t^i - i_t)}RX$):

$$Rx_{t+1}^i = c^i + \beta_{HML}^i HML_{FX,t+1} + \beta_{Dollar}^i Cond.RX_{t+1} + \epsilon_{i,t+1}, \text{for a given } i, \forall t.$$

The second step runs cross-sectional regressions of all currency excess returns on betas:

$$Rx_t^i = \lambda_{HML,t}\beta_{HML}^i + \lambda_{RX,t}\beta_{RX}^i + \xi_t, \text{for a given } t, \forall i.$$

The market price of risk is the mean of all these slope coefficients: $\lambda_c = \frac{1}{T}\sum_{t=1}^{T}\lambda_{c,t}$ for $c = HML, Cond.RX$. Panel A reports the results of the Fama-MacBeth procedure on raw currency excess returns at the country-level. Panel B uses both raw and managed excess currency returns. Managed excess returns are obtained by multiplying the raw returns by the country-specific forward discounts (normalized by subtracting the average forward discount across currencies and dividing by the cross-sectional standard deviation of forward discounts in the given period) and the average forward discount. Panel C focuses on raw returns but considers conditional betas. The estimation assumes that $\beta_{HML,t}^i = h_0^i + h_1^i\widetilde{(i_t^i - i_t)}$, where $\widetilde{(i_t^i - i_t)}$ is the country-specific forward discount, standardized as described above, and $\beta_{RX,t}^i = d_0^i + d_1^i\overline{i_t^i - i_t}$, where $\overline{(i_t^i - i_t)}$ is the sign of the average forward discount. The parameters h_0^i, h_1^i, d_0^i, and d_1^i can be estimated from the linear regression:

$$Rx_{t+1}^i = c^i + h_0^i HML_{FX,t+1} + h_1^i\widetilde{(i_t^i - i_t)}HML_{FX,t+1} + d_0^i RX_{t+1} + d_1^i\overline{(i_t^i - i_t)}RX_{t+1} + \epsilon_{i,t+1}, \text{for a given } i.$$

The factor risk prices $\lambda_{HML,t}$ and $\lambda_{RX,t}$ can then be estimated by running a second-stage cross-sectional regressions on the fitted conditional betas:

$$Rx_{t+1}^i = \lambda_{HML,t}\beta_{HML,t}^i + \lambda_{RX,t}\beta_{RX,t}^i + \xi_{t+1}, \text{for a given } t, \forall i,$$

Panel D simply reports the mean of the risk factors. Market prices of risk λ, the adjusted R^2, the square-root of mean-squared errors $RMSE$, the mean absolute pricing error $MAPE$, and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes the vector of factor loadings. Excess returns used as test assets do *not* take into account bid-ask spreads because one does not know *a priori* whether investors should take a short or a long position on each particular currency. Risk factors HML and $Cond.RX$ come from portfolios of currency excess returns that take into account bid-ask spreads. All excess returns are multiplied by 12 (annualized). There is no constant in the second step of the FMB procedure. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). Data are monthly, from Barclays and Reuters in Datastream. The sample period is 11/1983–12/2010.

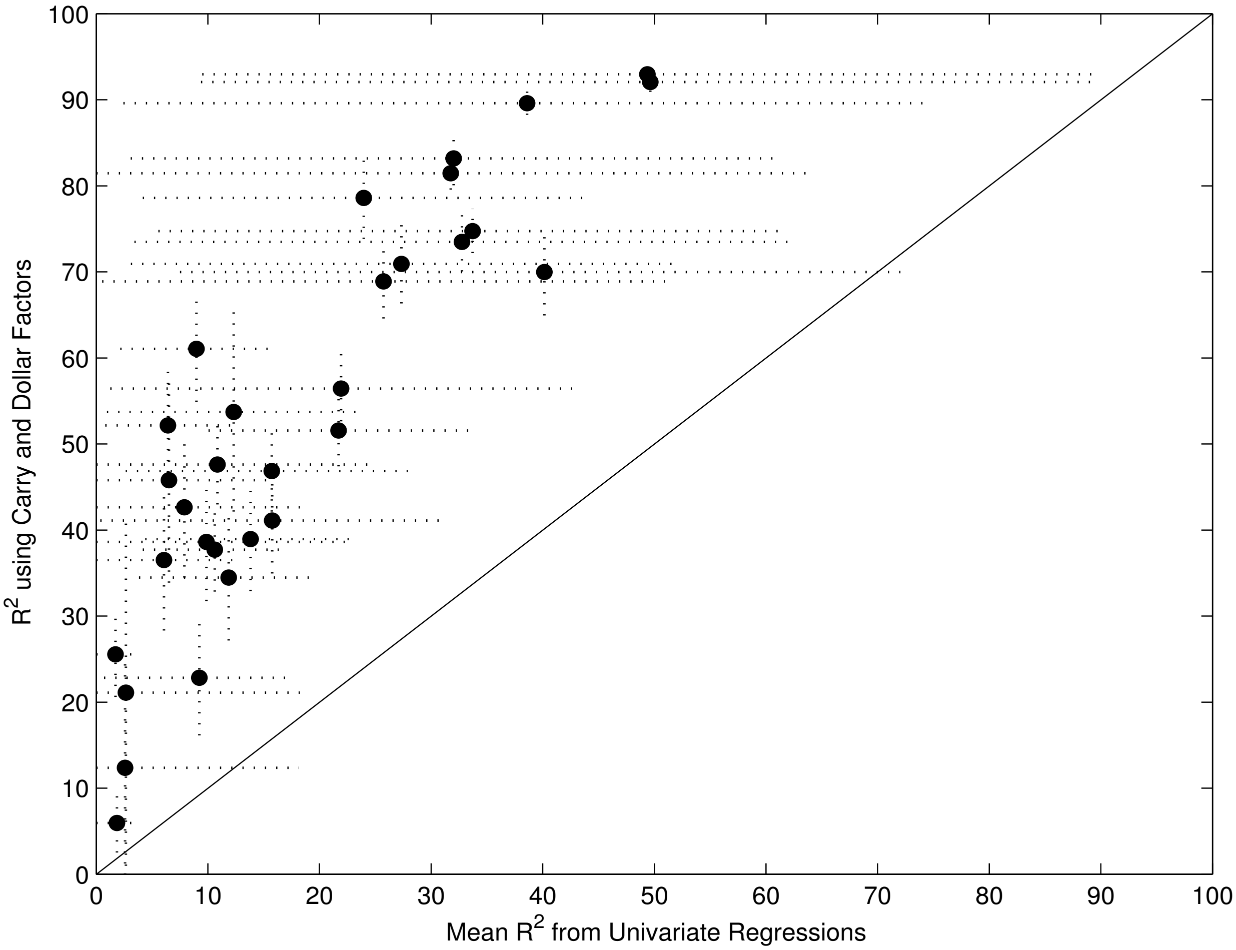

Figure 1: Measuring Systematic Risk with Factors vs. Individual Exchange Rates

The figure compares R^2s obtained with the carry and dollar factors (vertical axis) to those obtained from random univariate regressions of one exchange rate changes on others (horizontal axis).
Adjusted R^2s on the vertical axis correspond to the following regressions:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, $i_t^\star - i_t$ denotes the interest rate difference, $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. Dots correspond to point estimates, while dotted lines represent confidence intervals (defined as one-standard error above and below the point estimates). Standard errors are obtained by bootstrapping.
Adjusted R^2s on the horizontal axis correspond to the following experiment. Each currency i is regressed (in log changes) on a constant and another currency j ($i \neq j$):

$$\Delta s_{t+1}^i = \alpha + \beta \Delta s_{t+1}^j + \varepsilon_{t+1}^{i,j}.$$

Each regression delivers a pair-specific adjusted R-square, denoted $R^{2^{i,j}}$. For each currency i, the figure reports the mean of all $R^{2^{i,j}}$ for $j \neq i$). Dots correspond to the mean estimates, while dotted lines represent confidence intervals (defined as one-standard deviation above and below the mean estimates). Data are monthly. The sample period is 11/1983–12/2010.

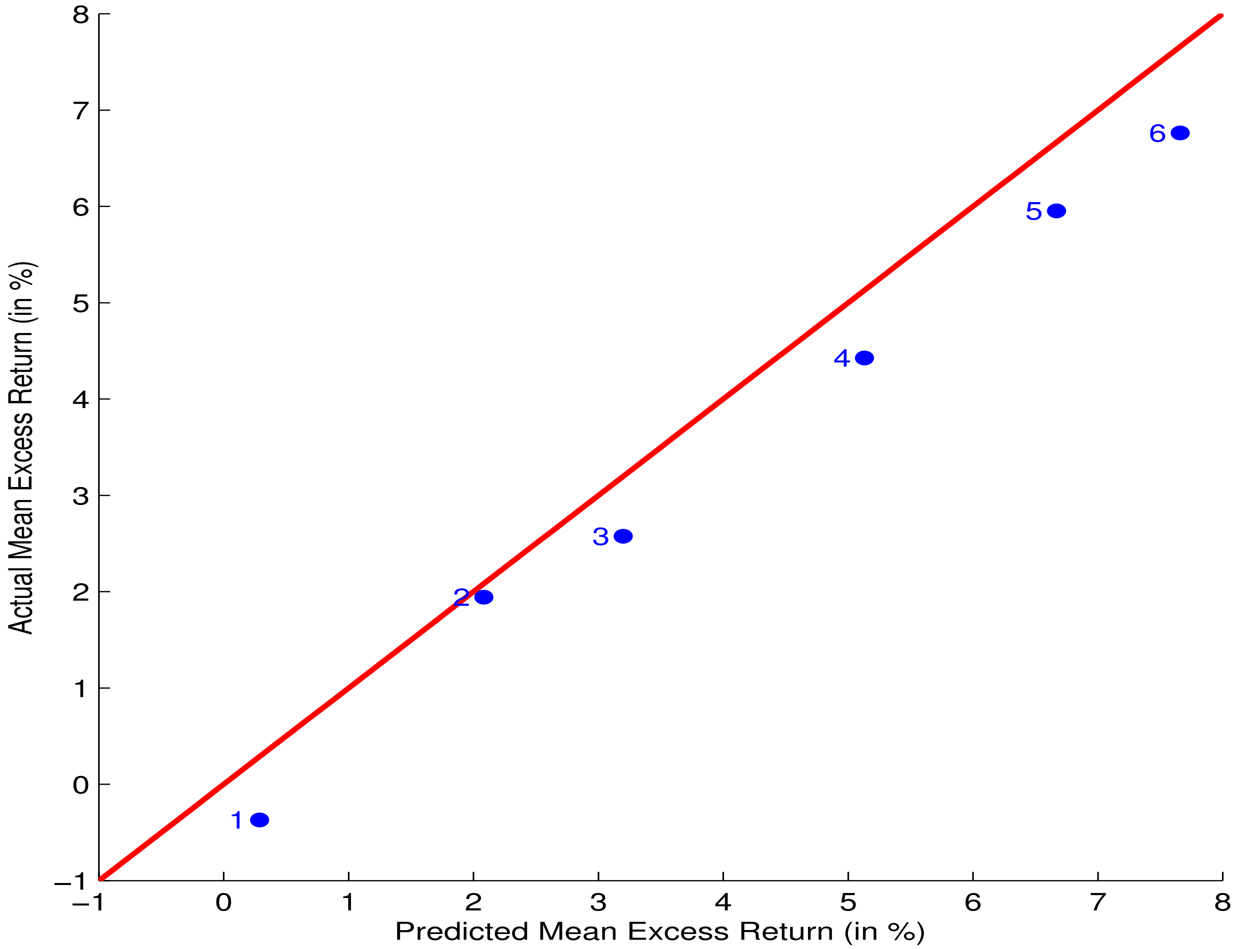

Figure 2: Realized vs Predicted Excess returns: Portfolios of Countries Sorted on Dollar Exposures

The figure plots realized average excess returns on the vertical axis against predicted average excess returns on the horizontal axis. The portfolios are based on each currency's exposure to the dollar factor. At each date t, each currency i change in exchange rate is regressed on a constant and the dollar and carry factors using a 60-month rolling window that ends in period $t-1$. Currency i's exposure to the *Dollar* factor is denoted τ_t^i. Currencies are then sorted into six groups at time t based on the slope coefficients τ_t^i. Portfolio 1 contains currencies with the lowest taus. Portfolio 6 contains currencies with the highest taus. At each date t and for each portfolio, the investor goes long if the average forward discount is positive and short otherwise. Each portfolio j's actual excess return is regressed on a constant and the conditional dollar excess return to obtain the slope coefficient β^j. Each predicted excess return then corresponds to the OLS estimate β^j multiplied by the mean of the conditional dollar excess return. All returns are annualized. Data are monthly. The sample period is 12/1988–12/2010.

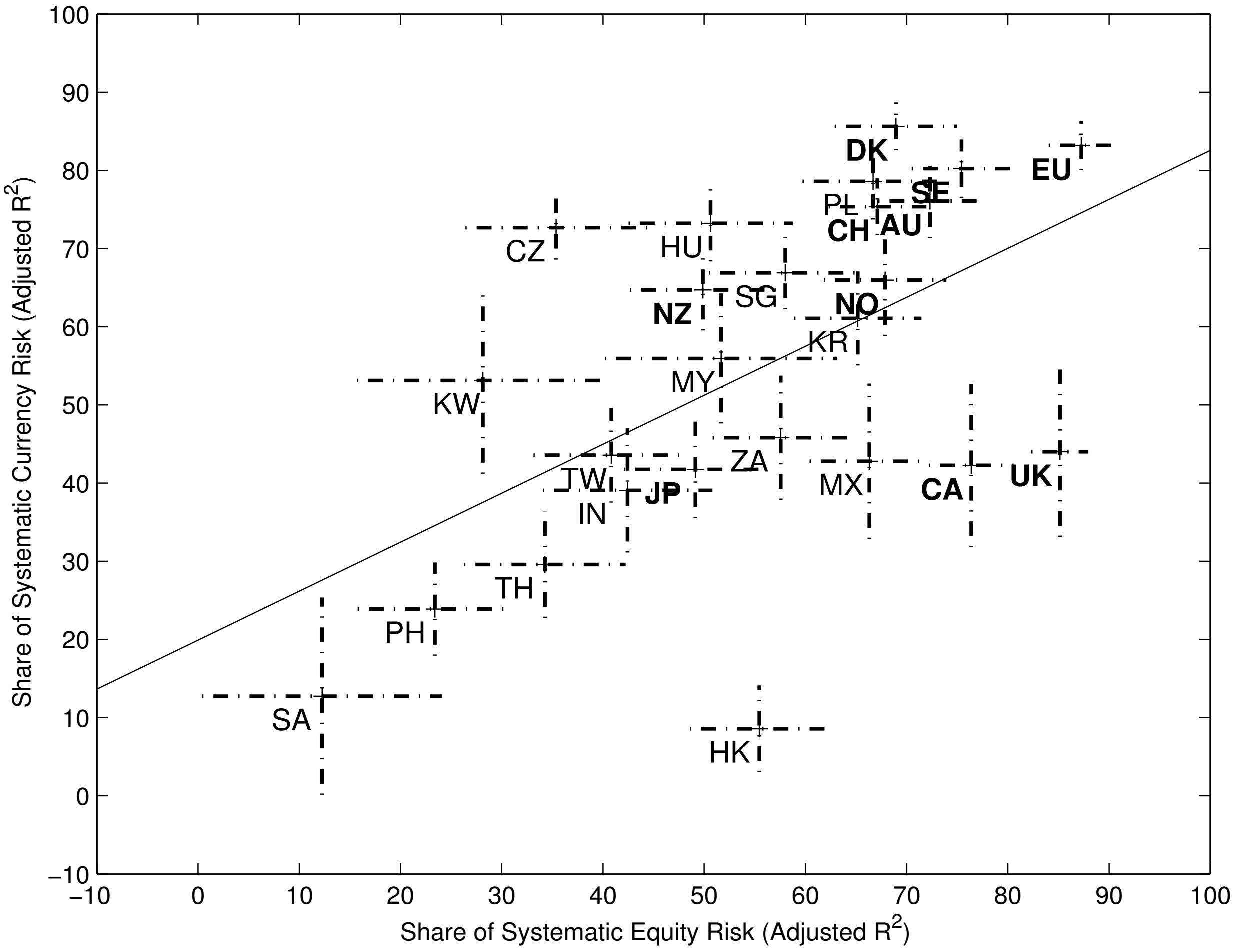

Figure 3: World Equity Market Integration and Systematic Currency Risk

The figure plots adjusted R^2s on currency markets as a function of adjusted R^2s on equity markets. Dots correspond to point estimates, while dotted lines represent confidence intervals (defined as one-standard error above and below the point estimates). Standard errors are obtained by bootstrapping. Adjusted R^2s on currency markets are obtained from the following regressions:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, $i_t^\star - i_t$ denotes the interest rate difference, $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. Adjusted R^2s on equity markets are derived from:

$$r_{t+1}^m = \alpha + \beta r_{t+1}^{m,world} + \gamma r_{t+1}^{hml,world} + \varepsilon_{t+1},$$

where r_{t+1}^m denotes the returns on a foreign country's MSCI stock market index, $r_{t+1}^{m,world}$ corresponds to returns on the MSCI world equity index, and $r_{t+1}^{hml,world}$ is the difference between returns on the world MSCI value equity index and the world MSCI growth equity index (i.e., high minus low book-to-market equity returns). Data are monthly. The sample is 1/1999–12/2010. The country codes correspond to the international standard: Australia (AU), Canada (CA), Hong Kong (HK), Czech Republic (CZ), Denmark (DK), Finland (FI), Hungary (HU), India (IN), Indonesia (ID), Japan (JP), Kuwait (KW), Malaysia (MY), Mexico (MX), New Zealand (NZ), Norway (NO), Philippines (PH), Poland (PL), Saudi Arabia (SA), Singapore (SG), South Africa (ZA), South Korea (KR), Sweden (SE), Switzerland (CH), Taiwan (TW), Thailand (TH), Turkey (TR), United Kingdom (UK), as well as the Euro area (EU).

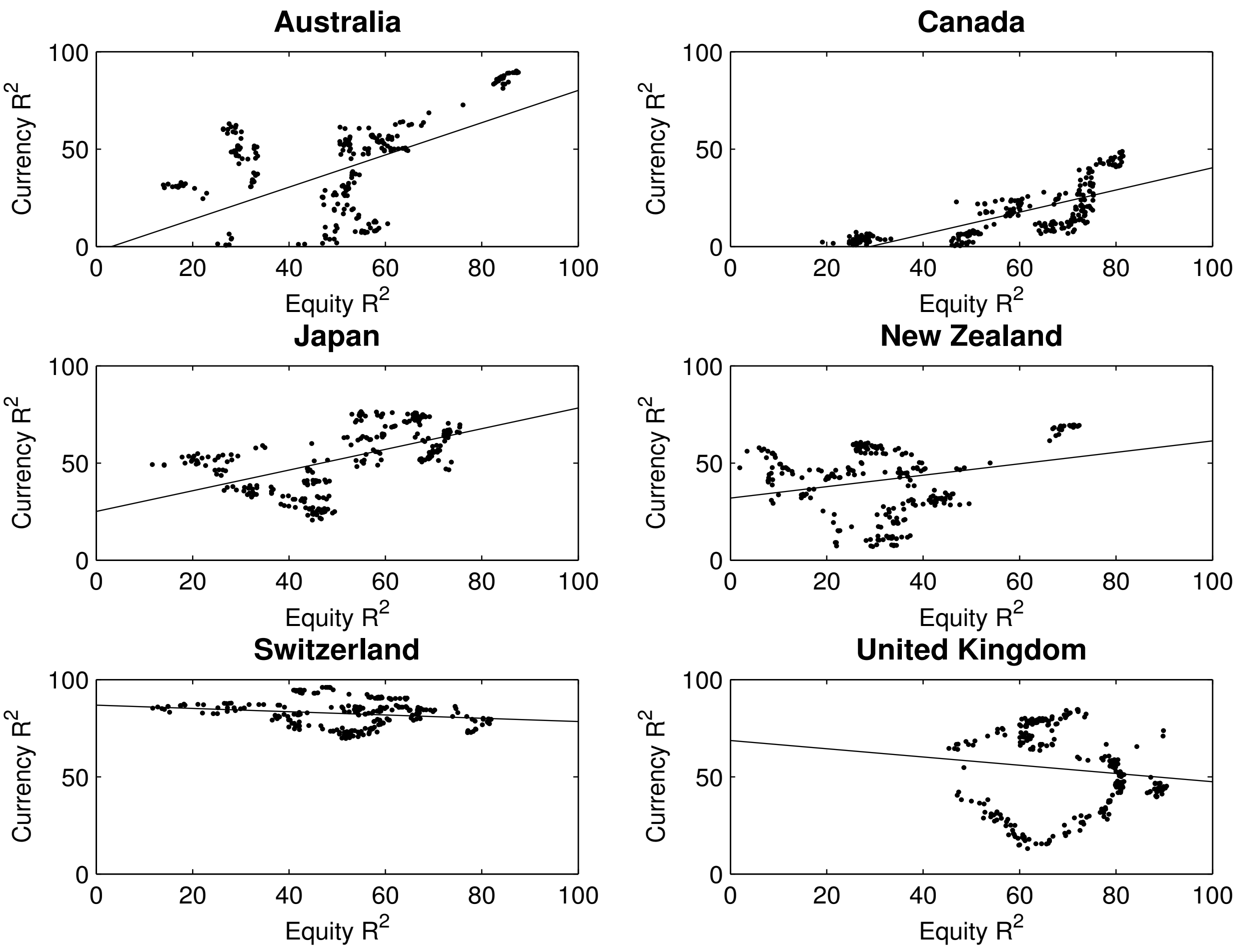

Figure 4: Time-Varying Shares of Systematic Equity and Currency Risk

The figure plots adjusted R^2s on currency markets as a function of adjusted R^2s on equity markets. R^2s are measured on rolling windows of 60 months. R^2s on currency markets are obtained from the following regressions:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, $i_t^\star - i_t$ denotes the interest rate difference, $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. Adjusted R^2s on equity markets are derived from:

$$r_{t+1}^m = \alpha + \beta r_{t+1}^{m,world} + \gamma r_{t+1}^{hml,world} + \varepsilon_{t+1},$$

where r_{t+1}^m denotes the returns on a foreign country's MSCI stock market index, $r_{t+1}^{m,world}$ corresponds to returns on the MSCI world equity index, and $r_{t+1}^{hml,world}$ is the difference between returns on the world MSCI value equity index and the world MSCI growth equity index (i.e., high minus low book-to-market equity returns). Data are monthly. The sample is 11/1983–12/2010.

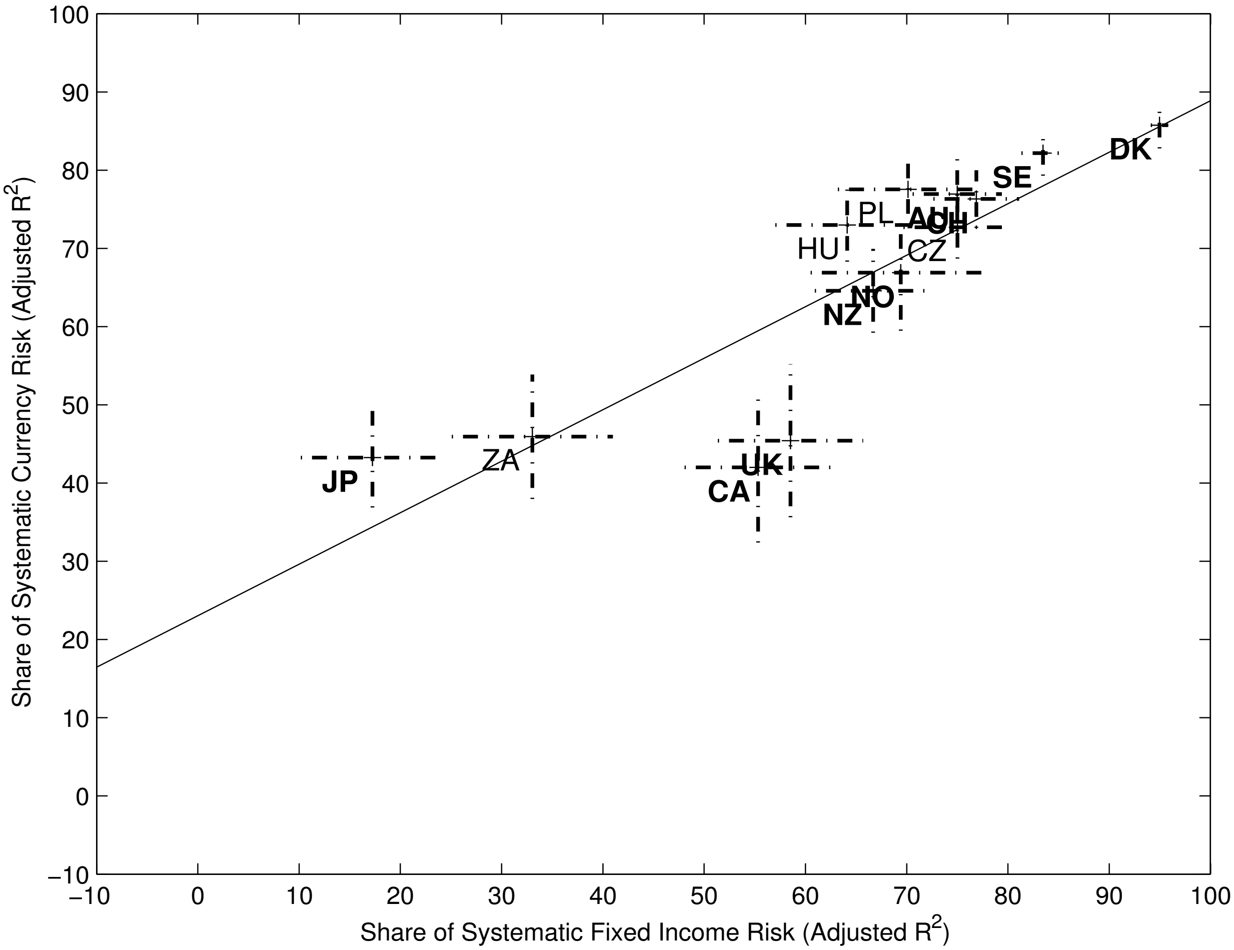

Figure 5: Shares of Systematic Fixed Income and Currency Risk

The figure plots adjusted R^2s on currency markets as a function of adjusted R^2s on bond markets. Dots correspond to point estimates, while dotted lines represent confidence intervals (defined as one-standard error above and below the point estimates). Standard errors are obtained by bootstrapping. Adjusted R^2s on currency markets are obtained from the following regressions:

$$\Delta s_{t+1} = \alpha + \beta(i_t^\star - i_t) + \gamma(i_t^\star - i_t)Carry_{t+1} + \delta Carry_{t+1} + \tau Dollar_{t+1} + \varepsilon_{t+1},$$

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, $i_t^\star - i_t$ denotes the interest rate difference, $Carry_{t+1}$ denotes the dollar-neutral average change in exchange rates obtained by going long a basket of high interest rate currencies and short a basket of low interest rate currencies, and $Dollar_{t+1}$ corresponds to the average change in exchange rates against the U.S. dollar. Adjusted R^2s on bond markets are derived from:

$$r_{t+1}^b = \alpha + \beta r_{t+1}^{m,world} + \gamma r_{t+1}^{b,world} + \varepsilon_{t+1},$$

where r_{t+1}^b denotes the returns on a given foreign country 10-year bond return index, $r_{t+1}^{m,world}$ corresponds to returns on the MSCI world equity index, and $r_{t+1}^{b,world}$ is the world bond return, obtained as the average of all the 10-year bond returns. Data are monthly. The sample is 1/1999–12/2010. The country codes correspond to the international standard: Australia (AU), Austria (AT), Belgium (BE), Canada (CA), Hong Kong (HK), Czech Republic (CZ), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), India (IN), Indonesia (ID), Ireland (IE), Italy (IT), Japan (JP), Kuwait (KW), Malaysia (MY), Mexico (MX), Netherlands (NL), New Zealand (NZ), Norway (NO), Philippines (PH), Poland (PL), Portugal (PT), Saudi Arabia (SA), Singapore (SG), South Africa (ZA), South Korea (KR), Spain (ES), Sweden (SE), Switzerland (CH), Taiwan (TW), Thailand (TH), Turkey (TR), United Arab Emirates (AE), United Kingdom, as well as the Euro area (EU).