The Share of Systematic Variation in Bilateral Exchange Rates *

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Abstract

Two factors account for 20% to 90% of the daily, monthly, quarterly, and annual exchange rate movements. These two factors — carry and dollar — are *risk* factors: the former accounts for the cross-section of interest rate-sorted currency returns, while the latter accounts for a novel cross-section of dollar beta-sorted currency returns. The different shares of systematic risk across currencies are related to financial and macroeconomic measures of international comovement. They point to large shares of global shocks in the dynamics of exchange rates, as well as large differences across countries. The results offer new challenges for international finance models.

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Regressions of changes in individual exchange rates on lagged or contemporaneous interest rate differences or other contemporaneous changes in macroeconomic variables at monthly, quarterly, and annual frequencies deliver very low R^2s. Contemporaneous industrial production growth and inflation rates, for example, lead to essentially zero adjusted R^2s on monthly series over the 1983–2010 period for developed countries. As a result, each individual exchange rate movement seems mostly idiosyncratic.

In this paper, to the contrary, I report that two variables — the carry and the dollar factors — account for a substantial share of individual exchange rate time-series in developed countries, as well as in emerging and developing countries with floating exchange rates. All exchange rates are defined with respect to the U.S. dollar, and the carry and the dollar factors are constructed from portfolios of currencies. The carry factor corresponds to the change in exchange rates between baskets of high and low interest rate currencies, while the dollar factor corresponds to the average change in the exchange rate between the U.S. dollar and all other currencies. I regress changes in exchange rates on the carry factor, the same carry factor multiplied by the country-specific interest rate difference (the latter is referred to as "conditional carry"), and the dollar factor. 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 are known at date t. Importantly, the carry and dollar factors do not include the bilateral exchange rate that is the dependent variable.

The factor regressions offer a novel picture of bilateral exchange rate movements. Each factor raises the adjusted R^2s of the usual macroeconomic regressions by an order of magnitude. With the carry factors, the adjusted R^2s range from 0% to 23%. With the addition of the dollar factor, R^2s increase further: as an example, the factor regression for the U.S. dollar / U.K. pound exchange rate has an R^2 of 51%. Crucially, the factor regressions uncover large differences in the shares of systematic variation: R^2s range from 19% to 91% in developed countries and from 10% to 75% among developing countries with floating currencies.

The substantial R^2s of the factor 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 those regressions would be zero. In the data, they are significantly different from zero. Moreover, the distribution of R^2s on the factor regressions is quite stable across frequencies; similar distributions appear at daily, monthly, quarterly, and annual frequencies.

The carry and dollar factors with their significant slope coefficients thus offer a powerful description of individual currencies. But their most important feature is their risk-based interpretation: both the carry and the dollar factors are *risk* factors in the asset pricing sense, consistent with the logic of an Euler equation.

The risk-based interpretation of the carry factor is well known. Previous research on currency portfolios shows that the carry factor accounts for the cross-section of currency excess returns sorted by interest rates: covariances of the carry factor with currency returns align with the cross-section of average excess returns (cf. Lustig, Roussanov, and Verdelhan, 2011). A consistent result appears here on individual currencies: the higher the interest rate, the larger the loading on the carry risk factor. This is the risk-based explanation of the classic currency carry trade.

This paper shows that, similarly, the dollar factor has a risk-based interpretation. Portfolios of countries sorted by interest rates do not allow for a significant estimation of the dollar risk because all portfolios load in the same way on this factor. Instead, I build portfolios of countries sorted by their time-varying exposures to the dollar factor (i.e., dollar betas). The low dollar-beta portfolio offers an average log excess return of just 0.4% per year for investors who go long foreign currencies when the average forward discount (average foreign minus U.S. interest rates) is positive and short otherwise. The high dollar-beta portfolio offers an average log excess return of 7.6% for similar investments. After transaction costs, the high dollar-beta portfolio still returns 6.3% on average, implying a large Sharpe ratio of almost 0.6 over the last 30 years. Conditioning on the average forward discount, covariances of the dollar factor with portfolio returns account for this new cross-section of average excess returns, while covariances with the carry factor do not. As a result, the carry and dollar factors are two, largely independent, *risk* factors.

Additional empirical evidence in favor of a risk-based approach to exchange rates comes from the link between the share of systematic risk in currency markets and other measures of cross-country systematic risk. This link is intuitive: the law of one price implies that 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: countries with a high share of systematic equity risk (measured by their loadings on world aggregate and value risk factors) tend also to 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 measures of comovement in output and consumption growth rates. These findings highlight a novel link across asset and good markets.

The cross-country differences in currency systematic risk revealed in this paper have key implications for the class of no-arbitrage models, without ruling out more behavioral explanations of exchange rates. I focus here on the rational, preference-free interpretation and implications, while also providing in the paper an interpretation of the dollar and carry factors in a reduced-form term structure model, as well as in a macro-finance general equilibrium model.

Without loss of generality, each pricing kernel can be decomposed into country-specific and world shocks. When the law of one price applies, 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. The carry factor, defined as a difference in baskets of exchange rates, is dollar-neutral and depends only on world shocks. The dollar factor, defined as 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 cross-country differences in dollar betas in the data have two necessary implications: foreign pricing kernels must differ in their loadings on global shocks, and the dollar factor must have a global component, implying that the U.S. pricing kernel loads differently than the average pricing kernel on world shocks.

Building on this intuition, the relative importance of the local and global shocks in exchange rate movements can be measured precisely, without any assumption on preferences. To focus on the global component of the dollar factor, I substitute the dollar factor with the change in exchange rates of the high dollar-beta portfolio minus the change in exchange rates of the low dollar-beta portfolio. The difference between the dollar-beta portfolios eliminate the U.S.-specific shocks from the dollar factor, thus focusing on its global component. The novel global risk factor is highly correlated with the average change in exchange rates expressed in U.S. dollars, thus its name. But it is not correlated with the carry factor, thus measuring different global shocks. Regressions of changes in bilateral exchange rates on the global component of the dollar factor and the carry factors deliver R^2s between 18% and 87% for exchange rates defined in U.S. dollars and R^2s between 6% and 45% for exchange rates defined in Japanese Yen and U.K. pounds, pointing to large shares of global shocks in the dynamics of exchange rates, as well as large differences across countries.

The share of global shocks in exchange rates and pricing kernels is a key moment to consider in macroeconomic models. As an example, in the model of Colacito and Croce (2011), global long-run risk shocks drive most of the variation in the pricing kernels, but they do not affect exchange rates (i.e., the differences in pricing kernels). As a result, the model solves the Backus and Smith (1993) and Brandt, Cochrane, and Santa-Clara (2006) puzzle: pricing kernels are volatile and equity risk premia are high, yet exchange rates are as volatile as in the data. The findings in this paper raise the bar: global shocks cannot cancel out from domestic and foreign pricing kernels because they actually account for a large part of exchange rate variation. More generally, the factor regressions offer a set of precisely estimated, useful, and challenging new moments to match.

The paper is organized as follows. Section 1 reviews the related literature. Section 2 shows that the dollar and carry factors explain a large share of bilateral exchange rates. Section 3 uncovers a new cross-section of currency excess returns that is explained by the dollar risk factor. Section 4 compares the shares of currency systematic risk to measures of world market integration. Section 5 spells out the preference-free implications of the previous findings, relating them to recent models in international finance. Section 6 concludes. A data Appendix at the end of this document describes the data set. The changes in exchange rates, the interest rates, the carry and dollar factors, as well as the time-varying loadings on those factors and the dollar beta portfolios, are available on my website and thus the results in this paper can be easily replicated. A separate Appendix, also available on my website, reports several robustness checks and extensions, as well as model proofs and simulation details.[1]

1 Related Literature

Numerous studies in the 1970s and early 1980s 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, even when macroeconomic variables are assumed to be known one period in advance. 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 dollar factor, and conditional and unconditional carry factors are not persistent variables and the common shocks that account for each currency pair could be close to random walks.

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) estimates 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. More importantly, they do not offer any interpretation of their principal components. To

[1]The separate Appendix and the data are available at: http://web.mit.edu/adrienv/www/Research.html.

the contrary, the current paper focuses on two risk factors, noting that the existence of a principal component does not imply the existence of a cross-section of expected excess returns on beta-sorted currencies. Unlike principal components, the carry and dollar risk factors have a natural interpretation in any no-arbitrage model.

Although this paper builds on Lustig, Roussanov and Verdelhan (2011), it is clearly distinct from it: Lustig et al. (2011) do not report R^2s on any time-series regressions of bilateral exchange rates. They focus on the dynamics of *portfolios* of currencies. When they check their asset pricing results on bilateral exchange rates, they report only measures of cross-sectional, not time-series, fit. Importantly, their carry trade portfolios cannot pin down the characteristics of the dollar risk factor that appears so crucial for bilateral rates. More generally, the current paper is part of a growing literature that focuses on currency portfolios to study currency risk.[2] Portfolios are a very useful tool to extract and study risk premia: they are built in order to average out idiosyncratic components and to focus only on systematic risk. Thus, by construction, they are silent on the share of systematic versus idiosyncratic variation in *each* currency pair, which is the focus of this paper.

Hundreds of papers have been written on the forward premium puzzle and the associated currency carry trades. Froot and Thaler (1990) survey 75 published estimates of the uncovered interest rate parity condition. Many more papers have run similar tests and offered potential explanations. A simple search in *Scopus* in 2012 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 the carry factor accounts for only 2% to 20% of daily or monthly

[2]Following Lustig and Verdelhan (2005, 2007), DeSantis and Fornari (2008), Jurek (2008), Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009), Galsband and Nitschka (2010), Christiansen, Ranaldo, and Soderlind (2011), Gilmore and Hayashi (2011), Hassan and Mano (2012), Menkhoff, Sarno, Schmeling, and Schrimpf (2012a, 2012b), Mueller, Stathopoulos and Vedolin (2012), Gavazzoni, Sambalaibat and Telmer (2012), and Lettau, Maggiori and Weber (2013) study the properties of one-month interest rate-sorted portfolios of currency excess returns. Ang and Chen (2010), Hu, Pan, and Wang (2010), Kozak (2011) consider new sorts, focusing on properties of the foreign yield curves at longer horizons or on liquidity risk. Lustig, Roussanov, and Verdelhan (2012) study the predictability of the dollar risk factor (thus focusing on one single currency portfolio), while Maggiori (2012b) uses a conditional-Capital Asset Pricing Model to price the dollar excess return. Ranaldo and Soderlind (2008) and Hoffmann and Suter (2010) study the risk characteristics of the Swiss franc and other safe-haven currencies.

changes in exchange rates, while the dollar factor accounts for 20% to 90% of them, with a key role for global shocks.

Finally, the findings 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 of 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 Measuring Currency Systematic Variations

This section shows that the dollar and carry factors explain a large part of each currency pair variations, uncovering cross-country differences in the shares of systematic currency risk. I start from the usual UIP and macroeconomic regressions and then turn to the carry and dollar factors.

2.1 Interest Rates and Other Macroeconomic Variables

Notation and Data A lower case 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. Interest rate differences are derived from forward rates. 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.[3]

End-of-month series are built from daily spot and forward exchange rates in U.S. dollars and the sample period runs from November 1983 to December 2010. These data are collected by

[3] 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. While this relation was violated during the extreme episodes of the financial crisis in the fall of 2008 (see Baba and Packer, 2009), including or excluding those observations does not have a major effect on the results.

Barclays and Reuters and available on Datastream. Spot and forward exchange rates correspond to midpoint quotes. The Data Appendix lists all the countries in the data set.

UIP Redux 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 is equivalent to an Euler equation for risk-neutral investors. It 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.[4]

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.

Panel I of Table 1 reports country-level results from the usual UIP tests:

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

As in the rest of the literature, betas are always below one, and most of them are negative. All but one are statistically insignificant. Out of 13 developed countries, only three lead to positive betas, none of which is statistically significant. Those betas are, however, more than one standard error away from one — the value implied by UIP — for 10 out of 13 countries. As in the rest of the paper,

[4]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.

all R^2s are adjusted for the degrees of freedom. The adjusted R^2s on these regressions are tiny, often negative, with a maximum of 1.7%, and an average of -0.2%. Evans (2012) report similar results. UIP tests are predictability tests because the returns on the nominal notes between t and $t+1$ are known at date t. Yet R^2s are not much higher when using contemporaneous macroeconomic variables.

[Table 1 about here.]

Industrial Production and Inflation To focus on the monthly frequency, I use U.S. industrial production growth rates and inflation differentials to account for changes in exchange rates. Panel II of Table 1 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 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. Many adjusted R^2s are negative, and the highest value is 2.5%. Using foreign minus domestic (instead of U.S.) industrial production growth rates limits the sample in terms of countries and time windows but 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% and none of them appears significantly different from zero.

This experiment does not mean that exchange rates are unrelated to macroeconomic variables. It simply highlights how difficult it is to uncover such links at the monthly frequency and for individual currency pairs (instead of, for example, an annual frequency and portfolios of currencies). While adding lagged macroeconomic variables and long-run cointegration residuals might increase the adjusted R^2s for some currencies and some periods, I do not know of any macroeconomic variable that would consistently account for changes in exchange rates at the monthly frequency as well as the carry and dollar factors.

2.2 Carry and Dollar Factors

Developed Countries Following Lustig and Verdelhan (2005, 2007), and like Lustig et al. (2011), I build six *portfolios* of currencies by sorting all developed and emerging countries each month according to their interest rates. By averaging out idiosyncratic risk and conditioning on interest rates, these portfolios deliver a cross-section of exchange rates and currency risk premia. The carry factor, denoted $Carry_{t+1}$, 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).

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. 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. Each variable is expressed in percentage points; as a result, the slope coefficient on the conditional carry factor is 100 times smaller than if all series were not in percentage points. As already noted, 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 Data Appendix at the end of this paper reports summary statistics and graphs on the carry and dollar factors.

The loadings on the dollar factor are positive and statistically significant in all 13 developed countries, with values ranging from 0.3 to 1.6. 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, but in different proportions. This common component explains a large share of the variation in bilateral exchange rates. The adjusted R^2s are now all between 19% and 91%. The average R^2 among the 13 developed countries is 61%. Without the carry factors, the average R^2 is 57%; unsurprisingly, the difference is particularly large for Australia and Japan (26% vs. 20% and 30% vs 24%), two textbook examples of carry traders' favorites. Without the dollar factor, adjusted R^2s range from 0% to 23%, with an average of 7%.

The conditional carry loadings (γ) in Table 2 are positive in 11 out of 13 countries (the only exceptions are Canada and Japan, where the coefficienta are negative but insignificant). They are positive and statistically significant in 9 out of 13 countries. These findings are consistent with those of Lustig et al. (2011): as already noted, in their portfolios of currencies sorted by 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. The findings in the current paper are, however, different from those of Lustig et al. (2011), which pertain to cross-sectional differences in interest rates (i.e., whether one currency has a higher interest rate than another). Here, the conditional carry loading indicates that, for a given country, times of larger interest rate differences are also times of higher comovement with the carry factor. By focusing on one bilateral exchange rate at a time, each test explores time-series, not cross-sectional, variations (see Hassan and Mano (2012) for more on this difference).

The total sensitivity of each bilateral exchange rate to the carry factor depends on the conditional and unconditional carry components. Table 2 shows that the corresponding slope coefficients are jointly statistically significant at the 1% (10%) confidence level in 11 (12) out of 13 countries (the only exception is the U.K.).[5] A total sensitivity that is positive means that the foreign currency depreciates when the carry does too. In the data, the Japanese yen tends to appreciate when the carry factor tanks, while the Australian dollar tends to depreciate. Such currency movements correspond to the funding and investment roles of these currencies that are commonly reported in articles on carry trades. The Japanese yen appreciates in bad times, while the Australian dollar depreciates: this difference is at the heart of any risk-based explanation of carry trades. But for many countries, the total sensitivity to the carry factor switches sign along the sample. For example, the Swiss franc depreciated in the 1980s (a time of relatively high Swiss interest rates)

[5]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. Table 2 thus reports the result of a Wald test where the null hypothesis is that the loadings gamma (γ) and delta (δ) on the conditional and unconditional carry factors are jointly zero. The null hypothesis is rejected at the 10% confidence interval for all developed countries except the U.K. At a daily frequency, the null hypothesis is rejected at the 1% level for all countries. Results are reported in the separate Appendix.

when the carry factor paid badly; recently, it has appreciated. This result is particularly clear for estimates based on rolling windows. The "safe-haven" characteristic of the Swiss franc thus appears sample-dependent, and linked to the interest rate level.

[Table 2 about here.]

Emerging Markets To explore exchange rate dynamics further, and as an initial robustness check, Table 3 reports similar tests on a set of 18 developing countries (using the same factors as for developed countries). Adjusted R^2s tend to be high for floating currencies. A simple finding emerges: for floating currencies, the results tend to be similar to those of developed countries, whereas pegs, reassuringly, appear different. On the one hand, loadings on the dollar factor are positive and significant for 15 out of 18 countries; loadings on the carry factors are jointly significant for nine countries; and R^2s in Table 3 range from 10% to 75% for floating currencies. On the other hand, Hong Kong, Saudi Arabia, and the United Arab Emirates, which have pegged their currencies to the U.S. dollar at some point in the sample, do not exhibit significant loadings on the dollar factor. This broad dichotomy hides more subtle nuances: for example, Thailand and Malaysia, although they also experienced currency pegs, do not appear much different from the other developing countries. The carry and dollar factors thus highlight the uncertainty behind exchange rate regime classifications, and rolling window estimates could be used to refine such classifications.

[Table 3 about here.]

The large cross-country differences in R^2s and the significant loadings on the dollar and carry factors are the first benchmark results of this paper. I consider additional robustness checks (other factors, like momentum; daily, quarterly, and annual frequencies; bid-ask spreads; and different base currencies) and also study the stability of the factor structure, comparing the implied pseudo-predictability to those of random walks and principal components, as well as the time-variation in the share of systematic currency risk. The results are presented and commented in the separate

Appendix. They all reinforce the findings presented in the main text. I end this section with a comparison to pairwise currency correlations often used in practice.

How Large Are the R^2s? The factor regressions deliver larger R^2s than interest rates and macroeconomic variables. The large R^2s can also be favorably compared to those of simple pairwise currency regressions. For each currency 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^2, denoted $R^{2^{i,j}}$. This is the R^2 equivalent to the Option-Metrics correlation coefficient that many practitioners use. 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 intrinsic 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 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 in capturing exchange rate variation, all points in Figure 1 should be above the 45-degree line, which is clearly the case. It turns out that the factors' 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 three: Saudi Arabia and the United Arab Emirates, which are unsurprising outliers since they have pegged their currencies to the U.S dollar, and Indonesia, which has few observations. 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. Conversely, the dollar and the carry factor have the same economic interpretation for all currencies.[6] They deliver R^2s that are large, not only compared to those of UIP tests (arguably, a low bar) and macroeconomic variables, but also to those of bivariate exchange rate regressions.

[Figure 1 about here.]

3 Dollar Risk

The carry and dollar factors offer more than a simple statistical description of individual exchange rates: they are *risk* factors, in the asset pricing sense. Thus, they capture the share of systematic risk in bilateral exchange rates. The literature review at the beginning of this paper presents evidence in favor of a risk-based interpretation of the carry factor. This section presents new evidence on the dollar risk factor.

3.1 Portfolios of Countries Sorted by Dollar Exposures

Lustig, Roussanov and Verdelhan (2013) show that the average forward discount rate of developed countries (i.e., the average interest rate difference between foreign and U.S. short-term interest rates) predicts the returns on the aggregate currency portfolio and its exchange rate component (i.e., the dollar factor). They report a high average excess return, along with 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 rate is positive and short otherwise. The resulting excess return is the aggregate conditional dollar excess return.

I combine the dollar predictability shown in Lustig et al. (2013) with the heterogeneity in the loadings on the dollar shown in the previous section in order to build a new large cross-section of portfolio excess returns. The new portfolios are based on each currency's 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 section, using a 60-month rolling

[6] The carry and dollar factors only differ across currencies because of the exclusion of the currency under study. But simple carry and dollar factors that use the whole sample produce similar results.

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 exposures (τ), while portfolio 6 contains currencies with the highest exposures. I refer to these portfolios as dollar beta-sorted. At each date t and for each portfolio, the investor goes long if the average forward discount rate among all developed countries is positive and goes short otherwise.

Panel I of Table 4 reports summary statistics on the portfolios of countries sorted by dollar exposures. Average log excess returns range from 1.3% to 7.1% on an annual basis from portfolios 1 to 6. 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). Taking bid-ask spreads into account reduces the average excess returns (from 0.6% to 5.8%) but does not change the cross-sectional pattern. Unsurprisingly, the volatility of excess returns increases from portfolio 1 to 6: portfolio 6 contains more systematic variation than portfolio 1 by construction.

[Table 4 about here.]

The cross-section of dollar beta-sorted currencies is novel. How does it relate to previous work? The comparison of unconditional and conditional currency excess returns links this result to exchange rate predictability: without conditioning on the average forward discount rate, the dollar beta-sorted portfolios deliver a cross-section of gross average excess returns ranging from 0.3% to 2.4%. Because the average forward discount rate predicts future dollar returns, the conditional average excess returns are much larger, particularly for large loadings on the dollar factor: the higher the loading on the dollar factor, the more predictable the future currency excess returns, and thus the higher the average conditional excess returns. The set of average currency excess returns is thus consistent with the aggregate predictability results in Lustig et al. (2013).

The cross-section of dollar beta-sorted currencies is key to estimating the price of dollar risk. This estimation does not appear in previous work on currency carry trades, because all portfolios of currencies sorted by interest rates load in the same way on the dollar factor; they do not offer the different dollar exposures needed to estimate the price of dollar risk. As a result, the dollar factor plays the role of a constant in the second stage of a Fama-McBeth regression on currency carry trades and its price appears insignificant. The novel cross-section of dollar beta-sorted currencies, on the contrary, leads to a precise estimation of the market price of dollar risk.

3.2 The Price of Dollar Risk

Panel II of Table 4 reports Generalized Method of Moments (GMM) and Fama-McBeth (FMB) 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.[7] Average excess returns of the dollar beta-sorted portfolios correspond to the covariances between excess returns and a single risk factor, the aggregate conditional dollar excess return. The pricing errors are not statistically significant. Panel III of Table 4 reports Ordinary Least Squares (OLS) estimates of the factor betas. Betas increase monotonically from 0.11 to 1.52; they are precisely estimated. They are driven by the dynamics of exchange rates, not by changes in interest rates: similar regressions on changes in exchange rates instead of excess returns deliver similar results. The alphas (which measure the returns after correction for their risk exposure) are not statistically different from zero. The dollar risk differs from both 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 (not reported) tend to increase from portfolios 1 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. Likewise, the loadings on the carry trade risk factor are small and imply large and statistically significant pricing errors. Sorts on dollar exposures thus reveal a novel cross-section of currency risk premia.

Figure 2 reports the realized and predicted average 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

[7]The Euler equation implies a beta-pricing model: $E[R^e] = \beta\lambda$, where β measures the quantity of risk and λ the price of risk. Since the risk factor is a return, the Euler equation applies to the risk factor itself, which as a beta of one, and thus implies that $E[R^e_{Dollar}] = \lambda$.

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. 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 pricing kernels are higher in the U.S. than abroad, i.e., when the U.S. experiences relatively bad times. 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. 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. The pricing errors are unsurprisingly larger than those obtained on currency portfolios, but the null hypothesis that all pricing errors are jointly zero cannot be rejected.

Portfolios of countries sorted by dollar exposures and conditional excess returns at the country level thus offer clear evidence in favor of a risk-based explanation of exchange rates. Providing additional evidence, the next section explores the link between shares of systematic risk in different markets.

4 World Comovement and Systematic Currency Variation

If the law of one price applies, the change in the nominal exchange rate Δs between the home country and foreign country i is equal to:

$$\Delta s^i_{t+1} = m_{t+1} - m^i_{t+1},$$

where m and m^i denote the nominal log pricing kernels of respectively the domestic and foreign investors.[8] Pricing kernels, also known as stochastic discount factors (SDFs), correspond to the intertemporal marginal rates of substitution. Currency markets thus potentially offer appealing measures of comovement in inter-temporal marginal rates of substitution: unlike macroeconomic series, they are precisely estimated and available at high frequencies. Unlike equity returns, sometimes used in the context of world market integration studies, R^2s on currencies do not depend on the properties of the domestic and foreign dividend cash flows.

Since all exchange rates are defined with respect to the U.S. dollar, m is a common component of all exchange rates. Shares of systematic currency risk vary across countries because the properties of foreign stochastic discount factors vary. Such variation should affect other asset prices (e.g., equity and fixed income markets). This section thus compares the cross-sectional variation in the shares of systematic currency risk to the cross-sectional variation in the shares of systematic equity and fixed income risk, as well as other macroeconomic measures of comovement, often considered in the context of world integration studies. I first define these different measures of systematic risk, and then study their links.

4.1 Measures of Systematic Risk in Asset and Good Markets

Systematic Risk in Asset Markets 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 (2011).

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 corre-

[8]This result derives from the Euler equations of the domestic and foreign investors buying any asset R^i that pays off in foreign currency: $E_t[M_{t+1}R^iS_t/S_{t+1}] = 1$ and $E_t[M^i_{t+1}R^i] = 1$. When markets are complete, the pricing kernel is unique and thus exchange rates are defined as $S_{t+1}/S_t = M_{t+1}/M^i_{t+1}$, or in logs $\Delta s_{t+1} = m_{t+1} - m^i_{t+1}$. This definition of exchange rates holds even if markets are incomplete. In that case, the pricing kernels should be replaced by their projections on the space of traded assets (which includes exchange rates). If the law of one price applies and investors can form portfolios freely, then there is a unique pricing kernel in the space of traded assets (cf. Chapter 4 in Cochrane's (2005) textbook), implying again that $S_{t+1}/S_t = M_{t+1}/M^i_{t+1}$, where M and M^i denote the projections of the pricing kernels on the space of traded assets.

sponds 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.[9] 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. Likewise, 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 in U.S. dollars on a foreign country's 10-year bond return index and $r_{t+1}^{b,world,\$}$ is the world bond return, obtained as the average of all the 10-year bond returns. On equity (bond) markets, adjusted R^2s range from 27% (32%) to 87% (89%).

Comovement of GDP and consumption 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 comovement based on consumption or output

[9]Note that such measures of comovement are not necessarily informative about asset market integration or risk-sharing in general; their interpretation in those terms depends on the model of the economy. For example, models with segmented markets may exhibit a large correlation of the pricing kernels of domestic and foreign market participants in an overall poorly diversified economy [see e.g. Alvarez, Atkeson, and Kehoe (2002, 2009)]. Likewise, asset market integration may be assessed through the significance of alphas in the regression above, but the assessment then depends on the validity of the risk factors.

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 and 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 in U.S. dollars or at purchasing power parity, come from the World Bank. They are only available at an annual frequency.

4.2 Systematic Currency Risk and World Comovement

The different shares of systematic currency risk across countries appear related to measures of world equity, fixed income, and macroeconomic comovement. 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, obtained as in the previous sections using the carry and dollar factors. $R_i^{2,X}$ denotes the share of systematic variation measured with either equity returns, bond returns, or macroeconomic variables.

Panel I of Table 5 reports the slope coefficients (β) on this cross-country regression. On the full sample period (1983–2010) as on the post-1999 sample, all the slope coefficients are positive and significant. A large share of systematic risk in equity returns, bond returns, output growth, or consumption growth is associated with a large share of systematic currency risk. Slope coefficients range between 0.6 and 1.1 across asset and macroeconomic measures of world comovement.

[Table 5 about here.]

As an example, Figure 3 reports the share of systematic *currency* risk as a function of the share of systematic *equity* risk, as well as one-standard error confidence intervals (obtained by bootstrapping) on both sides of each point estimate. The figure 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. 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.

Saudi Arabia (SA) and Hong Kong (HK) appear as outliers because their share of systematic equity risk is much higher than their share of systematic currency risk, which is close to zero. This finding is not surprising: again, both countries have pegged their currencies to the U.S. dollar throughout the sample. Among the developed countries, the U.K., for example, also exhibits 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 SDFs and the properties of the dividend processes. Thus, one potential hypothesis is that 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. I leave a thorough study of outliers for subsequent research and focus on the main finding, i.e., a strong link between measures of systematic equity and currency risk.

[Figure 3 about here.]

Part of this link is mechanical because asset returns and macroeconomic variables are converted into U.S. dollars.[10] If returns and growth rates in local currencies are much less volatile than currency movements, then tests of world integration boil down to measures of systematic currency risk using the dollar risk factor, and thus the link between systematic risk measured on equity, bond, output, and consumption on the one hand and currency markets on the other hand. The factor

[10] As a first approximation, the world equity return corresponds 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 comovement thus correspond to:

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

regressions in Section 2 thus offer new insight on the large literature on asset market integration, showing that part of its results are driven by exchange rates.

But the link between measures of systematic risk is not purely mechanical: it also exists for series converted at purchasing power parities (PPP). PPP series are much smoother than realized exchange rates and do not drive asset or macroeconomic measures of integration. Panel II of Table 5 reports similar slope coefficients (β) to those of Panel I, but the underlying asset and macroeconomic measures of integration are now based on series converted using PPP. Again, all the slope coefficients are positive — ranging from from 0.4 to 1.1. — 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, and the number of observations (one per country, subject to data availability) is limited.

To push the comparison further and to increase the sample size, I compare time-varying equity and currency R^2s. The methodology remains the same, but equity and currency regressions are now run on rolling windows of 60 months. Panels III and IV of Table 5 report the results obtained on series in either U.S. dollars or PPP dollars, on either the full sample or the last ten years, with country fixed effects and a time trend. Again, in all cases, the R^2s on currency markets are positively and significantly related to the R^2s on equity and bond markets.[11]

To take a precise example, the integration of the Australian stock market appears highly correlated through time to the integration of the Australian dollar. But for Switzerland, this relationship does not exist, suggesting that trading on the Swiss franc is not linked to trading on the Swiss stock market. Data on capital flows collected by the U.S. Treasury are consistent with this 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.

[11] All slope coefficients are significant (even after clustering by country), except for bond markets in PPP dollars over the last ten years: there, systematic risks in currency and bond markets share a common strong upward trend, although there is not enough variation around this trend to measure an additional link between shares of systematic risk. The common trend, however, implies a strong link between the two markets.

Overall, the cross-country regression results reported in Table 5 highlight a clear link across measures of systematic risk obtained on different asset and good markets. These results, combined with the asset pricing power of the dollar factor, point to a risk-based approach to exchange rates. The carry and dollar factors thus not only measure the share of systematic variation, but also the share of systematic risk in bilateral exchange rates. Pursuing this risk perspective on exchange rates, the next section highlights the key theoretical implications of the empirical findings.

5 Implications and Interpretations

In this section, I first highlight the preference-free implications of the cross-country differences in currency systematic risk, before reviewing a reduced-form and a macro-finance model to propose an interpretation of the carry and dollar factors.

5.1 Preference-free Results

Let us start again from the definition of the change in the nominal exchange rate Δs^i:

$$\Delta s^i_{t+1} = m_{t+1} - m^i_{t+1},$$

where m and m^i denote the nominal pricing kernels of the domestic and country i investors. Without loss of generality, each pricing kernel can be decomposed into country-specific and world shocks:

$$\Delta s^i_{t+1} = \overbrace{m^{US-spec.}_{t+1} + m^W_{t+1}}^{m_{t+1}} - \overbrace{m^{i-spec.}_{t+1} - m^{W,i}_{t+1}}^{m^i_{t+1}},$$

where $m^{US-spec.}_{t+1}$ and $m^{i-spec.}_{t+1}$ denote the U.S.- and country i-specific components of the U.S. and country i pricing kernels, while m^W_{t+1} and $m^{W,i}_{t+1}$ denote their respective global components. Each component can be a vector of several shocks. By construction, the country-specific shocks are orthogonal across countries and orthogonal to the world shocks: $cov(m^{i-spec.}, m^{j-spec.}) = 0$ and $cov(m^{i-spec.}, m^{W,j}) = 0$, for any i, j. Bilateral exchange rates depend on (home minus foreign) differences in country-specific and world shocks. Foreign country-specific shocks drive part of the exchange rate movements, but since they can be diversified away, they are not part of a risk factor built from the perspective of the representative U.S. investor. In this general framework, I consider the implications of the dollar and carry factors and the dollar beta-sorted portfolios, before turning to the share of global shocks in exchange rates.

Dollar Risk Factor In large baskets of currencies, foreign country-specific shocks average out (assuming that there are enough currencies in the baskets for the law of large number to apply). The dollar risk factor is the average exchange rate of all currencies defined in terms of U.S. dollars and thus corresponds to:

$$Dollar_{t+1} = \frac{1}{N}\sum_i \Delta s^i_{t+1} = m^{US-spec.}_{t+1} + m^W_{t+1} - \frac{1}{N}\sum_i m^{W,i}_{t+1},$$

where N denotes the number of currencies in the sample. As a result, the dollar risk factor depends on both U.S.-specific and world shocks, but not on foreign-specific shocks. The covariance between the change in exchange rate and the dollar risk factor is:

$$cov(\Delta s^i, Dollar) = Var(m^{US-spec.}) + Cov(m^W, m^W - \frac{1}{N}\sum_i m^{W,i}) - cov(m^{W,i}, m^W - \frac{1}{N}\sum_i m^{W,i}).$$

The first two terms are the same for all currencies. The U.S.-specific part of the U.S. pricing kernel shows up in each bilateral exchange rate and in the dollar factor: that component of the change in exchange rate is regressed on itself. Likewise, the global component of the U.S. pricing kernel is regressed on the global component of the dollar factor. But those first two terms are clearly not the whole story. In the data, there are large differences in the slope coefficients of bilateral exchange rates on the dollar risk factor. Thus the third term in the covariance decomposition must be non-zero. This is the only way to obtain differences across countries in their dollar betas, and different excess returns on dollar beta-sorted portfolios. It implies that the dollar factor must depend on world shocks, not only on U.S.-specific shocks and that foreign pricing kernels must differ in their loading on those global shocks.

Carry Risk Factor The carry risk factor is the average exchange rate of high- versus low-interest rate currencies:

$$Carry_{t+1} = \frac{1}{N_H}\sum_{i\in H}\Delta s^i_{t+1} - \frac{1}{N_L}\sum_{i\in L}\Delta s^i_{t+1} = \frac{1}{N_H}\sum_{i\in H} m^{W,i}_{t+1} - \frac{1}{N_L}\sum_{i\in L} m^{W,i}_{t+1},$$

where N_H (N_L) denotes the number of high (low) interest rate currencies in the sample. The carry factor, defined as a difference in baskets of exchange rates, is dollar-neutral. As Lustig et al. (2011) show, the carry factor accounts for world shocks, provided that pricing kernels differ in their exposure to world shocks — without heterogeneity, the carry factor would not exist. Lustig et al. (2011) show that these world shocks are priced globally. The intuition is the following. Borrowing in low interest rate currencies and lending in high interest rate currencies provides the same return to any investor in the world. Since these returns are the same from the perspective of any investor, they must compensate them for taking on global risk that is priced globally (i.e. with the same price across countries). Total returns to carry trades vary across investors only because they need to convert their gains expressed in low interest rate currencies back into their own currency.

Dollar-beta Portfolios and Global Shocks The dollar-beta portfolios corresponds to sorts on the covariances between some world shocks in each country's pricing kernel and the corresponding world shocks in the U.S. pricing kernel. It is key to note that such world shocks must be different from those captured by the carry factor. The correlation between the dollar and carry factors is less than 0.1. Moreover, recall that the carry factor does not price the cross-section of dollar-beta portfolios. In other words, the exchange rate of the high dollar beta portfolio minus the exchange rate of the low dollar beta portfolio has a low correlation with the carry trade factor. Any model in international finance must then feature two kinds of global shocks.

In the data, the global shocks can be measured using long-short strategies. The difference in exchange rates between high and low interest rate portfolios captures the global shocks responsible for the carry trade risk premia. Likewise, the difference in exchange rates between high and low dollar beta portfolios cancels out the U.S.-specific component of the U.S. pricing kernel and focuses on its global component, thus extracting the global component of the dollar factor.

One potential interpretation of these two global shocks relates carry risk to global volatility risk (as measured for example on world equity markets) and dollar risk to global growth risk. The difference in returns between the high and low dollar beta portfolios tends to be low when developed countries are close to the troughs of their business cycles, as measured by the OECD turning points. This tentative interpretation does not naturally exclude others, based on global shocks to, for example, liquidity, monetary policies, or international trade. These are interesting research avenues beyond the scope of this paper. Instead, I show that global shocks account for a significant share of exchange rate variation.

Global Systematic Shocks in Bilateral Exchange Rates In order to focus on global risk factors in exchange rates, I regress the changes in bilateral exchange rates on the conditional and unconditional carry factors and the global component of the dollar factor. Table 6 reports the results. They are obtained on a smaller number of observations than in the previous tables because building the dollar-beta portfolios uses 60 observations. Loadings on the global component of the dollar factor are significant for all developed currencies. Unsurprisingly, the global component of the dollar factor accounts for a lower share of the exchange rate variations than the dollar factor itself. The difference in R^2s range from 2 to 15 percentage points. Overall, global shocks account for a large share of the exchange rate changes, with R^2s ranging from 17% to 82%.

[Table 6 about here.]

Other Base Currencies and Cross Exchange Rates All regressions so far pertain to exchange rates defined with respect to the U.S. Dollar. The global component of the dollar factor, however, explains also part of some cross-exchange rates (i.e. exchange rates not defined with respect to the U.S. dollar). Table 7 reports regression results similar to those in Table 6 but obtained for exchange rates expressed in Japanese Yen and in U.K. pound.

[Table 7 about here.]

Table 7 thus does not report the total share of systematic currency risk from the perspective of the Japanese or U.K. investor (as that should include the Japan-specific or U.K.-specific shocks that cannot be diversified away by those investors). Instead, the table focuses on the share of global shocks. In a no-arbitrage model, the Swiss Franc / Yen exchange rate, for example, depends on the Swiss and Japanese SDFs and there is thus no role for U.S.-specific shocks, but this exchange rate should also depend on global shocks that affect the dollar factor. In the data, the global component of the dollar factor appears significant for 9 out of 13 exchange rates defined in Yen, and 10 out of 13 exchange rates defined in pounds. The conditional and unconditional carry factors, along with the global component of the dollar factor, account for 6% to 45% of those exchange rates. The carry and part of the dollar factor are thus key global drivers of exchange rates. The name "dollar" factor is justified by the high correlation (0.85) between this global component and the average of all exchange rates defined in U.S. dollars.

The Return of an Old Puzzle The large share of global shocks in exchange rates constitute a new challenge for models in international economics. Backus and Smith (1993) note that constant relative risk-aversion implies that changes in real exchange rates should be perfectly correlated to relative consumption growth rates. In the data, however, the unconditional correlation is close to zero, if not negative. Generalizing this point in a preference-free setting, Brandt, Cochrane and Santa-Clara (2006) point that volatile pricing kernels (as implied by the Hansen and Jagannathan (1991) bounds for example) imply very volatile exchange rates, unless pricing kernels are highly correlated across countries.[12] In the data, this correlation must be above 0.9, in strong contrast to the low cross-country correlation of consumption growth rates.

Colacito and Croce (2011) propose a solution to the Backus and Smith (1993) and Brandt et al. (2006) quandaries. As noted in the introduction, the solution relies on global long-run risk shocks driving the pricing kernels, but not affecting their differences and thus exchange rates. A crucial assumption here is that countries are symmetric such that global shocks cancel out. This solution

[12] In complete markets (or for the projection of SDFs on the space of traded assets), the change in real exchange rates is $\Delta q^i_{t+1} = m^{real}_{t+1} - m^{real,i}_{t+1}$. Thus the variance of exchange rates is: $Var[\Delta q^i_{t+1}] = Var[m^{real}_{t+1}] + Var[m^{real,i}_{t+1}] - 2cov(m^{real}_{t+1}, m^{real,i}_{t+1})$.

to the puzzle needs to be refined in light of the new evidence reported in this paper: global factors account for a significant share of the exchange rate variations. As a result, the Backus and Smith (1993) and Brandt et al. (2006) puzzles are back.

The empirical findings clearly indicate that countries must differ in their pricing kernels, more precisely in how their pricing kernels respond to global shocks. The sources and impact of heterogeneity in international finance is the subject of ongoing research. For example, Hassan (2012) considers the impact of different country sizes on asset returns, Gourinchas, Rey and Govillot (2011) entertain different risk-aversion coefficients, while Maggiori (2012a) studies the consequence of different levels of financial development.

I end this paper with a brief overview of a reduced-form model and a long-run risk model. These models aid the interpretation of the dollar and carry factors and the empirical results. The detailed presentations of the models, the proofs, and the simulations are in the separate appendix; the paper focuses only on the intuition derived from the models.

5.2 A Reduced-Form Model

Building on Cox, Ingersoll and Ross (1985) and Backus, Foresi and Telmer (2001), Lustig et al. (2013) start from the law of motion of the log pricing kernel or stochastic discount factor (SDF) m^i.

Stochastic Discount Factors Lustig et al. (2013) assume that each SDF responds to country-specific shocks (denoted u^i, uncorrelated across countries) and two global shocks (denoted u^w and u^g). 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.[13] If SDFs were homoscedastic, expected excess returns would be constant and the UIP condition would be valid. The time-varying volatilities of the country-specific shocks are also country-specific, while those of global shocks are either country-specific (for

[13]If SDFs are not lognormal, expected currency excess returns depend on the higher cumulants, some of which must be time-varying.

the u^g shocks) or global (for the u^w shocks). In the language of finance, the u^w shocks are priced globally, while the u^g shocks are priced locally. Engel (2011) shows that risk-based explanations of carry trades need to include at least two sources of risk. To be parsimonious, all the parameters that govern the SDFs are the same across countries, except for the exposure of each SDF to the shocks priced globally (δ^i).

In the model, bilateral exchange rates, interest rates, average forward discounts, and the carry and dollar risk factors can all be derived in closed forms. Particularly simple expressions arise in the following special case: assuming that (i) the U.S. SDF's exposure to world shocks priced globally (u^w) is equal to the average exposure to world shocks across countries ($\overline{\delta^i} = \delta$), and (ii) baskets of high and low interest rate currencies exhibit the same level of country-specific volatilities. The first assumption implies that the time-series mean of the average forward discount among developed countries is zero, a close approximation to the data. The second assumption implies that the conditional correlation between the dollar and carry factors is zero; in the data, the unconditional correlation is less than 0.1. In that special case, the carry factor captures world shocks that are priced globally, while the dollar factor is driven by U.S.-specific shocks and world shocks that are priced locally. The average forward discount rate measures the gap between the average local volatility and its current value in the U.S. The change in exchange rate of country i responds to country i's specific shocks, U.S.-specific shocks, and world shocks, in proportion to the differential exposure to these world shocks in the foreign country and in the U.S. SDFs.

Intuitions for the Cross-Sections of Currency Excess Returns The reduced-form model provides a rationale for the two risk factors and their associated cross-sections of currency returns.

Sorting countries by their interest rates leads to a large cross-section of currency excess returns in the data. Low (high) interest rate currencies offer low (high) average excess returns. In the model, as Lustig et al. (2013) show, sorting countries by their interest rates is similar to sorting by the exposure (δ^i) to global shocks priced globally (u^w); high interest rate countries are low δ^i countries. During a bad global shock, $u^w < 0$, these currencies depreciate: carry trades are risky because high (low) interest rate currencies depreciate (appreciate) in bad times.

In the model, sorting countries by their dollar betas is similar to sorting by the level of the country-specific price of risk, which is relevant for global shocks priced locally (u^g). On the one hand, when the average forward discount rate is positive, the U.S. interest rate is lower than the world average, and the U.S.-specific market price of risk is above its long-run mean. Currencies with large loadings on the dollar factor are currencies with low country-specific prices of risk. They offer large excess returns on average to compensate investors for taking on global risks that are priced locally: during periods of a bad global shock ($u^g < 0$), these currencies depreciate. On the other hand, when the average forward discount is negative, currencies with large loadings on the dollar factor are currencies with large country-specific prices of risk. They tend to appreciate during a bad global shock ($u^g < 0$): again, this pattern is a source of risk since investors are short those currencies (and long the U.S. dollar) when the average forward discount rate is negative.

Shares of Systematic Variation Simulated data from the model, using the parameters reported in Lustig et al. (2013), reproduce the stark contrast between UIP and factor regressions. The interest rate difference accounts for only 0.2% to 0.4% of the bilateral exchange rate dynamics. The conditional and unconditional carry factors explain up to 25% of the exchange rate variation, thus slightly more than in the data. Adding the dollar factor delivers an average R^2 close to 60%, in line with the average value in the data. R^2s and slope coefficients are time-varying, as they are in the data. The model also implies a large cross-section of interest rate-sorted portfolio returns, from -4.8% to 2.3% per annum, thus delivering a high-minus-low carry trade excess return of 7.1%. The model, however, does not produce a large enough cross-section of dollar-sorted portfolio returns. This shortcoming is due to the low predictive power of the average forward discount in the model (cf Lustig, Roussanov, and Verdelhan, 2012) and the low dispersion in dollar loadings.

Overall, the reduced-form model offers a simple interpretation for the dollar and carry factors and their associated cross-section of returns. I turn now to a long-run risk example that illustrates the theoretical challenges brought by the empirical findings.

5.3 Long-Run Risk Example

The long-run risk literature works off the class of preferences due to Kreps and Porteus (1978) and Epstein and Zin (1989). Following Bansal and Yaron (2004), real consumption growth in each country exhibits a persistent long-run expected growth component and is subject to temporary shocks. The dynamics of consumption growth are key because they influence the properties of the SDF: shocks to the SDF are ultimately consumption shocks, while the market prices of risk are derived in equilibrium from the preference parameters and the properties of the consumption process.

Preferences and Endowments I start from the symmetric, two-country, long-run risk model of Bansal and Shaliastovich (2012) and extend it to N different countries. Following the insights of the reduced-form model, consumption growth should respond to local shocks, global shocks with a time-varying volatility that is common across countries, and global shocks with a country-specific volatility. The first set of global shocks is priced globally, while the second set is priced locally.

As in Bansal and Shaliastovich (2012), the long-run risk process is common across countries. Colacito and Croce (2011) show that the long-run risk components must be highly correlated across countries in order to deliver exchange rates that are as smooth as in the data. Bansal and Shaliastovich (2012) thus assume that the foreign economy shares the same long-run risk component as the domestic economy. This assumption is in line with empirical evidence: Nakamura, Sergeyev and Steinsson (2012) find a common long-run risk component across countries in the Barro and Ursua (2008) dataset.

Unlike in Bansal and Shaliastovich (2012), some temporary shocks to consumption growth are common across countries: yet, their volatilities are country-specific. In the data, consumption growth processes exhibit a low correlation across countries. To take into account this empirical fact, consumption growth also responds to country-specific temporary shocks; those shocks are homoscedastic.

The description of consumption growth is then rich enough to produce different kinds of local and global shocks. The key remaining question is the source of heterogeneity across countries. To narrow it down to the structural parameters, it is useful to derive the exchange rates and carry and dollar factors in the model.

Sources of Cross-country Differences For the carry factor to exist, high- and low-interest rate currencies must differ in their loadings on the common components of the SDF [see Lustig et al. (2011)]. Thus, countries must differ in their market price of short-run consumption growth risk, in their market price of long-run risk, and/or in their market prices of long-run volatility risk. Those market prices of risk depend on the risk-aversion coefficient, the EIS, the persistence of the long-run risk component, and the average wealth-consumption ratio (which is determined in equilibrium as a function of the preference and endowment parameters).

The dollar factor loads on global shocks only if the U.S. economy exhibits market prices of risk that differ from their cross-country average counterparts. It implies that the representative U.S. investor must differ in at least one of the dimensions above from the average world investor. The model thus links the necessary heterogeneity to differences in structural parameters, but the empirical relevance of each one of them is an open question.

Simulation Results As an illustration, I consider two sets of simulations: countries differ either by their risk-aversion coefficient or by the share of their country-specific volatility. There is no reason for countries to differ only along one dimension; the dichotomy is only there for clarity. There are 36 countries in the simulation and the first country is the domestic country (i.e., the U.S.). The preference and endowment parameters are those proposed in Bansal and Shaliastovich (2012), except for the following parameters: risk-aversion varies from 4 to 6, instead of 10 in Bansal and Shaliastovich (2012), and the inflation mean, the inflation shock volatility, and the expected inflation volatility are lower than in Bansal and Shaliastovich (2012) in order to reproduce the characteristics of aggregate inflation in the sample. All the parameters are listed in the separate Appendix, along with proofs and simulation results. The model starts from simple consumption dynamics (consistent with the cross-country correlations) and produces reasonable risk-free rates, as well as equity and bond risk premia; it is thus an interesting laboratory to study exchange rates.

When countries differ by their shares of country-specific volatility, exchange rates are driven almost exclusively by short-term shocks; there is no role for long-term shocks as market prices of risk do not vary significantly across countries. As a result, the carry factors account for only 0.2% to 0.7% of the monthly exchange rate movements.

Differences in risk-aversion coefficients have a higher impact. The model produces a cross-section of currency excess returns when countries are sorted by their short-term nominal interest rates (or dollar betas). In the model, as in the data, interest rate differences explain almost none of the exchange rate time-series. When risk-aversion differences are small, long-run risk shocks play no role in exchange rate variation because of the absence of cross-country differences in their market prices of risk. In this case, most of the exchange rate variation is due to country-specific shocks. When a country's risk-aversion differs (e.g., 4 to 6), common long-run risk shocks explain up to 36% of the exchange rate changes. This large increase in the role of common shocks accounts for the increase in the share of systematic risk measured by the dollar and carry factors: the carry factors account for 0.8% to 8.4% of the monthly changes in exchange rates, while the carry and dollar factors jointly deliver R^2s between 47% and 75% across countries, in line with the empirical results in Section 2. Likewise, systematic risk in equity markets ranges from 70% to 88%. As in the data, R^2s increase on both equity and currency markets across countries. This is the main achievement of the model, showing that the cross-asset and cross-country results of Section 4 can be reproduced in a simple model.

In light of the general discussion earlier in this section, some weaknesses of the simulations are unsurprising: the correlation between changes in exchange rates and relative consumption growth (cf. the Backus and Smith (1993) puzzle) is too high, and the changes in exchange rates are too volatile, with standard deviations ranging between 17% and 19% (cf. the Brandt et al. (2006) puzzle). Moreover, the cross-sections of carry and dollar beta-sorted excess returns are small, the cross-sectional variation in equity R^2s measured in local currencies is small, and the carry factors explain a large share of the dollar beta-sorted portfolios; all of these outcomes are at odds with the data. Reproducing all the empirical results reported in this paper constitute a challenge for models in international economics.

6 Conclusion

This paper shows that bilateral exchange rates are driven by country-specific shocks, as well as two global risk factors. Cross-currency differences in the shares of systematic variation appear related to financial and macroeconomic measures of comovement. The findings point to a risk-based approach to currency markets, suggesting that a large share of exchange rate movement is due to global risk.

The findings are important for both academics and practitioners. For practitioners, they imply the need for global currency risk management. Many international mutual fund managers do not hedge their currency exposures. If changes in exchange rates were independent and random, then buying assets in many different currencies would offer a simple diversification mechanism of currency risk. This paper, however, shows that such diversification is wishful thinking. The decomposition of exchange rates in two risk factors also simplifies optimal portfolio allocation and hedging. As an example, a mean-variance investor allocating resources among, for example, 12 currencies would need to estimate the inverse of a 3x3 (instead of a 12x12) covariance matrix.

For researchers, the role of the carry and dollar factors motivate the study of systematic components in exchange rates, since those components account for a large share of bilateral exchange rate movements. Unlike many covariances between exchange rates and macroeconomic variables, the loadings on the risk factors and R^2s are precisely estimated. They offer a new source of cross-country differences and thus new potential targets for future models in macroeconomics that seek to link the deep characteristics of each economy to the behavior of its exchange rate.

References

Akram, Q. Farooq, Dagfinn Rime, and Lucio Sarno, "Arbitrage in the Foreign Exchange Market: Turning on the Microscope," *Journal of International Economics*, 2008, *76* (2), 237–253.

Alvarez, Fernando, Andrew Atkeson, and Patrick J. Kehoe, "Money, Interest Rates and Exchange Rates with Endogenously Segmented Markets," *Journal of Political Economy*, 2002, *110(1)*, 73–112.

——, ——, and ——, "Time-Varying Risk, Interest Rates and Exchange Rates in General Equilibrium," *Review of Economic Studies*, 2009, *76*, 851 – 878.

Andrews, Donald W.K., "Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimation," *Econometrica*, 1991, *59* (1), 817–858.

Ang, Andrew and Joseph S. Chen, "Yield Curve Predictors of Foreign Exchange Returns," 2010. Working Paper Columbia University.

Asness, Cliff, Tobias Moskowitz, and Lasse Pedersen, "Value and Momentum Everywhere," *Journal of Finance, forthcoming*, 2012.

Baba, Naohiko and Frank Packer, "From turmoil to crisis: Dislocations in the FX swap market before and after the failure of Lehman Brothers," *Journal of International Money and Finance*, 2009, *28*, 1350–1374.

Backus, David and Gregor Smith, "Consumption and Real Exchange Rates in Dynamic Economies with Non-Traded Goods," *Journal of International Economics*, 1993, *35*, 297–316.

——, Silverio Foresi, and Chris Telmer, "Affine Term Structure Models and the Forward Premium Anomaly," *Journal of Finance*, 2001, *56* (1), 279–304.

Bansal, Ravi, "An Exploration of the Forward Premium Puzzle in Currency Markets," *Review of Financial Studies*, 1997, *10*, 369–403.

—— and Amir Yaron, "Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles," *Journal of Finance*, 2004, *59* (4), 1481 – 1509.

—— and Ivan Shaliastovich, "A Long-Run Risks Explanation of Predictability Puzzles in Bond and Currency Markets," *Review of Financial Studies*, 2012, *26* (1), 1–33.

—— and Magnus Dahlquist, "The Forward Premium Puzzle: Different Tales from Developed and Emerging Economies," *Journal of International Economics*, 2000, *51*, 115–144.

Barro, Robert, "Rare Disasters and Asset Markets in the Twentieth Century," *Quarterly Journal of Economics*, 2006, *121*, 823–866.

Barro, Robert J. and José F. Ursua, "Macroeconomic Crises since 1870," *Brookings Papers on Economic Activity*, 2008, *Spring*, 255–335.

Bekaert, Geert, "The Time Variation of Risk and Return in Foreign Exchange Markets: A General Equilibrium Perspective," *The Review of Financial Studies*, 1996, *9* (2), 427–470.

—— **and Campbell R. Harvey**, "Time-Varying World Market Integration," *Journal of Finance*, 1995, *50 (2)*, 403–444.

—— **, Campbell Harvey, Christian T. Lundblad, and Stephan Siegel**, "What Segments Equity Markets?," *Review of Financial Studies*, 2011, *24 (12)*, 3847–3890.

—— **, Robert J. Hodrick, and Xiaoyan Zhang**, "International Stock Return Comovements," *Journal of Finance*, 2009, *64*, 2591–2626.

Bilson, John F. O., "The Speculative Efficiency Hypothesis," *The Journal of Business*, 1981, *54 (3)*, 435–451.

Bollerslev, Tim, "Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized Arch Model," *Review of Economics and Statistics*, August 1990, *72* (3), 498–505.

Brandt, Michael W., John Cochrane, and Pedro Santa-Clara, "International Risk-Sharing is Better Than You Think, or Exchange Rates are Too Smooth," *Journal of Monetary Economics*, May 2006, *53* (4), 671–698.

Campbell, John Y., "A Variance Decomposition for Stock Returns," *Economic Journal*, 1991, *101*, 157–179.

—— **and John H. Cochrane**, "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior," *Journal of Political Economy*, 1999, *107* (2), 205–251.

Chaboud, Alain P. and Jonathan H. Wright, "Uncovered interest parity: it works, but not for long," *Journal of International Economics*, 2005, *66* (2), 349–362.

Cheung, Yin-Wong, Menzie D. Chinn, and Antonio Garcia Pascual, "Empirical exchange rate models of the nineties: Are any fit to survive?," *Journal of International Money and Finance*, 2005, *24*, 1150–1175.

Chinn, Menzie D., "The (partial) rehabilitation of interest rate parity in the floating rate era: Longer horizons, alternative expectations, and emerging markets," *Journal of International Money and Finance*, 2006, *25*, 7–21.

Christiansen, Charlotte, Angelo Ranaldo, and Paul Soderlind, "The Time-Varying Systematic Risk of Carry Trade Strategies," *Journal of Financial and Quantitative Analysis*, 2011, *1*, 1–35.

Cochrane, John H., *Asset Pricing*, Princeton, N.J.: Princeton University Press, 2005.

Colacito, Riccardo, "Six Anomalies Looking For a Model. A Consumption-Based Explanation of International Finance Puzzles," 2008. Working Paper, University of North Carolina.

—— **and Mariano M. Croce**, "Risks For The Long Run And The Real Exchange Rate," *Journal of Political Economy*, 2011, *119* (1), 153–182.

—— **and** —— , "International Asset Pricing with Recursive Preferences," *Journal of Finance, forthcoming*, 2012.

Cox, John C., Jonathan E. Ingersoll, and Stephen A. Ross, "A Theory of the Term Structure of Interest Rates," *Econometrica*, 1985, *53* (2), 385–408.

DeSantis, Roberto A. and Fabio Fornari, "Does Business Cycle Risk Account for Systematic Returns from Currency Positioning? The International Perspective," June 2008. European Central Bank.

Diebold, Francis X. and Marc Nerlove, "The Dynamics of Exchange Rate Volatility: A Multivariate Latent Factor ARCH Model," *Journal of Applied Econometrics*, 1989, *4*, 1–21.

Engel, Charles, "The Forward Discount Anomaly and the Risk Premium: A Survey of Recent Evidence," *Journal of Empirical Finance*, October 1996, *3*, 123–192.

—— , "The Real Exchange Rate, Real Interest Rates, and the Risk Premium," 2011. Working Paper.

—— **and Kenneth West**, "Exchange Rates and Fundamentals," *Journal of Political Economy*, 2005, *113*, 485–517.

—— **, Nelson C. Mark, and Kenneth D. West**, "Factor Model Forecasts of Exchange Rates," *Econometric Reviews, forthcoming*, 2012.

Epstein, Larry and Stan Zin, "Substitution Risk Aversion and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework," *Econometrica*, 1989, *57*, 937–968.

Evans, Martin D.D., "Exchange-Rate Dark Matter," 2012. Working Paper, Georgetown University.

——— **and Richard K. Lyons**, "Meese-Rogoff Redux: Micro-Based Exchange Rate Forecasting," *American Economic Review*, 2005, *95* (2), 405–414.

Fama, Eugene F., "Forward and Spot Exchange Rates," *Journal of Monetary Economics*, 1984, *14*, 319–338.

——— **and James MacBeth**, "Risk, Return and Equilibrium: Empirical Tests," *Journal of Political Economy*, 1973, *81*, 607–636.

——— **and Kenneth R. French**, "Common Risk Factors in the Returns on Stocks and Bonds," *Journal of Financial Economics*, 1993, *33*, 3–56.

Farhi, Emmanuel and Xavier Gabaix, "Rare Disasters and Exchange Rates," 2008. NBER Working Paper 13805.

———**, Samuel P. Fraiberger, Xavier Gabaix, Romain Ranciere, and Adrien Verdelhan**, "Crash Risk in Currency Markets," 2009. Working Paper MIT Sloan.

Ferraro, Domenico, Barbara Rossi, and Kenneth S. Rogoff, "Can Oil Prices Forecast Exchange Rates?," *Duke University Working Paper*, 2011.

Frankel, Jeffrey A., "On the Mark: A Theory of Floating Exchange Rates Based on Real Interest Differentials," *American Economic Review*, 1979, *69 (4)*, 610–622.

Froot, Kenneth and Richard Thaler, "Anomalies: Foreign Exchange," *The Journal of Economic Perspectives*, 3 1990, *4*, 179–192.

Gabaix, Xavier, "Variable Rare Disasters: An Exactly Solved Framework for Ten Puzzles in Macro-Finance," *Quarterly Journal of Economics*, 2012, *127* (2), 645–700.

Galsband, Victoria and Thomas Nitschka, "Foreign currency returns and systematic risks," 2010. Swiss National Bank Working Papers.

Gavazzoni, Federico, Batchimeg Sambalaibat, and Chris Telmer, "Currency Risk and Pricing Kernel Volatility," 2012. Working Paper, Carnegie Mellon University.

Gilmore, Stephen and Fumio Hayashi, "Emerging Market Currency Excess Returns," *American Economic Journal: Macroeconomics*, 2011, *3*, 85–111.

Gourinchas, Pierre-Olivier, Helene Rey, and Nicolas Govillot, "Exorbitant Privilege and Exorbitant Duty," 2011. London School of Economics Working Paper.

Gourio, Francois, Michael Siemer, and Adrien Verdelhan, "International Risk Cycles," *Journal of International Economics*, 2013, *89*, 471–484.

Hansen, Lars Peter and R. Jagannathan, "Implications of Security Markets Data for Models of Dynamic Economies," *Journal of Policitical Economy*, 1991, *99*, 252–262.

Hassan, Tarek, "Country Size, Currency Unions, and International Asset Returns," *Journal of Finance, forthcoming*, 2012.

—— **and Rui Mano**, "Carry Trade: Beyond the Forward Premium Puzzle," 2012. Chicago Booth Working Paper.

Hoffmann, Mathias and Rahel Suter, "The Swiss Franc Exchange Rate and Deviations from Uncovered Interest Parity: Global vs Domestic Factors," *Swiss Journal of Economics and Statistics*, 2010, *146 (1)*, 349371.

Hooper, Peter and John Morton, "Fluctuations in the Dollar: A Model of Nominal and Real Exchange Rate Determination," *Journal of International Money and Finance*, 1982, *1*, 39–56.

Hu, Xing, Jun Pan, and Jiang Wang, "Noise as Information for Illiquidity," 2010. Working Paper MIT Sloan.

Huisman, Ronald, Kees Koedijk, Clemens Kool, and Francois Nissen, "Extreme support for uncovered interest parity," *Journal of International Money and Finance*, 1998, *17*, 211–228.

Jurek, Jakub W., "Crash-neutral Currency Carry Trades," 2008. Working Paper Princeton University.

Kozak, Serhiy, "Bond and Foreign Exchange Risk Premia," 2011. Working Paper University of Chicago.

Kreps, David and Evan L. Porteus, "Temporal Resolution of Uncertainty and Dynamic Choice Theory," *Econometrica*, 1978, *46*, 185–200.

Lettau, Martin, Matteo Maggiori, and Michael Weber, "Conditional Risk Premia in Currency Markets and Other Asset Classes," 2013. Working Paper, University of California-Berkeley and New York University.

Lewis, Karen K., "Global Asset Pricing," *Annual Review of Financial Economics*, 2011.

Litterman, Robert and Jose Scheinkman, "Common Factors Affecting Bond Returns," *Journal of Fixed Income*, 1991, *1* (1), 54 – 61.

Lothian, James R. and Liuren Wu, "Uncovered Interest-Rate Parity over the Past Two Centuries," June 2005. Working Paper Fordham University.

Lustig, Hanno and Adrien Verdelhan, "The Cross-Section of Foreign Currency Risk Premia and Consumption Growth Risk," 2005. NBER Working Paper No 11104.

___ and ___, "The Cross-Section of Foreign Currency Risk Premia and Consumption Growth Risk," *American Economic Review*, March 2007, *97* (1), 89–117.

___, Nikolai Roussanov, and Adrien Verdelhan, "Common Risk Factors in Currency Markets," *Review of Financial Studies*, 2011, *24 (11)*, 3731–3777.

___, ___, and ___, "Countercyclical Currency Risk Premia," 2013. Working Paper MIT Sloan.

Maggiori, Matteo, "Financial Intermediation, International Risk Sharing, and Reserve Currencies," 2012. NYU Working Paper.

___, "The U.S. Dollar Safety Premium," 2012. NYU Working Paper.

Meese, Richard A. and Kenneth Rogoff, "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?," *Journal of International Economics*, 1983, *14*, 3–24.

Menkhoff, Lukas, Lucio Sarno, Maik Schmeling, and Andreas Schrimpf, "Carry Trades and Global Foreign Exchange Rate Volatility," *Journal of Finance*, 2012, *67 (2)*, 681–718.

___, ___, ___, and ___, "Currency momentum strategies," *Journal of Financial Economics*, 2012, *106* (3), 660 – 684.

Meredith, Guy and Menzie D. Chinn, "Testing Uncovered Interest Rate Parity at Short and Long Horizons during the Post-Bretton Woods Era," 2005. Working Paper NBER 11077.

Mueller, Philippe, Andreas Stathopoulos, and Andrea Vedolin, "International Correlation Risk," 2012. Working Paper, London School of Economics and University of Southern California.

Nakamura, Emi, Dmitriy Sergeyev, and Jon Steinsson, "Growth-Rate and Uncertainty Shocks in Consumption: Cross-Country Evidence," 2012. NYU Working Paper.

Newey, Whitney K. and Kenneth D. West, "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 1987, *55* (3), 703–708.

Piazzesi, Monika and Martin Schneider, "Equilibrium Yield Curves," *National Bureau of Economic Analysis Macroeconomics Annual*, 2006.

Pukthuanthong, Kuntara and Richard Roll, "Global market integration: An alternative measure and its application," *Journal of Financial Economics*, 2009, *94* (2), 214 – 232.

Ranaldo, Angelo and Paul Soderlind, "Safe Haven Currencies," *Review of Finance*, 2008, *14* (3), 385–407.

Rietz, Thomas A., "The Equity Risk Premium: A Solution," *Journal of Monetary Economics*, 1988, *22*, 117–131.

Roll, Richard, "R-squared," *Journal of Finance*, 1988, *43* (2), 541 – 566.

Rossi, Barbara, "Exchange Rate Predictability," 2011. Working Paper Duke University.

Steeley, James M., "Modelling the Dynamics of the Term Structure of Interest Rates," *Economic and Social Review - Symposium on Finance*, 1990.

Tryon, Ralph, "Testing for Rational Expectations in Foreign Exchange Markets," 1979. International Finance Discussion Papers.

Verdelhan, Adrien, "A Habit-Based Explanation of the Exchange Rate Risk Premium," *Journal of Finance*, 2010, *65* (1), 123–145.

Wachter, Jessica, "A Consumption-Based Model of the Term Structure of Interest Rates," *Journal of Financial Economics*, 2006, *79*, 365–399.

Table 1: Interest Rates, Industrial Production, and Inflation

	Panel I: Interest Rates			Panel II: Industrial Production and Inflation					
Country	α	β	R^2	α	β	γ	δ	R^2	N
Australia	0.16	-0.88	**0.08**	0.24	-3.31	-5.37	81.59	**2.04**	312
	(0.25)	(0.68)	[0.73]	(0.27)	(1.83)	(10.62)	(79.86)	[3.27]	
Canada	-0.03	-1.02	**0.21**	-0.25	-2.16	-12.48	-67.84	**0.75**	312
	(0.14)	(0.74)	[0.78]	(0.23)	(1.40)	(8.85)	(59.33)	[1.71]	
Denmark	-0.21	-0.26	**-0.27**	-0.18	-0.33	-3.65	-91.06	**1.54**	312
	(0.19)	(0.71)	[0.53]	(0.17)	(0.63)	(6.16)	(47.73)	[2.12]	
Euro Area	-0.18	-2.66	**0.55**	-0.27	-0.65	-0.93	-192.36	**8.00**	143
	(0.27)	(2.22)	[2.31]	(0.33)	(1.80)	(8.34)	(91.11)	[6.10]	
France	-0.19	-0.17	**-0.54**	-0.09	-0.91	0.78	40.50	**-1.64**	107
	(0.26)	(1.14)	[1.20]	(0.28)	(0.85)	(10.56)	(88.83)	[2.96]	
Germany	-0.23	0.43	**-0.43**	-0.18	-0.00	-9.65	-15.22	**-1.05**	181
	(0.28)	(1.12)	[1.12]	(0.36)	(1.03)	(9.05)	(60.34)	[1.87]	
Italy	-0.12	0.40	**-0.45**	0.02	0.44	-6.55	35.18	**-0.93**	177
	(0.34)	(1.01)	[2.07]	(0.24)	(1.23)	(8.88)	(80.02)	[3.24]	
Japan	-0.91	-2.42	**1.71**	-1.40	-2.10	-13.46	-133.39	**3.07**	325
	(0.26)	(0.90)	[1.59]	(0.59)	(1.15)	(7.91)	(64.78)	[2.37]	
New Zealand	0.21	-0.99	**0.91**	-0.13	0.65	-11.39	-40.94	**-0.22**	312
	(0.25)	(0.49)	[1.44]	(0.22)	(0.78)	(9.40)	(44.19)	[1.51]	
Norway	-0.23	0.44	**-0.17**	-0.02	-0.41	-6.77	-39.77	**0.10**	312
	(0.22)	(0.89)	[0.93]	(0.14)	(0.76)	(7.86)	(37.35)	[1.68]	
Sweden	-0.04	-0.35	**-0.23**	-0.02	-0.92	-8.86	-84.85	**2.76**	312
	(0.21)	(0.99)	[0.78]	(0.16)	(0.73)	(7.16)	(34.31)	[2.31]	
Switzerland	-0.35	-0.53	**-0.19**	-0.59	-0.87	-7.98	-68.13	**0.82**	325
	(0.28)	(1.07)	[0.77]	(0.30)	(0.71)	(6.52)	(53.33)	[1.66]	
United Kingdom	0.22	-1.39	**0.43**	-0.19	-1.38	-11.68	-6.94	**0.42**	325
	(0.23)	(1.24)	[1.43]	(0.23)	(1.27)	(7.89)	(32.75)	[1.65]	

Notes: Panel I 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. Panel II 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 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. The table reports the constant α, the slope coefficients β, γ, and δ, as well as the adjusted R^2 of this regression (in percentage points), and the number N 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: Carry and Dollar Factors: Monthly Tests in Developed Countries

Country	α	β	γ	δ	τ	R^2	$R^2_{\$}$	$R^2_{no\ \$}$	W	N
Australia	0.07	-0.44	0.77	0.16	0.74	**25.59**	20.05	7.71	***	312
	(0.23)	(0.60)	(0.49)	(0.13)	(0.13)	[5.77]	[5.72]	[4.31]		
Canada	-0.11	-0.02	-0.61	0.21	0.34	**19.38**	13.11	8.14	***	312
	(0.11)	(0.63)	(0.42)	(0.06)	(0.07)	[6.94]	[4.34]	[4.97]		
Denmark	-0.01	-0.20	0.53	-0.16	1.51	**86.08**	83.63	3.97	***	312
	(0.07)	(0.38)	(0.13)	(0.03)	(0.04)	[1.67]	[2.03]	[3.99]		
Euro Area	0.07	-0.52	0.10	-0.28	1.62	**80.60**	76.22	-0.05	***	143
	(0.11)	(0.86)	(0.23)	(0.05)	(0.08)	[3.58]	[3.99]	[4.81]		
France	-0.15	-0.10	0.80	-0.13	1.38	**90.97**	87.58	12.30	***	181
	(0.07)	(0.34)	(0.14)	(0.03)	(0.04)	[1.48]	[1.93]	[5.90]		
Germany	-0.21	-0.03	0.79	-0.03	1.42	**91.00**	88.35	22.83	***	181
	(0.09)	(0.34)	(0.17)	(0.04)	(0.04)	[1.36]	[1.75]	[6.20]		
Italy	-0.03	0.26	0.68	-0.07	1.24	**68.97**	64.59	2.16	***	177
	(0.22)	(0.69)	(0.20)	(0.11)	(0.10)	[5.25]	[6.92]	[6.13]		
Japan	-0.44	-1.13	-0.10	-0.39	0.83	**29.52**	23.58	5.34	***	325
	(0.24)	(0.86)	(0.45)	(0.11)	(0.12)	[5.51]	[5.45]	[3.47]		
New Zealand	0.10	-0.58	0.76	-0.11	0.95	**29.80**	26.96	3.43	*	312
	(0.20)	(0.39)	(0.38)	(0.11)	(0.11)	[5.31]	[5.78]	[2.85]		
Norway	-0.07	0.29	0.48	-0.06	1.35	**71.23**	69.87	3.13	***	312
	(0.12)	(0.37)	(0.11)	(0.05)	(0.08)	[3.99]	[3.98]	[3.36]		
Sweden	0.06	-0.28	0.99	-0.06	1.39	**72.42**	67.65	5.94	***	312
	(0.10)	(0.35)	(0.16)	(0.04)	(0.06)	[2.90]	[3.41]	[3.46]		
Switzerland	-0.14	-0.19	0.94	-0.11	1.46	**74.61**	69.03	12.09	***	325
	(0.11)	(0.41)	(0.19)	(0.06)	(0.06)	[2.45]	[2.98]	[3.70]		
United Kingdom	0.06	-0.15	0.63	-0.03	1.06	**50.76**	49.90	2.13		325
	(0.15)	(0.71)	(0.47)	(0.09)	(0.09)	[5.09]	[5.29]	[3.01]		

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 adjusted 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 adjusted R^2 of a similar regression with only the *Dollar* factor (i.e., without the conditional and unconditional *Carry* factors). $R^2_{no\ \$}$ denotes the adjusted R^2 of a similar regression without the *Dollar* factor. 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 asterisks (***) correspond to a rejection of the null hypothesis at the 1% confidence level; two asterisks and one asterisk 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: Carry and Dollar Factors: Monthly Tests in Emerging and Developing Countries

Country	α	β	γ	δ	τ	R^2	$R^2_{\$}$	$R^2_{no\ \$}$	W	N
Hong Kong	-0.00	-0.15	0.06	0.00	0.02	**5.40**	4.85	1.29		325
	(0.01)	(0.09)	(0.05)	(0.00)	(0.01)	[3.32]	[3.10]	[2.29]		
Czech Republic	-0.14	-0.11	-0.04	-0.21	1.76	**64.09**	62.28	-0.62	**	167
	(0.17)	(0.35)	(0.16)	(0.09)	(0.09)	[4.71]	[4.64]	[2.34]		
Hungary	0.39	-0.35	-0.40	0.18	1.86	**67.69**	67.14	1.17	**	158
	(0.38)	(0.57)	(0.18)	(0.15)	(0.14)	[5.09]	[4.89]	[4.54]		
India	0.31	-0.57	0.22	0.03	0.49	**31.38**	30.72	7.61		158
	(0.24)	(0.66)	(0.29)	(0.11)	(0.07)	[7.05]	[6.59]	[5.80]		
Indonesia	1.93	-1.21	0.21	0.22	1.75	**9.75**	10.80	1.72		90
	(1.31)	(1.41)	(0.44)	(0.44)	(0.50)	[7.14]	[5.88]	[6.22]		
Kuwait	-0.16	2.17	0.53	-0.09	0.22	**52.24**	44.45	25.66	***	167
	(0.03)	(0.19)	(0.10)	(0.02)	(0.04)	[11.14]	[10.00]	[14.37]		
Malaysia	0.09	0.10	0.10	0.19	0.42	**23.04**	18.17	6.40		230
	(0.13)	(0.53)	(0.23)	(0.10)	(0.07)	[5.19]	[4.57]	[5.22]		
Mexico	0.40	-0.36	-0.29	0.68	0.22	**26.09**	9.11	24.48	***	167
	(0.28)	(0.36)	(0.15)	(0.16)	(0.15)	[8.44]	[6.94]	[8.19]		
Philippines	0.13	-0.02	0.63	-0.01	0.47	**32.59**	19.48	23.92	***	167
	(0.37)	(0.88)	(0.21)	(0.10)	(0.10)	[7.79]	[6.35]	[8.63]		
Poland	-0.08	1.09	1.13	0.10	1.89	**74.77**	70.73	18.44	***	106
	(0.20)	(0.71)	(0.30)	(0.08)	(0.11)	[5.43]	[6.09]	[8.37]		
Saudi Arabia	0.00	-0.39	0.18	-0.00	0.00	**8.57**	2.83	8.84		167
	(0.01)	(0.35)	(0.10)	(0.00)	(0.00)	[11.24]	[8.18]	[10.84]		
Singapore	-0.17	-0.29	0.12	0.08	0.50	**48.19**	47.19	6.29	*	312
	(0.11)	(0.60)	(0.15)	(0.03)	(0.04)	[4.19]	[4.38]	[4.05]		
South Africa	0.87	-0.58	0.04	0.18	1.07	**24.87**	24.14	2.36		324
	(0.51)	(0.79)	(0.37)	(0.28)	(0.14)	[5.50]	[5.66]	[2.44]		
South Korea	0.27	0.60	0.62	0.14	1.38	**51.83**	51.30	13.63		106
	(0.27)	(1.71)	(0.49)	(0.11)	(0.27)	[6.21]	[5.99]	[9.19]		
Taiwan	0.05	0.45	0.29	0.08	0.50	**35.77**	34.39	6.94	**	167
	(0.12)	(0.31)	(0.13)	(0.06)	(0.06)	[5.41]	[6.11]	[5.19]		
Thailand	-0.07	-0.36	0.88	-0.01	0.79	**27.98**	19.20	13.50		167
	(0.18)	(1.16)	(0.43)	(0.12)	(0.17)	[5.82]	[5.63]	[7.29]		
Turkey	-0.71	0.69	-0.19	1.12	0.65	**39.03**	27.34	32.80	***	154
	(0.39)	(0.11)	(0.04)	(0.25)	(0.17)	[8.08]	[8.00]	[7.26]		
United Arab Emirates	-0.00	-0.22	0.10	-0.00	0.00	**15.10**	3.32	15.39		162
	(0.00)	(0.14)	(0.07)	(0.00)	(0.00)	[19.30]	[12.36]	[19.27]		

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 adjusted R^2 of this regression and the number of observations N. $R^2_{\$}$ ($R^2_{no\ \$}$) denotes the adjusted R^2 of a similar regression with only (without) 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 By Dollar Exposures

	Panel I: Summary Statistics					
Portfolio	1	2	3	4	5	6
	Spot change: Δs					
Mean	−0.97	−2.12	−2.88	−3.66	−2.99	−5.07
Std	3.29	5.31	6.70	7.72	10.19	10.68
	Forward Discount: $f - s$					
Mean	0.34	0.74	0.99	1.47	2.00	2.07
Std	0.54	1.11	1.24	1.44	0.70	0.55
	Excess Return: rx					
Mean	1.31	2.86	3.87	5.13	4.99	7.14
	[0.70]	[1.17]	[1.41]	[1.61]	[2.16]	[2.18]
Std	3.34	5.38	6.68	7.62	10.20	10.64
SR	0.39	0.53	0.58	0.67	0.49	0.67
	Excess Return: rx (with bid-ask spreads)					
Mean	0.58	1.43	2.11	3.73	3.73	5.84
	[0.72]	[1.11]	[1.40]	[1.61]	[2.05]	[2.37]
	Panel II: Risk Prices					
	$\lambda_{Cond.Dollar}$	$b_{Cond.Dollar}$	R^2	$RMSE$	χ^2	
GMM_1	4.73	0.94	83.06	0.80		
	[1.54]	[0.31]			66.57	
GMM_2	4.51	0.90	81.74	0.83		
	[1.50]	[0.30]			66.91	
FMB	4.73	0.94	85.22	0.80		
	[1.41]	[0.28]			50.40	
	[1.41]	[0.28]			52.96	
Mean	4.61					
	Panel III: Factor Betas					
Portfolio	1	2	3	4	5	6
α	0.81	0.87	0.64	0.76	−1.17	0.44
	[0.90]	[1.00]	[1.06]	[0.91]	[0.99]	[0.90]
β	0.11	0.44	0.71	0.99	1.40	1.52
	[0.03]	[0.06]	[0.06]	[0.06]	[0.06]	[0.05]
R^2	4.40	28.98	48.00	71.64	78.97	86.39

Notes: Panel I reports summary statistics on portfolios of currencies sorted on their exposure to the dollar factor. See Section 3 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 and the mean excess returns net of bid-ask spreads. 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 ($m_{t+1} = 1 - bCond.Dollar_{t+1}$). The last row reports the mean of the risk factor. Excess returns used as test assets and risk factors do not 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: Shares of Currency Systematic Variation and World Comovement

	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	0.77	0.65	1.10	0.66	0.73	0.63
s.e	[0.28]	[0.19]	[0.16]	[0.12]	[0.15]	[0.29]
R^2	19.55	31.86	76.28	72.54	47.82	16.26
N	33	28	17	13	29	27
			Panel II: Constant R^2s, series in PPP dollars			
β	0.56	0.50	1.11	0.38	0.73	0.67
s.e	[0.35]	[0.23]	[0.28]	[0.21]	[0.22]	[0.28]
R^2	7.61	15.54	50.84	22.04	27.98	18.36
N	33	28	17	13	30	27
			Panel III: Time-Varying R^2s, series in U.S. dollars			
β	0.47	0.30	0.81	0.55		
s.e	[0.07]	[0.07]	[0.07]	[0.11]		
s.e	(0.07)	(0.12)	(0.10)	(0.13)		
trend	2.44	0.17	1.22	-1.03		
R^2	79.75	82.72	90.80	90.97		
N	5253	2915	3085	1578		
			Panel IV: Time-Varying R^2s, series in PPP dollars			
β	0.25	0.28	0.41	0.04		
s.e	[0.08]	[0.08]	[0.11]	[0.10]		
s.e	(0.10)	(0.11)	(0.14)	(0.12)		
trend	3.57	0.38	2.51	1.02		
R^2	76.74	82.35	77.41	86.12		
N	5253	2915	3085	1578		

Notes: Panels I and II 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. Panels III and IV 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 $R_{i,t}^{2,X}$ are estimated on rolling windows of 60 months. Panels I and III use financial and macroeconomic series expressed in U.S. dollars. Panels II and IV use series expressed in purchasing power parity (PPP) 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 (in brackets) and from clustering by country (in parenthesis).

Table 6: Monthly Shares of Global Shocks in Bilateral Exchange Rates

Country	α	γ	δ	τ	R^2	$R^2_{\$}$	$R^2_{Global\$}$	W	N
Australia	-0.10	0.83	0.31	0.33	**24.81**	39.55	13.42	***	266
	(0.18)	(0.57)	(0.12)	(0.10)	[7.14]	[6.93]	[6.06]		
Canada	-0.10	-0.86	0.24	0.21	**17.67**	25.59	8.58	***	266
	(0.11)	(0.48)	(0.06)	(0.06)	[8.17]	[7.62]	[5.05]		
Denmark	0.10	0.04	0.04	0.87	**80.61**	85.26	80.65		266
	(0.08)	(0.12)	(0.04)	(0.03)	[3.26]	[1.93]	[3.08]		
Euro Area	0.15	-0.21	-0.15	0.89	**82.68**	83.44	81.72	**	143
	(0.10)	(0.20)	(0.06)	(0.04)	[3.45]	[3.24]	[3.84]		
France	0.04	-0.02	0.16	0.88	**82.03**	89.58	80.31	***	122
	(0.10)	(0.16)	(0.04)	(0.06)	[4.69]	[2.26]	[4.75]		
Germany	0.07	-0.13	0.14	0.92	**82.22**	89.04	80.85	***	122
	(0.11)	(0.17)	(0.04)	(0.06)	[4.98]	[2.14]	[4.87]		
Italy	0.22	0.82	0.15	0.66	**68.98**	71.16	51.34	***	122
	(0.17)	(0.24)	(0.07)	(0.06)	[4.95]	[5.61]	[8.87]		
Japan	0.05	-0.27	-0.51	0.43	**24.40**	40.06	13.17	***	266
	(0.17)	(0.50)	(0.12)	(0.09)	[5.72]	[5.79]	[5.13]		
New Zealand	-0.04	0.23	0.18	0.49	**27.28**	44.12	24.45	***	266
	(0.17)	(0.61)	(0.18)	(0.08)	[6.55]	[5.39]	[5.94]		
Norway	0.06	0.24	0.15	0.77	**68.04**	72.53	65.82	***	266
	(0.10)	(0.12)	(0.04)	(0.06)	[5.91]	[4.15]	[5.68]		
Sweden	0.14	0.54	0.17	0.81	**68.58**	75.30	64.63	***	266
	(0.10)	(0.26)	(0.05)	(0.04)	[4.45]	[2.83]	[5.48]		
Switzerland	0.05	0.27	-0.11	0.84	**69.03**	77.14	67.61	*	266
	(0.10)	(0.29)	(0.07)	(0.05)	[3.84]	[2.49]	[4.16]		
United Kingdom	0.11	0.93	0.09	0.55	**47.73**	50.12	41.84	***	266
	(0.11)	(0.55)	(0.10)	(0.06)	[5.91]	[6.57]	[5.91]		

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

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

with the same notation as in the previous tables, and where $Dollar_{t+1}^{global}$ corresponds to the change in exchange rates in a high dollar-beta portfolio minus the change in exchange rates in a low dollar-beta portfolio. See Section 3 for details on the construction of these portfolios. Note that, unlike in the previous tables, the currency on the left-hand side of these regressions is not excluded from the portfolios on the right-hand side: the dollar beta portfolios are built using all currencies in the sample; for consistency, the carry factors are also built using all currencies. The table reports the constant α, the slope coefficients γ, δ, and τ, as well as the adjusted 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. $R^2_{Global\$}$ denotes the adjusted R^2 of a similar regression with only the $Dollar^{global}$ factor (i.e., without the conditional and unconditional $Carry$ factors). $R^2_{\$}$ denotes the adjusted R^2 of a similar regression using the same $Carry$ factors, along with the $Dollar$ factor. 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 asterisks (***) correspond to a rejection of the null hypothesis at the 1% confidence level; two asterisks and one asterisk 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 7: Other Base Currencies and Cross Exchange Rates

Country	α	γ	δ	τ	R^2	α	γ	δ	τ	R^2	N
	Yen-based Exchange Rates					Pound-based Exchange Rates					
Australia	-0.11	2.57	-0.28	0.02	**30.96**	-0.18	2.23	0.19	-0.24	**13.38**	266
	(0.23)	(0.72)	(0.30)	(0.13)	[6.91]	(0.19)	(0.60)	(0.10)	(0.10)	[6.25]	
Canada	-0.15	-0.11	0.69	-0.23	**19.60**	-0.21	1.18	0.16	-0.39	**16.34**	266
	(0.21)	(0.65)	(0.19)	(0.12)	[5.27]	(0.16)	(0.59)	(0.12)	(0.08)	[5.29]	
Denmark	0.06	-0.25	0.55	0.47	**31.67**	0.03	-0.82	-0.27	0.35	**20.89**	266
	(0.17)	(0.36)	(0.16)	(0.07)	[7.44]	(0.12)	(0.42)	(0.10)	(0.06)	[5.21]	
Euro Area	0.23	-1.31	0.82	0.58	**45.54**	0.02	-1.48	-0.37	0.41	**25.60**	143
	(0.20)	(0.67)	(0.16)	(0.08)	[9.47]	(0.16)	(1.23)	(0.21)	(0.10)	[7.96]	
France	-0.13	1.37	-0.11	0.22	**21.08**	0.03	-0.62	-0.29	0.27	**15.39**	122
	(0.26)	(0.49)	(0.24)	(0.08)	[8.17]	(0.19)	(0.37)	(0.12)	(0.06)	[5.83]	
Germany	-0.07	0.34	0.29	0.31	**18.14**	0.04	-0.45	-0.32	0.26	**14.72**	122
	(0.27)	(0.32)	(0.15)	(0.08)	[8.64]	(0.20)	(0.54)	(0.17)	(0.07)	[6.17]	
Italy	0.15	1.04	0.03	0.19	**24.57**	0.21	0.97	-0.04	0.06	**15.25**	122
	(0.32)	(0.39)	(0.32)	(0.12)	[9.49]	(0.19)	(0.17)	(0.07)	(0.06)	[8.67]	
United States	-0.05	-0.27	0.51	-0.43	**24.40**	-0.05	-1.37	-1.26	-0.10	**25.35**	266
/Japan	(0.17)	(0.50)	(0.12)	(0.09)	[5.87]	(0.19)	(0.54)	(0.25)	(0.08)	[6.58]	
New Zealand	-0.07	1.40	-0.09	0.15	**20.70**	-0.13	1.65	-0.16	-0.07	**5.77**	266
	(0.22)	(0.64)	(0.34)	(0.12)	[6.86]	(0.17)	(0.57)	(0.12)	(0.11)	[4.61]	
Norway	-0.00	0.47	0.41	0.37	**29.23**	-0.02	-0.21	-0.05	0.24	**7.91**	266
	(0.19)	(0.39)	(0.18)	(0.08)	[7.42]	(0.13)	(0.33)	(0.07)	(0.05)	[3.64]	
Sweden	0.08	0.79	0.34	0.43	**33.35**	0.05	-0.08	-0.01	0.29	**10.01**	266
	(0.19)	(0.39)	(0.17)	(0.08)	[6.74]	(0.14)	(0.45)	(0.08)	(0.06)	[4.24]	
Switzerland	0.00	0.39	0.23	0.45	**23.67**	-0.03	-1.07	-0.70	0.36	**23.15**	266
	(0.17)	(0.65)	(0.12)	(0.07)	[6.03]	(0.14)	(0.53)	(0.20)	(0.08)	[4.44]	
United Kingdom	0.05	-1.37	1.26	0.10	**25.35**	-0.11	0.93	-0.09	-0.55	**47.73**	266
/ United States	(0.19)	(0.54)	(0.25)	(0.08)	[6.53]	(0.11)	(0.55)	(0.10)	(0.06)	[6.07]	

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

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

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per Japanese Yen (left panel) or per U.K. pound (right panel), and $i_t^\star - i_t$ is the interest rate difference between the foreign country and Japan (left panel) or the U.K.(right panel), $Carry_{t+1}$ 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 $Dollar_{t+1}^{global}$ corresponds to the change in exchange rates in a high dollar-beta portfolio minus the change in exchange rates in a low dollar-beta portfolio. See the caption of Table 6 for the definition of the variables and the list of parameters reported. Note that, as in Table 6 but unlike in the previous tables, the currency on the left-hand side of these regressions is not excluded from the portfolios on the right-hand side. In the left panel (where exchange rates are defined in units of foreign currency per Yen), regression results for Japan are replaced by those for the United States (U.S. dollars per Yen). Likewise, in the right panel (where exchange rates are defined in units of foreign currency per U.K. pound), regression results for the U.K. are replaced by those for the United States (U.S. dollars per U.K. pound). Data are monthly, from Barclays and Reuters (Datastream). All variables are in percentage points. The sample period is 11/1983–12/2010.

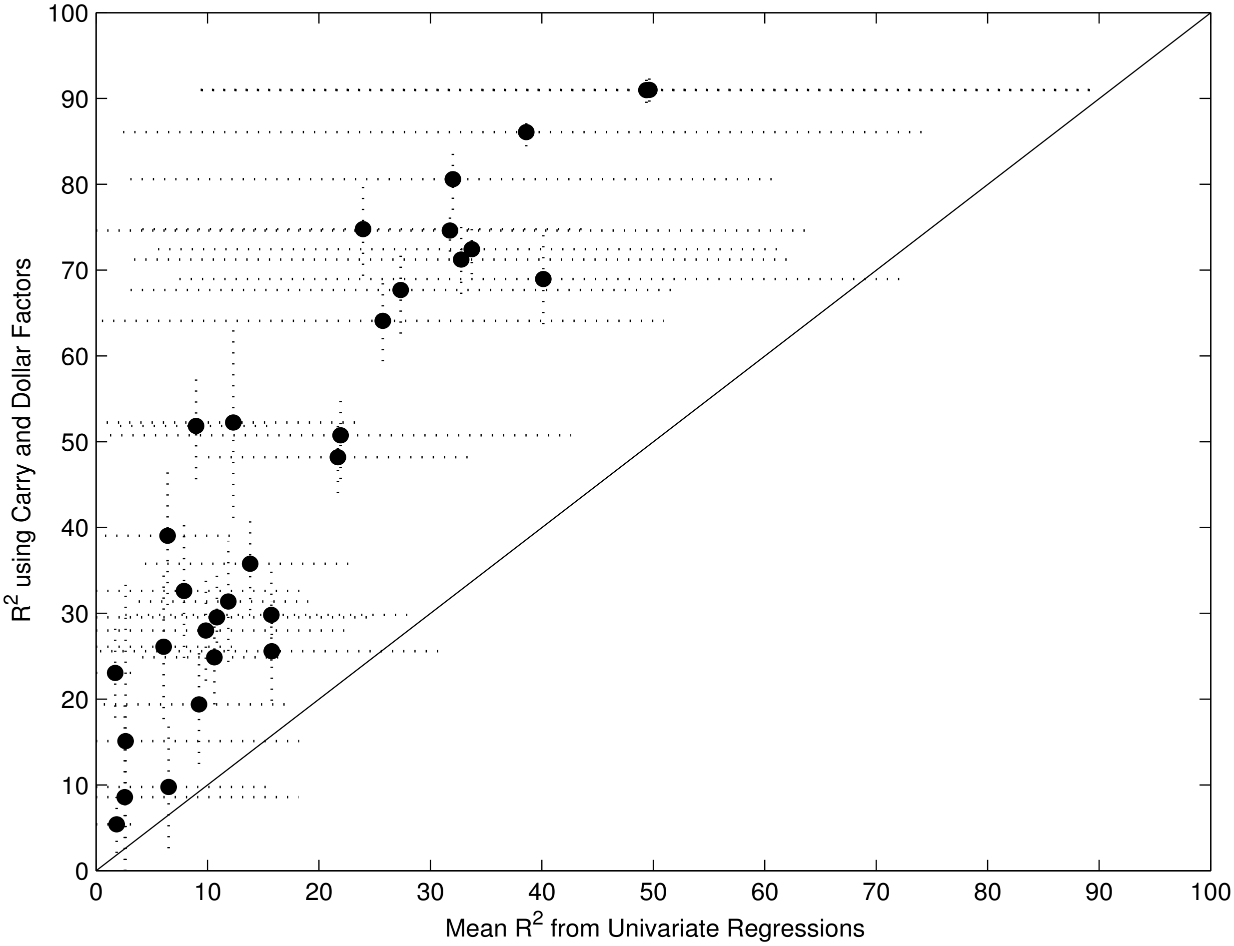

Figure 1: Measuring Systematic Risk with Factors vs. Individual Exchange Rates

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.

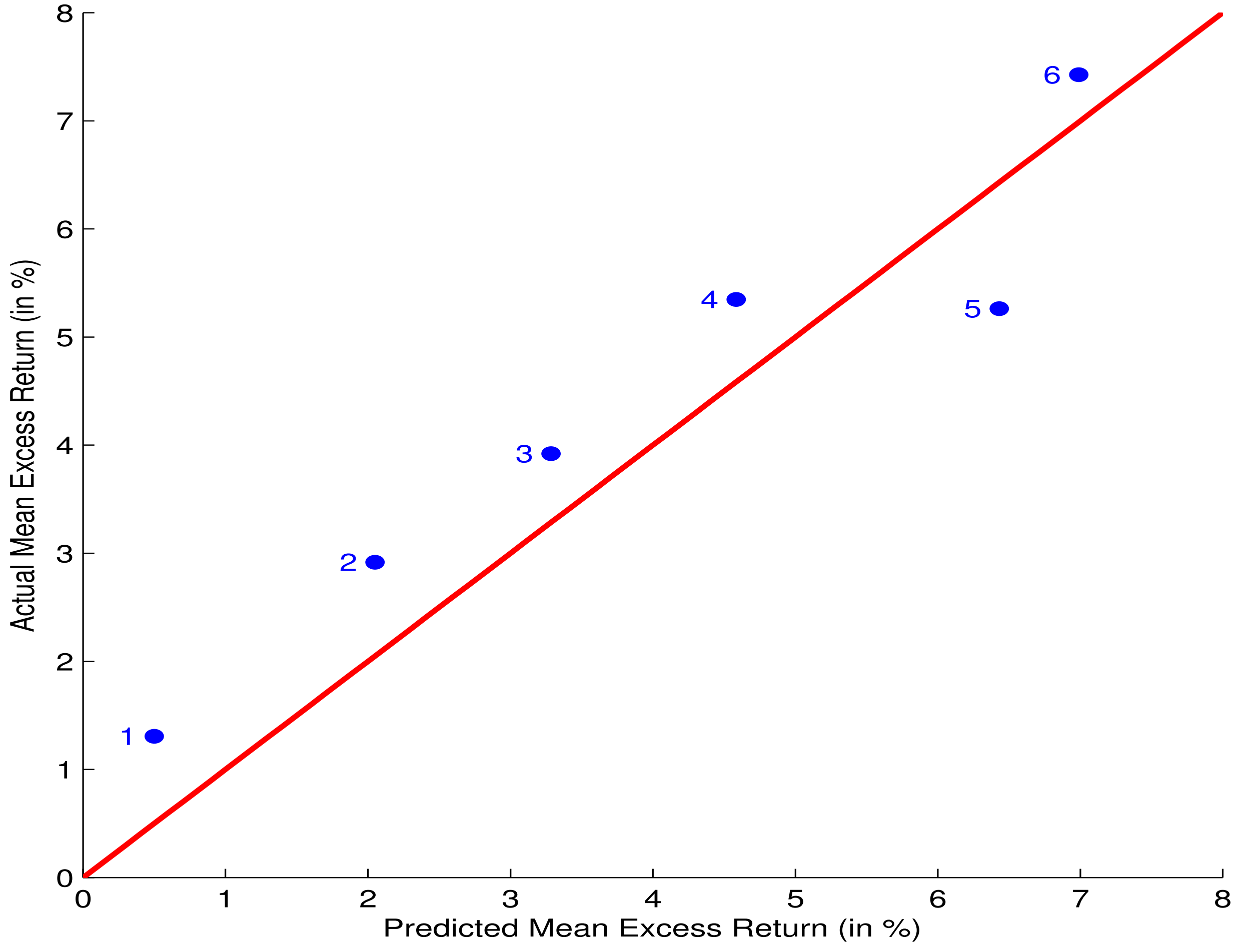

Figure 2: Realized vs. Predicted Excess Returns: Portfolios of Countries Sorted on Dollar Exposures

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.

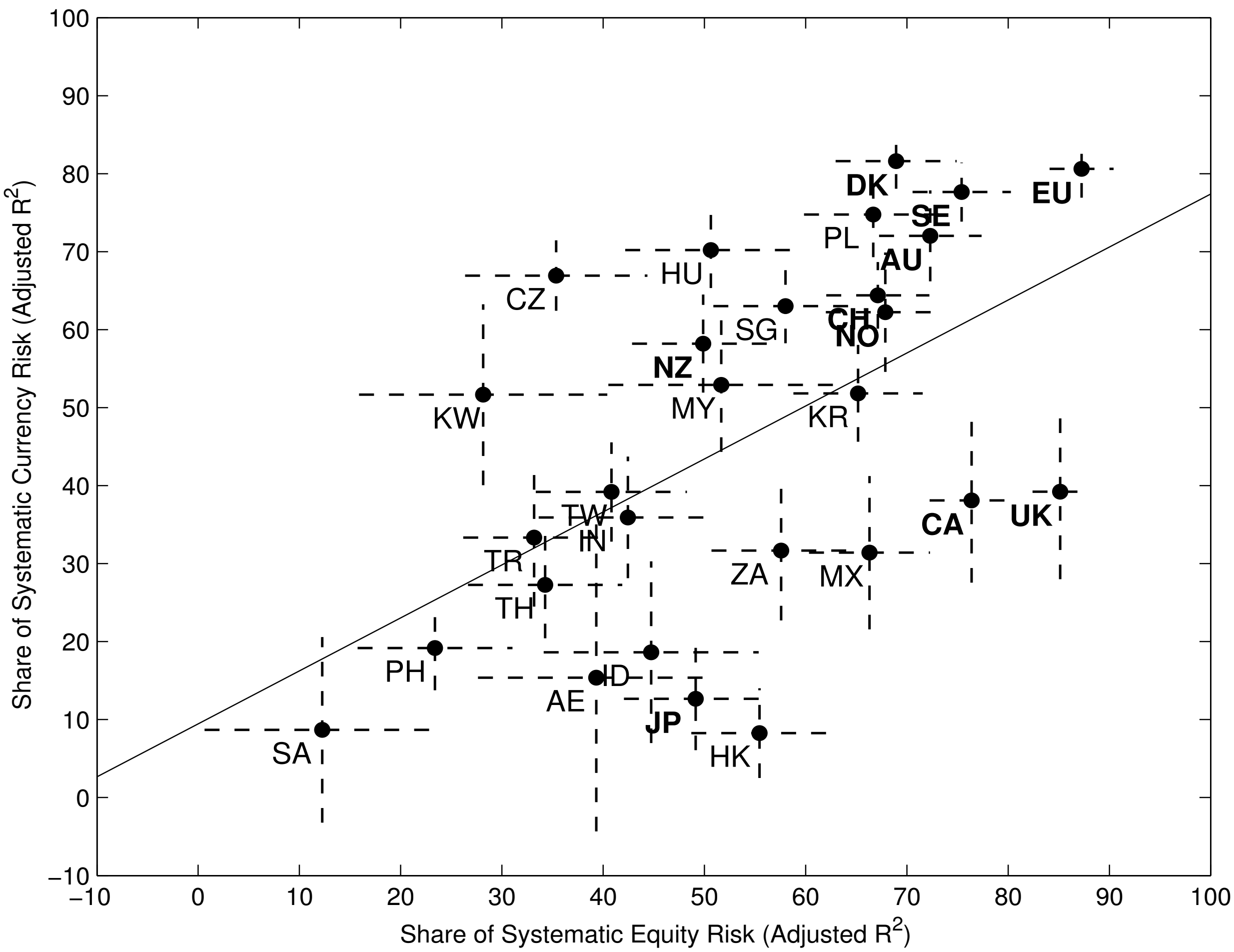

Figure 3: Systematic Equity and Currency Risk

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 in U.S. dollars, $r_{t+1}^{m,world}$ corresponds to returns on the MSCI world equity index in U.S. dollars, 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 in U.S. dollars (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).

Data Appendix

The main data set contains at most 39 different currencies of the following countries: Australia, Austria, Belgium, Canada, China (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, Turkey, United Arab Emirates, United Kingdom, as well as the euro area. The euro series start in January 1999. Euro area countries are excluded after this date; only the euro series remains. All the countries are included in the carry and dollar factors. Tables 1, 2, 6, and 7 report regressions results for 13 developed countries, while Table 3 reports regressions results for 18 developing countries. To save space in the tables, 8 country-level results are not reported. Austria, Finland, Greece, Ireland, Portugal, and Spain are omitted because there are few forward rate observations for these countries (less than 30 months of data for these countries). Belgium and the Netherlands are also omitted because the tables already contain many European countries (results on these countries are similar to those of France and Germany).

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.

Two important points need to be highlighted. First, note that for each currency inserted 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. Excluding one currency does not mean that all relevant information is dropped. 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. The average forward discount is obtained using all developed countries in the sample: Australia, Austria, Belgium, Canada, Denmark, Euro Area, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom.

The factors, as all the bilateral exchange rates, are posted online on my website. The carry factor has an annualized standard deviation of 9.1% and a first-order autocorrelation of 0.14, while the dollar factor has a standard deviation of 7.0% and a first-order autocorrelation of 0.08. The correlation between the dollar and carry factors is equal to 0.09.

The Share of Systematic Risk
in Bilateral Exchange Rates
- Supplementary Online Appendix -
NOT FOR PUBLICATION

This appendix presents robustness checks and extensions of the empirical results reported in the paper (Appendix A), as well as proofs and simulation results for the reduced-form model (Appendix B) and on the long run risk model (Appendix C).

Appendix A Robustness Checks and Extensions

This section reports several robustness checks to the main result obtained with other factors (like momentum, Appendix A.1), at daily, quarterly, and annual frequencies (Appendix A.2), over the pre-crisis sample (Appendix A.3), and the dynamics of bid-ask spreads (Appendix A.4). I redo similar tests using different base currencies (Appendix A.5) and study the stability of the factor structure (Appendix A.6) and time-varying estimates (Appendix A.7). Finally, I check that the carry and dollar factors are priced in country-level excess returns (Appendix A.8).

Appendix A.1 Other Factors

Momentum appears as a pervasive phenomenon in equity markets and seems also present in currency markets (see Asness, Moskowitz, and Pedersen, 2012). 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 is significant only for the U.K, but never in the other 12 developed 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 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.

Appendix A.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 8 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 17% to almost 90% even when looking at daily changes in exchange rates. The average adjusted R^2 is 54% 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 all 13 countries. The dollar loadings are quite similar to the monthly estimates too. They range from 0.4 (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 8 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.

Appendix A.3 Pre-Crisis Sample

Results obtained on a sample that ends in December 2007 are very similar to those reported in the paper. Regressions of bilateral exchange rates on the carry and dollar factors on a pre-crisis sample lead to similar results as on the full sample. Out of the 13 currencies reported in Table 2, only two countries exhibit a significantly lower R^2 over the pre-crisis sample (Australia and Canada). For all the other countries, the R^2s obtained on the two samples are less than one standard deviation away from each other. Figure 4 presents the time-series of the carry and dollar factors; there is no clear difference between the pre- and post-crisis samples.

[Figure 4 about here.]

Appendix A.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.

Appendix A.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. Regression 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 reduced-form model presented in the main text 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.

To provide some preliminary intuition on this novel global risk factor, Figure 5 presents the 12-month cumulative returns on a simple investment strategy: long the high dollar beta portfolio and short the low dollar beta portfolio. This simple long-short strategy focuses on global risk, not U.S.-specific risk. Figure 5 compares the currency returns with the troughs of the business cycles in the G7 countries, as determined by the OECD. All low returns tend to happen close to those troughs. With the exception of the 2003 trough in three European countries, all recorded troughs coincide with low realized excess returns. The lowest return in the sample happens during the recent global recession.

[Figure 5 about here.]

Appendix A.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 known 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 0.4 to 0.9 for developed countries.

A quick comparison with the predictive power of macroeconomic variables puts the results above 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. 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 only beat the carry and dollar factors for currency pegs; in all the other cases, RMSEs are lower with the carry and dollar factors than with the principal components.

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.

Appendix A.7 Time-Varying R^2s

Figure 6 plots time-varying adjusted R^2s on currency markets as a function of time-varying adjusted R^2s on equity markets for six countries: Australia, Canada, Japan, New Zealand, Switzerland, and the United Kingdom.

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).

In the first four countries, high R^2s on equity markets are associated with high R^2s on currency markets, but not in Switzerland or the United Kingdom.

[Figure 6 about here.]

Appendix A.8 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. (2011), except that the average currency market excess return RX used in Lustig et al. (2011) 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 $(\overline{i^i_t - i_t})RX$ 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).

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.]

Table 8: Carry and Dollar Factors: Daily Tests in Developed Countries

Country	α	β	γ	δ	τ	R^2	$R^2_{\$}$	$R^2_{no\ \$}$	W	N
Australia	-0.00	0.01	0.38	0.22	0.80	**24.28**	20.24	7.91	***	6776
	(0.01)	(0.03)	(0.12)	(0.03)	(0.03)	(1.62)	[1.36]	[1.42]		
Canada	-0.01	0.05	-0.45	0.20	0.38	**17.23**	12.80	6.75	***	6776
	(0.01)	(0.03)	(0.10)	(0.02)	(0.02)	(1.43)	[1.08]	[1.06]		
Denmark	-0.00	-0.01	0.50	-0.17	1.52	**79.76**	77.40	8.13	***	6776
	(0.00)	(0.01)	(0.04)	(0.01)	(0.02)	(0.64)	[0.73]	[0.85]		
Euro Area	0.00	-0.04	0.25	-0.25	1.56	**63.78**	59.85	1.53	***	3110
	(0.01)	(0.04)	(0.11)	(0.02)	(0.03)	(1.43)	[1.59]	[0.60]		
France	-0.01	0.01	0.65	-0.07	1.41	**82.05**	79.96	11.11	***	3937
	(0.00)	(0.02)	(0.08)	(0.02)	(0.02)	(1.07)	[1.21]	[1.88]		
Germany	-0.01	0.00	0.66	-0.01	1.48	**86.10**	84.08	17.39	***	3937
	(0.00)	(0.02)	(0.06)	(0.02)	(0.02)	(0.70)	[0.72]	[1.66]		
Italy	0.00	-0.00	0.48	-0.10	1.26	**67.11**	65.26	6.47	***	3865
	(0.01)	(0.04)	(0.15)	(0.04)	(0.02)	(2.23)	[2.21]	[1.78]		
Japan	-0.02	-0.05	-0.23	-0.37	0.82	**22.88**	18.30	2.73	***	7048
	(0.01)	(0.04)	(0.12)	(0.04)	(0.04)	(1.41)	[1.54]	[0.56]		
New Zealand	-0.01	-0.00	0.25	0.15	0.85	**22.17**	19.68	5.12	***	6776
	(0.01)	(0.03)	(0.08)	(0.04)	(0.03)	(1.43)	[1.24]	[0.89]		
Norway	-0.00	0.02	0.39	-0.03	1.47	**66.30**	65.51	5.41	***	6776
	(0.01)	(0.02)	(0.05)	(0.02)	(0.02)	(1.57)	[1.58]	[0.89]		
Sweden	-0.00	0.01	0.41	0.02	1.32	**56.30**	55.10	5.55	***	6776
	(0.01)	(0.02)	(0.05)	(0.02)	(0.02)	(1.37)	[1.30]	[0.87]		
Switzerland	-0.01	-0.01	0.57	-0.15	1.56	**67.91**	64.53	10.27	***	7048
	(0.01)	(0.02)	(0.08)	(0.03)	(0.02)	(0.91)	[1.01]	[0.95]		
United Kingdom	-0.00	0.03	0.45	-0.04	1.15	**51.90**	51.43	3.48	***	7048
	(0.01)	(0.03)	(0.09)	(0.03)	(0.02)	(1.30)	[1.29]	[0.77]		

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 adjusted 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. $R^2_{no\ \$}$ denotes the adjusted R^2 of a similar regression without 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 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	10.09	11.48	0.88	12.29	1.07
Canada	7.04	6.72	7.39	0.91	7.76	1.05
Denmark	11.06	4.47	10.76	0.42	10.86	1.01
Euro Area	10.73	4.66	11.05	0.42	11.32	1.02
France	11.20	3.81	10.66	0.36	10.74	1.01
Germany	11.72	3.98	10.90	0.36	10.89	1.00
Italy	11.30	7.58	11.14	0.68	10.87	0.98
Japan	11.50	10.28	11.30	0.91	11.74	1.04
New Zealand	12.18	9.41	11.26	0.84	11.98	1.06
Norway	10.99	6.14	10.88	0.56	11.04	1.02
Sweden	11.47	6.59	11.82	0.56	11.45	0.97
Switzerland	11.91	6.49	11.31	0.57	11.47	1.01
United Kingdom	10.52	7.48	9.89	0.76	10.01	1.01
			Panel B: Developing Countries			
Hong Kong	0.54	0.48	0.47	1.03	0.47	1.00
Czech Republic	13.13	8.20	13.17	0.62	13.49	1.02
Hungary	13.73	8.70	14.91	0.58	14.54	0.98
India	5.91	5.36	6.10	0.88	6.04	0.99
Indonesia	30.79	28.88	18.38	1.57	17.41	0.95
Kuwait	2.69	2.23	2.88	0.77	3.13	1.09
Malaysia	10.57	7.77	11.30	0.69	11.35	1.00
Mexico	9.36	7.90	9.02	0.88	9.50	1.05
Philippines	9.68	6.83	7.13	0.96	7.39	1.04
Poland	13.82	8.34	16.58	0.50	14.39	0.87
Saudi Arabia	0.35	1.35	0.39	3.49	0.68	1.77
Singapore	5.30	3.86	5.32	0.73	5.31	1.00
South Korea	15.47	12.19	13.97	0.87	13.97	1.00
South Africa	17.56	10.55	14.11	0.75	12.32	0.87
Taiwan	5.88	4.22	4.73	0.89	4.89	1.03
Thailand	12.85	8.69	7.00	1.24	7.21	1.03
Turkey	18.01	22.83	19.22	1.19	20.18	1.05
United Arab Emirates	0.18	1.53	0.27	5.62	0.84	3.06

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 carry and dollar 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							
4.02	3.99	4.59	7.83	28.89	3.15	2.13	
[2.35]	[2.76]	[2.86]	[5.65]				40.67
Panel B: Raw and Managed Currency Excess Returns							
4.93	5.88	5.55	11.64	50.32	3.47	1.83	
[2.43]	[1.41]	[2.98]	[2.91]				45.43
Panel C: Dynamic Betas using Forward Discounts							
6.37	6.43	7.27	12.63	41.05	2.62	1.77	
[2.27]	[1.35]	[2.78]	[2.75]				70.19
Panel D: Risk Factors' Expected Excess Returns							
4.82	5.51						
[1.95]	[1.36]						

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. $Cond.RX = \overline{(i_t^i - i_t)}RX$):

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

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

$$Rx^i_t = \lambda_{HML,t}\beta^i_{HML} + \lambda_{RX,t}\beta^i_{RX} + \xi_t, \text{for a given } t, \forall i.$$

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 $\beta^i_{HML,t} = h^i_0 + h^i_1\widetilde{(i^i_t - i_t)}$, where $\widetilde{(i^i_t - i_t)}$ is the country-specific forward discount, standardized as described above, and $\beta^i_{RX,t} = d^i_0 + d^i_1\overline{i^i_t - i_t}$, where $\overline{(i^i_t - i_t)}$ is the sign of the average forward discount. The parameters h^i_0, h^i_1, d^i_0, and d^i_1 can be estimated from the linear regression:

$$Rx^i_{t+1} = c^i + h^i_0 HML_{FX,t+1} + h^i_1\widetilde{(i^i_t - i_t)}HML_{FX,t+1} + d^i_0 RX_{t+1} + d^i_1\overline{(i^i_t - i_t)}RX_{t+1} + \epsilon_{i,t+1}, \text{for a given } i.$$

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:

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

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 ($m_{t+1} = 1 - bf_{t+1}$, where m denotes the SDF and f the risk factors). 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.

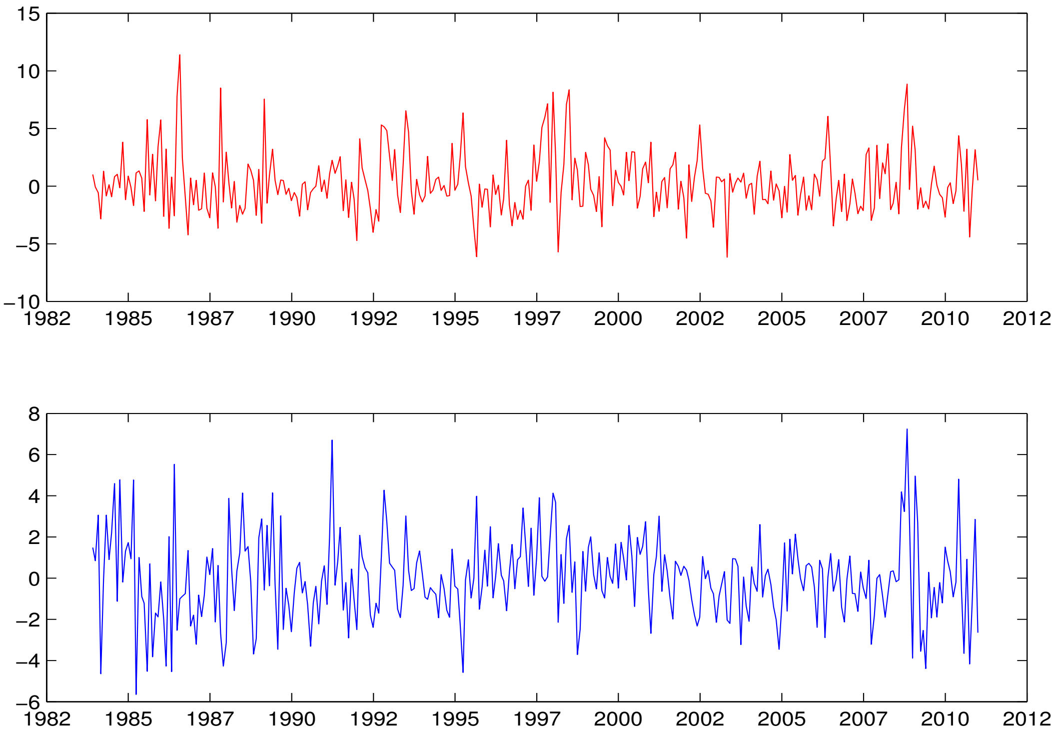

Figure 4: Carry and Dollar Factors at the Monthly Frequency

The figure presents the time-series of the carry and dollar factors. Data are monthly. The sample period is 11/1983–12/2010.

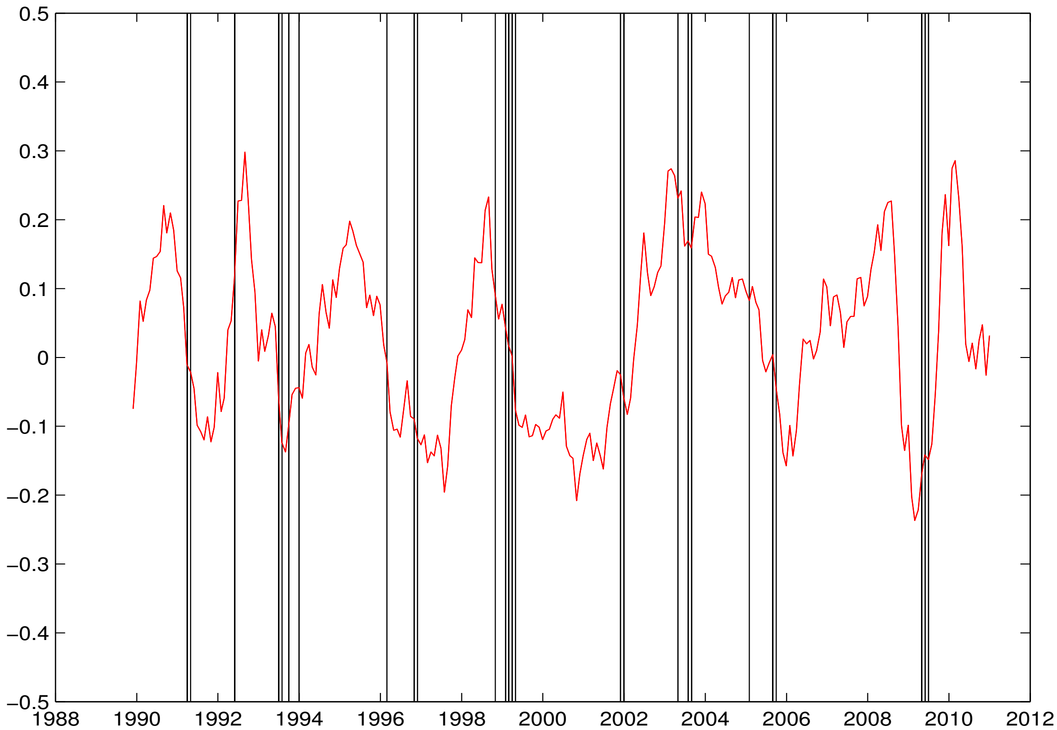

Figure 5: Twelve-month Returns on Dollar-beta Portfolios and G7 Troughs

The figure presents the cumulative 12-month returns obtained by going long the high dollar beta portfolio and short the low dollar beta portfolio. The long-short strategy focuses on the global component of the dollar risk factor. The figure also presents the trough dates of the G7 countries' business cycles established by the OECD. Data are monthly. The sample period is 11/1983–12/2010.

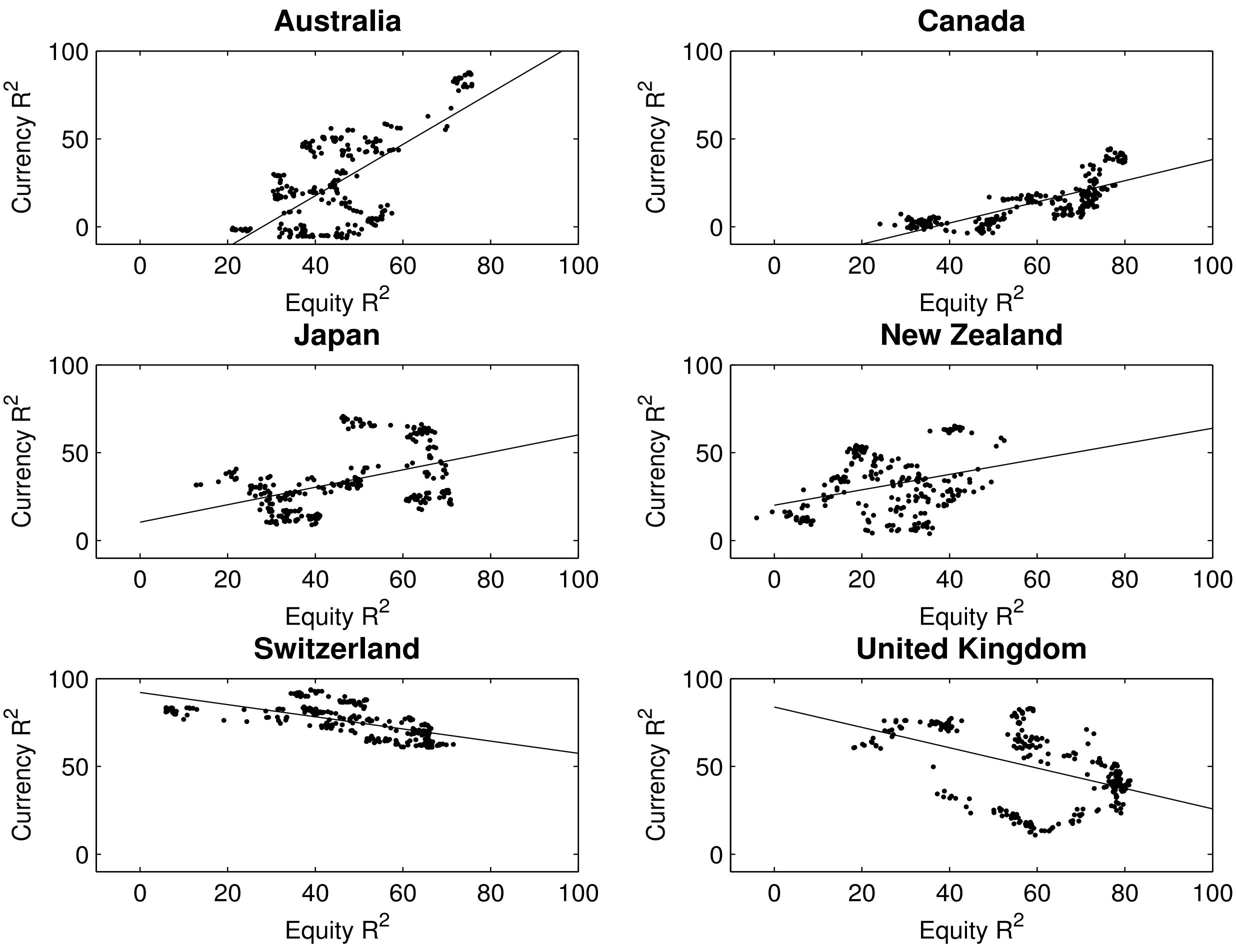

Figure 6: Time-Varying Shares of Systematic Equity and Currency Risk

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.

Appendix B Reduced-Form Model

Let us 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. The risk prices of country-specific shocks depend only on the country-specific factors, but the risk prices of world shocks depend either on world or country-specific factors. Building on Cox et al. (1985) and Backus et al. (2001), the logarithm of the real SDF m^i follows a two-factor conditionally-Gaussian process:

$$-m^i_{t+1} = \alpha + \chi z^i_t + \sqrt{\gamma z^i_t} u^i_{t+1} + \chi z^w_t + \sqrt{\delta^i z^w_t} u^w_{t+1} + \sqrt{\kappa z^i_t} u^g_{t+1}.$$

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.[14] If SDFs were homoscedastic, expected excess returns would be constant and the UIP condition would be valid. Lustig et al. (2011) show that the cross-sectional variation in the loadings (denoted δ^i) on world shocks (denoted u^w) is key to understanding the carry trade. To be parsimonious, the heterogeneity in the SDF parameters is thus limited to the δ^is; all the other parameters are identical for all countries.

Two minor comments are in order. First, all variables in the model so far are real: a law of motion for inflation can easily be added, or the SDF can be reinterpreted as nominal variables. In the Lustig et al. (2013) paper, inflation in each country is defined as $\pi^i_{t+1} = \pi_0 + \eta^w z^w_t + \sigma_\pi \epsilon^i_{t+1}$. 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 keep the exact same notation and model as in Lustig et al. (2013) and use it to interpret the empirical results of Sections 2 and 3.

In this model, there is a common global factor z^w_t and a country-specific factor z^i_t. The currency-specific innovations u^i_{t+1} (uncorrelated across countries) and global innovations u^w_{t+1} and u^g_{t+1} are *i.i.d* gaussian, with zero mean and unit variance; u^w_{t+1} and u^g_{t+1} are world shocks, common across countries, while u^i_{t+1} is country-specific. The first world shock, u^w_{t+1}, is priced globally, while the second world shock, u^g_{t+1}, is priced locally. The country-specific and world volatility components that drive risk prices

[14] If SDFs are not lognormal, expected currency excess returns depend on the higher cumulants, some of which must be time-varying.

are governed by autoregressive square root processes:

$$
\begin{aligned}
z_{t+1}^{i} &= (1-\phi)\theta + \phi z_t^i - \sigma\sqrt{z_t^i} u_{t+1}^i, \\
z_{t+1}^{w} &= (1-\phi^w)\theta^w + \phi^w z_t^w - \sigma^w\sqrt{z_t^w} u_{t+1}^w.
\end{aligned}
$$

Interest Rate Difference The same variables used in the exchange rate 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:

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

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, Verdelhan (2010) shows that the precautionary savings effect must dominate the intertemporal substitution effect 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.

The average forward discount corresponds to the average interest rate difference between the rest of the world and the U.S. In the following, a bar superscript ($\overline{x}$) denotes the average of any variable or parameter x across all countries. If there are enough countries in a portfolio, country-specific shocks average out. In this case, $\overline{z_t^i}$ is constant in the limit (when the number of countries N is infinitely large, i.e., $N \rightarrow \infty$) by the law of large numbers. The average forward discount is thus:

$$
\overline{r_t^i} - r_t = \left(\chi - \frac{1}{2}(\gamma+\kappa)\right)(\theta - z_t) - \frac{1}{2}\left(\overline{\delta^i} - \delta\right) z_t^w.
$$

Empirically, the time-series mean of the average forward discount among developed countries is close to zero. It implies that the U.S. exposure to world shocks is close to the average exposure of developed countries. For expositional purposes, I thus consider the special case of $\overline{\delta^i} = \delta$ and:

$$
\overline{r_t^i} - r_t = \left(\chi - \frac{1}{2}(\gamma+\kappa)\right)(\theta - z_t).
$$

Dollar and Carry Factors In this special case, the dollar factor is simply:

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

The carry factor corresponds to the average change in exchange rates between high and low interest rate countries:

$$
Carry_{t+1} = \chi\left(\overline{z_t^i}^H - \overline{z_t^i}^L\right) + \left(\overline{\sqrt{\delta^i}}^H - \overline{\sqrt{\delta^i}}^L\right)\sqrt{z_t^w} u_{t+1}^w + \sqrt{\kappa}(\overline{\sqrt{z_t^i}}^H - \overline{\sqrt{z_t^i}}^L) u_{t+1}^g,
$$

where $\overline{x^i}^H = \frac{1}{N_H}\sum_{i\in H} x^i$, $\overline{x^i}^L = \frac{1}{N_L}\sum_{i\in L} x^i$, and where N_H and N_L denote the number of currencies in the high (H) and low (L) interest rate portfolios. The countries that end up in the first or last portfolios are not randomly chosen. As the closed form expression for interest rate differences shows, these countries belong to those portfolios partially because of the values of their market prices of risk z^i and their exposure δ^i to world shocks.

Empirically, the correlation between the dollar and carry factors is low. Since the dollar captures U.S. specific shocks and world shocks that are priced locally, the carry factor must be mostly driven by world shocks that are priced globally (u^w_{t+1}). It implies that most interest rate variations are driven by the common state variable z^w: $\overline{\sqrt{z^i_t}}^H \simeq \overline{\sqrt{z^i_t}}^L$. For expositional purpose, let us consider the special case of $\overline{\sqrt{z^i_t}}^H = \overline{\sqrt{z^i_t}}^L$.[15] In this case, the Carry factor is simply:

$$Carry_{t+1} = \chi\left(\overline{z^i_t}^H - \overline{z^i_t}^L\right) + \left(\overline{\sqrt{\delta^i}}^H - \overline{\sqrt{\delta^i}}^L\right)\sqrt{z^w_t}u^w_{t+1}.$$

This result is intuitive: carry trade excess returns are similar for all foreign investors; they must be compensation for global shocks that affect all foreign investors similarly, and thus carry a global price of risk.

Finally, the change in bilateral exchange rates is:

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

Results The intuition for the cross-section of currency excess returns sorted by interest rates or dollar-betas is presented in the main text. Table 11 reports regression results on simulated data from this reduced form model, using the parameter values in Lustig et al. (2013). The results are commented in the main text.

[Table 11 about here.]

[15] In this case, there is no role for the conditional carry factor. The carry factor captures world shocks u^w perfectly. A role for the conditional carry factor arises if the price of world shocks u^w depends on both local and global volatilities, as in the Lustig et al. (2011) model, or if the carry factor also depends on global shocks that are priced locally, i.e. when $\overline{\sqrt{z^i_t}}^H \neq \overline{\sqrt{z^i_t}}^L$. In this general case, the exposure to world shocks now depends on the local price of risk, and thus can be proxied by the interest rate difference $r^i_t - r_t$: both the carry and the conditional carry factors now appear in the regressions.

Appendix C Long-Run Risk Model

I start from the symmetric, two-country, long-run risk model of Bansal and Shaliastovich (2012) and extend it to N different countries.[16]

Appendix C.1 Model

Preferences and Endowments The long-run risk literature works off the class of preferences due to Kreps and Porteus (1978) and Epstein and Zin (1989). Let $U_t(C_t)$ denote the utility derived from consuming C_t. The value function of the representative agent takes the following recursive form:

$$U_t(C_t) = \left[(1-\delta)C_t^{\frac{1-\gamma}{\theta}} + \delta\left(E_t U_{t+1}^{1-\gamma}\right)^{\frac{1}{\theta}}\right]^{\frac{\theta}{1-\gamma}}.$$

The time discount factor is δ, the risk aversion parameter is $\gamma \geq 0$, and the inter-temporal elasticity of substitution (IES) is $\psi \geq 0$. The parameter θ is defined by $\theta \equiv (1-\gamma)/(1-\frac{1}{\psi})$. When $\psi > 1$ and $\gamma > 1$, then $\theta < 0$ and agents prefer an early resolution of uncertainty.

Following Bansal and Yaron (2004), real consumption growth in country i, Δc^i_{t+1}, exhibits a persistent long-run expected growth component x_t and is subject to temporary shocks η_{t+1} and ϵ^i_{t+1}. A superscript ^{i} indicates a country i-specific variable. Consumption growth in each country evolves as:

$$\begin{aligned}
\Delta c^i_{t+1} &= \mu_g + x_t + \sigma^i_{g,t}\eta_{t+1} + \sigma^i\epsilon^i_{t+1}, \\
x_{t+1} &= \rho x_t + \sigma_{x,t}e_{t+1},
\end{aligned}$$

where the conditional variance of the short-run consumption growth is $\sigma^{i,2}_{g,t}$, while the conditional variance of the long-run component x_t is denoted $\sigma^2_{x,t}$. Shocks to the variances (respectively $w^i_{g,t+1}$ and $w_{x,t+1}$) are drawn from Gamma distributions so that variances remain positive throughout the simulation, while the other shocks are Gaussian. All shocks are orthogonal.[17]

Let me describe the consumption dynamics in detail. As in Bansal and Shaliastovich (2012), the long

[16] In the class of rational expectation frameworks, three general equilibrium models, through volatile stochastic discount factors, can replicate the UIP puzzle and are thus potential starting points. Verdelhan (2010), in a Campbell and Cochrane (1999) habit model, offers the first rational expectation model of the UIP puzzle. Bansal and Shaliastovich (2012), Colacito (2008), and Colacito and Croce (2012) 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 (2012). These models start from endowment economies. See Gourio, Siemer and Verdelhan (2013) for an international real business cycle version of the disaster risk model. I start from Bansal and Shaliastovich (2012) because its dual volatility process offers the closest counterpart to the reduced-form model.

[17] The dividend process is similar to the consumption process, although leverage implies that dividend growth rates load more on the long-run risk and short-run consumption shocks than consumption growth itself. The inflation process is similar to that in Wachter (2006) and Piazzesi and Schneider (2006): its expected and unexpected parts also load on the long-run risk component. The Appendix details all laws of motions and parameter values, and derives the equilibrium wealth-consumption ratio, stochastic discount factor, as well as equity, bond, and currency returns.

run risk process x_t is common across countries. Colacito and Croce (2011) show that the long-run risk components must be highly correlated across countries in order to deliver exchange rates that are as smooth as in the data. Bansal and Shaliastovich (2012) thus assume that the foreign economy shares the same long-run risk component x_t as the domestic economy: as a result, the foreign economy is hit by the same long-run risk (e_{t+1}) and long-run risk volatility ($w_{x,t+1}$) shocks, while the other shocks are uncorrelated to their domestic counterparts. This assumption is in line with empirical evidence: Nakamura et al. (2012) find a common long-run risk component across countries in the Barro and Ursua (2008) dataset.

I depart from Bansal and Shaliastovich (2012) by assuming that the temporary shocks η_{t+1} are also common across countries: note, however, that their market prices of risk (notably their volatilities $\sigma^i_{g,t}$) are country-specific. In the data, consumption growth processes exhibit a low correlation across countries. To take into account this empirical fact, I introduce country-specific temporary shocks ϵ_{t+1}; those shocks are homoscedastic.

Following the insights of the reduced-form model, the general equilibrium model thus includes local shocks (ϵ^i_{t+1}), global shocks that are priced globally (e_{t+1}), and global shocks that are priced locally (η_{t+1}). The key remaining question is the source of heterogeneity across countries. To narrow it down to the key parameters, let us look at the exchange rates and carry and dollar factors in the model.

Exchange Rates, Dollar, and Carry Factors In this model, the unexpected part of the real stochastic discount factor is:

$$m_{t+1} - \mathbb{E}_t[m_{t+1}] = -\lambda_\eta \epsilon_{t+1} - \lambda_\eta \sigma_{g,t} \eta_{t+1} - \lambda_e \sigma_{x,t} e_{t+1} - \lambda_{gw} w_{g,t+1} - \lambda_{xw} w_{x,t+1},$$

where the loadings are functions of the preference parameters and endowment processes: $\lambda_\eta = \gamma$, $\lambda_e = (\gamma - \frac{1}{\psi})\frac{\kappa_1^c}{1-\kappa_1^c\rho}$, $\lambda_{gw} = -(\gamma - \frac{1}{\psi})(\gamma - 1)\frac{\kappa_1^c}{2(1-\kappa_1^c\nu_g)}$, and $\lambda_{xw} = -(\gamma - \frac{1}{\psi})(\gamma - 1)\frac{\kappa_1^c}{2(1-\kappa_1^c\nu_x)}\left(\frac{\kappa_1^c}{1-\kappa_1^c\rho}\right)^2$, and where ν_g and ν_x are the persistence coefficients of the short-run and long-run volatilities and κ_1^c is an increasing function of the average wealth-consumption ratio.

Financial markets are complete and the log change in the real exchange rate is thus:

$$\begin{aligned}\Delta q^i_{t+1} - \mathbb{E}_t[\Delta q^i_{t+1}] \quad &= \quad -\lambda_\eta \sigma \epsilon_{t+1} + \lambda^i_\eta \sigma^i \epsilon^i_{t+1} - (\lambda_{gw} w_{g,t+1} - \lambda^i_{gw} w^i_{g,t+1}) \\ &- \quad (\lambda_\eta \sigma_{g,t} - \lambda^i_\eta \sigma^i_{g,t})\eta_{t+1} - (\lambda_e - \lambda^i_e)\sigma_{x,t} e_{t+1} - (\lambda_{xw} - \lambda^i_{xw}) w_{x,t+1},\end{aligned}$$

where the second line regroups the shocks that are common across countries (η_{t+1}, e_{t+1}, and $w_{x,t+1}$).

The carry factor corresponds to the average change in exchange rates of high- versus low-interest rate currencies:

$$Carry_{t+1} - \mathbb{E}_t[Carry_{t+1}] \quad = \quad \left(\overline{\lambda^i_\eta \sigma^i_{g,t}}^H - \overline{\lambda^i_\eta \sigma^i_{g,t}}^L\right)\eta_{t+1} + \left(\overline{\lambda^i_e}^H - \overline{\lambda^i_e}^L\right)\sigma_{x,t} e_{t+1} + \left(\overline{\lambda^i_{xw}}^H - \overline{\lambda^i_{xw}}^L\right) w_{x,t+1},$$

assuming that there are enough currencies in each portfolio for the law of large numbers to apply. Averages in each corner portfolio are denoted by $\overline{\lambda^i_e}^H = \frac{1}{N_H}\sum_{i=1}^{N_H}\lambda^i_e$, and likewise $\overline{\lambda^i_e}^L = \frac{1}{N_L}\sum_{i=1}^{N_L}\lambda^i_e$, where N_H (N_L) corresponds to the number of currencies in the high- (low-) interest rate portfolio. For the carry factor to exist, high- and low-interest rate currencies must differ in their loadings on the common component of the stochastic discount factor [see Lustig et al. (2011)]. Thus, countries must differ in their market price of short-run risk $\lambda_\eta \sigma_{g,t}$, in their market price of long-run risk λ_e, and/or in their market prices of long-run volatility risk λ_{xw}.

The dollar factor corresponds to the average change in exchange rates across all currencies in the sample. The unexpected component of the dollar factor is:

$$\begin{aligned} Dollar_{t+1} - \mathbb{E}_t[Dollar_{t+1}] &= -\lambda_\eta \sigma \epsilon_{t+1} - \lambda_{gw} w_{g,t+1} \\ &- \left(\lambda_\eta \sigma_{g,t} - \overline{\lambda_\eta \sigma_{g,t}}\right) \eta_{t+1} - (\lambda_e - \overline{\lambda_e}) \sigma_{x,t} e_{t+1} - (\lambda_{xw} - \overline{\lambda_{xw}}) w_{x,t+1}. \end{aligned}$$

where $\overline{\lambda_\eta^i \sigma_{g,t}^i} = \frac{1}{N} \sum_{i=1}^N \lambda_\eta^i \sigma_{g,t}^i$, $\overline{\lambda_{gw}} = \frac{1}{N} \sum_{i=1}^N \lambda_{gw}^i$, $\overline{\lambda_{xw}} = \frac{1}{N} \sum_{i=1}^N \lambda_{xw}^i$, and $\overline{\lambda_e} = \frac{1}{N} \sum_{i=1}^N \lambda_e^i$, and assuming again that the number N of currencies is large enough for the law of large numbers to apply. The first two shocks to the dollar factor are specific to the U.S. economy and thus uncorrelated to any other economies; they cannot account for the cross-section of dollar betas because all exchange rates load similarly on those two shocks. The last three shocks to the dollar factor are global shocks. The dollar factor loads on these shocks only if the U.S. economy exhibits market prices of risk that differ from their cross-country average counterparts.[18] In other words, the representative U.S. investor must have a different risk-aversion, or a different EIS, or different endowment volatilities than the average world investor. If the U.S. representative investor is, for example, less risk-averse than the average investor worldwide ($\lambda_e < \overline{\lambda_e}$), then significant cross-country differences appear: loadings on the dollar factor increase with the risk-aversion of the foreign investor. The empirical relevance of different sources of heterogeneity across countries appears in simulation results.

Simulation Results I report two sets of simulations: countries differ either by their risk-aversion coefficient (in the left-hand side of Table 12) or by the share of their country-specific volatility (in the right-hand side of Table 12). There is no reason for countries to differ only along one dimension; the dichotomy in Table 12 is only there for clarity. All moments are annualized (multiplied by 12 for averages and $\sqrt{12}$ for standard deviations) and reported in percentages. There are 36 countries in the simulation and the first country is the domestic country (i.e., the U.S.). Table 12 presents results for the first, middle, and last country. The model starts from simple consumption dynamics and produces reasonable equity and bond risk premia; it is thus an interesting laboratory to study exchange rates.

For the first set of simulations, risk-aversion ranges from 4 to 6, while volatility parameters are held constant across countries. The volatility of consumption growth is 2.6% per year, and aggregate consumption growth rates exhibit a correlation of 0.2 across countries, as in the data. The volatility of dividend growth rates is 12.5%. Average equity excess returns increase with risk-aversion, ranging from

[18] If the U.S. representative investor prices all world risks as the average investor worldwide (i.e., $\lambda_\eta \sigma_{g,t} = \overline{\lambda_\eta \sigma_{g,t}}$, $\lambda_e = \overline{\lambda_e}$ and $\lambda_{xw} = \overline{\lambda_{xw}}$), then the dollar factor only captures U.S.-specific shocks and loadings on the dollar factor reduce to $\tau_t^i = \frac{\lambda_\eta^2 \sigma^2 + \lambda_{gw}^2 \sigma_g^2}{\mathbb{V}_t(Dollar_{t+1})}$. The numerator and denominator are the same across all currencies. As a result, there is no variation across countries in τ_t^i. This special case is clearly not a full description of the data because, empirically, the loadings on the dollar factor vary a lot across countries.

1.4% to 3.9%, while risk-free rate decrease from 2.1% to 1.9%. Inflation rates are 2.3% on average, with a 4% volatility, implying short-term nominal rates between 4.2% and 4.4% on average. The average five-year nominal interest rates range from 5.4% to 5.8%.

Exchange rates are volatile, with standard deviations ranging between 17% and 19%. When risk-aversion differences are small, long-run risk shocks play no role in exchange rate variation because of the absence of cross-country differences in their market prices of risk. In this case, most of the exchange rate variation is due to country-specific shocks ϵ. When country's risk-aversion differ (4 to 6), common long-run risk shocks explain up to 36% of the exchange rate changes. This large increase in the role of common shocks account for the increase in the share of systematic risk measured by the dollar and carry factors: R^2s range from 47% to 75% across countries. Likewise, systematic risk in equity markets range from 70% to 88%. Figure 7 shows that, as in the data, R^2s increase on both equity and currency markets across countries. The model also produces a cross-section of currency excess returns when countries are sorted by their short-term nominal interest rates (or dollar betas): average excess return increase from 1.3% (0.5%) in portfolio 1 to 2.2% (1.2%) in portfolio 6.

In the model, as in the data, interest rate differences explain almost none of the exchange rate time-series: the R^2s are zero and the slope coefficients are not significant. When risk-aversion differ across countries, the carry factors account for 0.8% to 8.4% of monthly changes in exchange rates, in line with the empirical results in Section 2. As in the data, adding the dollar factor increases the R^2s dramatically: the carry and dollar factors jointly account for 47% to 75% of exchange rate movements.

The weaknesses of the simulations are the following: the equity premium is low, the correlation between changes in exchange rates and relative consumption growth (i.e., the Backus and Smith (1993) puzzle) is too high, the changes in exchange rates are too volatile, the cross-sections of carry and dollar beta-sorted excess returns are small, the cross-sectional variation in equity R^2s measured in local currencies is small, and the carry factors explain a large share of the dollar beta-sorted portfolios.

For the second set of simulations, the volatility of common short-term consumption growth shocks increase from 0.5% to 2%, while risk-aversion is held constant across countries. At the same time, the volatility of country-specific short-term consumption growth shocks decrease from 2.4% to 1.5% in order to maintain the volatility of total consumption growth at 2.6%. The first two moments of equity returns, yields, and exchange rates are similar to the first set of simulations. But exchange rates are driven exclusively by short-term shocks; there is no role for long term shocks as market prices of risk do not vary significantly across countries. As a result, the carry factors account for only 0.2% to 0.7% of the monthly exchange rate movements. The second set of simulations shares the same weaknesses as the first set. Moreover, there is no cross-section of interest rate-sorted and dollar beta-sorted excess returns.

Intuition The model implies a large cross-section of currency and equity R^2s in both simulations. The underlying mechanism is, however, different in the two simulation sets. In the first simulations with heterogenous risk-aversions, the common variation arises through common long-run shocks which are priced differently in each country. In the second simulations, the result is simply driven by the increasing share of short-term common consumption growth shocks.

Overall, a complete model should certainly feature both sources of heterogeneity across countries. They both contribute to cross-country differences in the relative share of local and global shocks to the pricing kernels — a central theme to this paper. Differences in risk-aversion give a prominent role to common long-run risk shocks in the dynamics of exchange rates, while differences in the volatilities of common short-term consumption growth shocks magnify the role of those shocks.

The reduced-form model shows that the two sources of shocks are necessary. The clear distinction between the carry and dollar factors featured in the reduced-form model came through some simplifying assumptions that can also be implemented in the complete model: (i) the U.S. SDF has an average loading on the world shocks priced globally; (ii) the U.S. SDF loads differently on the world shocks priced locally than the average SDF. In the context of the long-run risk model simulations above, it means that the U.S. should exhibit an average risk-aversion coefficient ($\gamma = \overline{\gamma}$, and thus $\lambda_\eta = \overline{\lambda_\eta}$) , but not the average volatility of long-run consumption shocks ($\sigma_{g,t} \neq \overline{\sigma_{g,t}}$). In this case, the dollar factor loads mostly on U.S. specific shocks and on common short-term consumption growth shocks.

In such a model, the economic intuitions developed with the reduced-form model apply directly to understand carry and dollar risks. The carry factor mostly captures long-run risk shocks that are priced globally, but also short-term consumption growth shocks that are common across countries. The dollar factor mostly captures U.S. specific shocks and common short-term consumption growth shocks. Volatility shocks themselves play little role in the simulations. The average forward discount is mostly driven by the U.S.-specific price of risk, i.e. the U.S. volatility of common short-term consumption growth shocks. As a result, carry trades offer positive excess returns on average because high interest rate currencies (countries with low risk-aversion γ and thus low market prices of risk λ_e) tend to depreciate ($\Delta q^i > 0$) when negative global long-run risk shocks occur ($e_{t+1} < 0$). The average forward discount is positive when the U.S. volatility is above average. In this case, high dollar beta currencies tend to be associated with low foreign market prices of risk for common short-term shocks. High dollar beta-sorted portfolios (conditional on the average forward discount) offer positive excess returns on average because high dollar beta currencies tend to depreciate ($\Delta q^i > 0$) when negative global short-run risk shocks occur ($\eta_{t+1} < 0$).

In a nutshell, the model delivers rich exchange rate dynamics: exchange rates in U.S. dollars are driven by common long-run risk shocks, which explained currency carry trade excess returns, as well as U.S. specific short-term consumption growth shocks and common short-term shocks that affect countries differently and are at the roots of the dollar beta excess returns.

[Table 12 about here.]

[Figure 7 about here.]

Appendix C.2 Proofs

This subsection presents the equilibrium wealth-consumption ratio, stochastic discount factor, as well as bond yields and equity returns in a modified version of the long-run risk model of Bansal and Shaliastovich (2012) that is summarized here for the reader's convenience:

Consumption growth, dividend growth, and inflation are defined as follows:

$$\begin{aligned}
\Delta c^i_{t+1} &= \mu_g + x_t + \sigma^i_{g,t}\eta_{t+1} + \sigma^i \epsilon^i_{t+1} \\
x_{t+1} &= \rho x_t + \sigma_{x,t} e_{t+1} \\
\sigma^{2,i}_{g,t+1} &= \nu_g \sigma^{2,i}_{g,t} + w^i_{g,t+1} \\
\sigma^2_{x,t+1} &= \nu_x \sigma^2_{x,t} + w_{x,t+1} \\
\Delta d^i_{t+1} &= \mu_d + \phi x_t + \varphi_{dg}\sigma^i_{g,t}\eta_{d,t+1} + \varphi_d \sigma^i_d \epsilon^i_{d,t+1} \\
\pi^i_{t+1} &= \mu_\pi + z^i_t + \varphi_{\pi g}\sigma^i_{g,t}\eta_{t+1} + \varphi_{\pi x}\sigma_{x,t} e_{t+1} + \sigma_\pi \xi^i_{t+1} \\
z^i_{t+1} &= \alpha_z z^i_t + \alpha_x x_t + \varphi_{zg}\sigma^i_{g,t}\eta_{t+1} + \varphi_{zx}\sigma_{x,t} e_{t+1} + \sigma_z \xi^i_{z,t+1}.
\end{aligned}$$

A superscript ^{i} indicates a country i-specific variable. The absence of a superscript denotes global variables. The shocks η_{t+1}, ϵ^i_{t+1}, e_{t+1}, $\epsilon^i_{d,t+1}$, $\eta_{d,t+1}$, ξ^i_{t+1}, and $\xi^i_{z,t+1}$ are i.i.d standard normal. Shocks to the variances are drawn from Gamma distributions whose parameters are chosen to target the following mean and volatility of the volatility shocks:

$$E(w_{g,t+1}) = \sigma^2_g(1-\nu_g), \quad Var(w_{g,t+1}) = \sigma^2_{gw}$$
$$E(w_{x,t+1}) = \sigma^2_x(1-\nu_x), \quad Var(w_{x,t+1}) = \sigma^2_{xw}.$$

The unconditional mean of the time-varying variance of consumption growth is σ^2_g, while the unconditional level of the expected growth variance is σ^2_x.

Wealth-Consumption Ratio and Consumption Risk Premium The log real stochastic discount factor (SDF) can be written as a function of log consumption growth and the return on wealth:

$$m_{t+1} = \theta \log \delta - \frac{\theta}{\psi}\Delta c_{t+1} + (\theta - 1)\, r^c_{t+1},$$

where κ^c_0 and κ^c_1 are linearization constants, which are a function of the long-run average log wealth-consumption ratio $E(wc) = A_0 + A_{gs}\sigma^2_g + A_{xs}\sigma^2_x = \log(\kappa^c_1/[1-\kappa^c_1])$. Note that when $\theta = 1$ ($\gamma = \frac{1}{\psi}$), the above recursive preferences collapse to the standard power utility preferences and the only priced shocks are short-run consumption growth shocks η_{t+1}.

The return on a claim to aggregate consumption, the *total wealth return*, is:

$$R^c_{t+1} = \frac{W_{t+1} + C_{t+1}}{W_t} = \frac{C_{t+1}}{C_t}\left(\frac{W_{t+1}}{C_{t+1}} + 1\right)\frac{C_t}{W_t}.$$

The Campbell (1991) approximation of the log total wealth return $r^c_t = \log(R^c_t)$ around the long-run average log wealth-consumption ratio $\mu_{wc} \equiv E[w_t - c_t]$ leads to:

$$r^c_{t+1} = \kappa^c_0 + \kappa^c_1 wc_{t+1} - wc_t + \Delta c_{t+1}$$

where the linearization constants κ^c_0 and κ^c_1 are non-linear functions of the unconditional mean log wealth-consumption ratio μ_{wc}:

$$\kappa_1^c = \frac{e^{\mu_{wc}}}{1+e^{\mu_{wc}}} < 1 \text{ and } \kappa_0^c = \log\left(1+e^{\mu_{wc}}\right) - \frac{e^{\mu_{wc}}}{1+e^{\mu_{wc}}}\mu_{wc}.$$

The Euler equation for any asset i is:

$$0 = \log \mathbb{E}_t\left[e^{m_{t+1}+r_{t+1}^i}\right] \tag{Appendix C.1}$$

Let us conjecture that the wealth-consumption ratio is linear in the state variables x_t, $\sigma_{g,t}^2$ and $\sigma_{x,t}^2$:

$$wc_t = A_0 + A_x x_t + A_{gs}\sigma_{g,t}^2 + A_{xs}\sigma_{x,t}^2$$

The moment generating function for the Gamma distribution of the $w_{g,t+1}$ shocks is:

$$\Psi_c(u) = Ee^{uw_{g,t+1}} = \left(1 - \frac{\sigma_{gw}^2 u}{\sigma_g^2(1-\nu_g)}\right)^{\left(-\frac{\sigma_g^2(1-\nu_g)}{\sigma_{gw}}\right)^2},$$

for $u < \sigma_g^2(1-\nu_g)/\sigma_{gw}^2$. A similar expression holds for moment generating function $\Psi_x(u)$ of the $w_{x,t+1}$ shocks.

Using the Euler equation (Appendix C.1) evaluated at $i = c$ yields:

$$\begin{aligned}
0 \;=\;& \theta\log\delta - \frac{\theta}{\psi}\mu_g + \theta\left[\kappa_0^c + \mu_g + \left(\kappa_1^c - 1\right)A_0\right] + \log\Psi_c(\theta A_{gs}\kappa_1^c) + \log\Psi_x(\theta A_{xs}\kappa_1^c) \\
+\;& \frac{1}{2}\theta^2\sigma^2\left(1-\frac{1}{\psi}\right)^2 && \text{(Appendix C.2)} \\
+\;& \left\{\left[-\frac{\theta}{\psi} + \theta\left(1 + A_x\left(\kappa_1^c\rho - 1\right)\right)\right]\right\}x_t && \text{(Appendix C.3)} \\
+\;& \left\{\theta A_{gs}\left(\kappa_1^c\nu_g - 1\right) + \frac{1}{2}\theta^2\left(1-\frac{1}{\psi}\right)^2\right\}\sigma_{g,t}^2 && \text{(Appendix C.4)} \\
+\;& \left\{\theta A_{xs}\left(\kappa_1^c\nu_x - 1\right) + \frac{1}{2}(A_x\kappa_1^c\theta)^2\right\}\sigma_{x,t}^2 && \text{(Appendix C.5)}
\end{aligned}$$

Then setting all coefficients equal to zero leads to:

$$\begin{aligned}
(Appendix C.3) &\implies A_x = \frac{1-\frac{1}{\psi}}{1-\kappa_1^c\rho} \\
(Appendix C.4) &\implies A_{gs} = \frac{(1-\gamma)\left(1-\frac{1}{\psi}\right)}{2\left(1-\kappa_1^c\nu_g\right)} \\
(Appendix C.5) &\implies A_{xs} = \frac{(1-\gamma)\left(1-\frac{1}{\psi}\right)}{2\left(1-\kappa_1^c\nu_x\right)}\left(\frac{\kappa_1^c}{1-\kappa_1^c\rho}\right)^2
\end{aligned}$$

If the IES exceeds 1, then $A_x > 0$, $A_{gs} < 0$, and $A_{xs} < 0$.

The mean log wealth -consumption ratio is:

$$E(wc) = A_0 + A_{gs}\sigma_g^2 + A_{xs}\sigma_x^2 = \log\left(\frac{\kappa_1^c}{1-\kappa_1^c}\right).$$

The constant term in the Euler equation implicitly defines a nonlinear equation in one unknown (κ_1^c):

$$\begin{aligned}\log\kappa_1^c &= \log\delta + \left(1-\frac{\theta}{\psi}\right)\mu_g + (1-\kappa_1^c)(A_{gs}\sigma_g^2 + A_{xs}\sigma_x^2) + \frac{1}{\theta}\left(\log\Psi_c(\theta A_{gs}\kappa_1^c) + \log\Psi_x(\theta A_{xs}\kappa_1^c)\right)\\ &+ \frac{1}{2}\theta\sigma^2\left(1-\frac{1}{\psi}\right)^2.\end{aligned}$$

The real stochastic discount factor is thus:

$$m_{t+1} = m_0 + m_x x_t + m_{gs}\sigma_{g,t}^2 + m_{xs}\sigma_{x,t}^2 - \lambda_\eta\sigma\epsilon_{t+1} - \lambda_\eta\sigma_{g,t}\eta_{t+1} - \lambda_e\sigma_{x,t}e_{t+1} - \lambda_{gw}w_{g,t+1} - \lambda_{xw}w_{x,t+1}$$

The SDF loadings are:

$$\begin{aligned}
m_0 &= \theta\log\delta + (1-\theta)\log\kappa_1^c - \gamma\mu_g + (\theta-1)(1-\kappa_1^c)(A_{gs}\sigma_g^2 + A_{xs}\sigma_x^2),\\
m_x &= -\frac{1}{\psi},\\
m_{gs} &= -\frac{1}{2}(\gamma-\frac{1}{\psi})(\gamma-1),\\
m_{xs} &= -\frac{1}{2}(\gamma-\frac{1}{\psi})(\gamma-1)\left(\frac{\kappa_1^c}{1-\kappa_1^c\rho}\right)^2,\\
\lambda_\eta &= \gamma,\\
\lambda_e &= (\gamma-\frac{1}{\psi})\frac{\kappa_1^c}{1-\kappa_1^c\rho},\\
\lambda_{gw} &= -(\gamma-\frac{1}{\psi})(\gamma-1)\frac{\kappa_1^c}{2(1-\kappa_1^c\nu_g)},\\
\lambda_{xw} &= -(\gamma-\frac{1}{\psi})(\gamma-1)\frac{\kappa_1^c}{2(1-\kappa_1^c\nu_x)}\left(\frac{\kappa_1^c}{1-\kappa_1^c\rho}\right)^2.
\end{aligned}$$

If the IES is sufficiently large ($\gamma > 1/\psi$), then $\lambda_e > 0$, $\lambda_{gw} < 0$, and $\lambda_{xw} < 0$.

Real Bond Returns and Term Risk Premium Let $p_t^b(n) = \log\left(P_t^b(n)\right)$ be the log price and $y_t^b(n) = -\frac{1}{n}p_t^b(n)$ the yield of an n-period real bond.

The log prices of real bonds are linear in the state variables:

$$p_t(n) = -B_0(n) - B_x(n)x_t - B_{gs}(n)\sigma_{g,t}^2 - B_{xs}(n)\sigma_{x,t}^2.$$

The Euler equation implies that:

$$P_t(n) = E_t\left[M_{t+1}P_{t+1}(n-1)\right].$$

The coefficients satisfy the following recursions:

$$\begin{aligned}
B_x(n) &= \rho B_x(n-1) - m_x, \\
B_{gs}(n) &= \nu_g B_{gs}(n-1) - m_{gs} - \frac{1}{2}\gamma^2, \\
B_{xs}(n) &= \nu_x B_{xs}(n-1) - m_{xs} - \frac{1}{2}(\lambda_e + B_{x,n-1})^2, \\
B_0(n) &= B_0(n-1) - m_0 - \log\Psi_c(-\lambda_{gw} - B_{gs,n-1}) - \log\Psi_x(\lambda_{xw} - B_{xs,n-1}) - \frac{1}{2}\lambda_\eta^2\sigma^2.
\end{aligned}$$

The one-period real risk-free rate is:

$$r_t^f = -\left(m_0 + m_x x_t + m_{gs}\sigma_{g,t}^2 + m_{xs}\sigma_{x,t}^2 + \frac{1}{2}\lambda_\eta^2\sigma^2 + \frac{1}{2}\lambda_\eta^2\sigma_{g,t}^2 + \frac{1}{2}\lambda_e^2\sigma_{x,t}^2\right) - \log\Psi_c(-\lambda_{gw}) - \log\Psi_x(-\lambda_{xw}).$$

Expected inflation (short-run volatility) unambiguously increases (decreases) nominal bond yields. The effect of long-run growth (long-run volatility) on nominal yields is positive (negative) at short maturities, but negative (positive) at long maturities. These sign reversals at long maturities do not arise for real yields; they result from a negative correlation between expected inflation and long-run growth.

The one-period expected excess return on a real bond with n months to maturity is:

$$\begin{aligned}
\mathbb{E}_t\left[r_{t+1}^{b,e}(n)\right] + \frac{1}{2}Var_t\left[r_{t+1}^{b,e}(n)\right] &= -\mathrm{Cov}_t\left[r_{t+1}^b, m_{t+1}\right] \\
&= -B_{xs}(n-1)\lambda_{xw}\sigma_{xw}^2 - B_{gs}(n-1)\lambda_{gw}\sigma_{gw}^2 - B_x(n-1)\lambda_e\sigma_{x,t}^2.
\end{aligned}$$

Nominal Bond Returns and Term Risk Premium A \$ superscript denotes nominal variables. The nominal stochastic discount factor is: $m_{t+1}^\$ \equiv m_{t+1} - \pi_{t+1}$.

Let $p_t^\$(n) = \log\left(P_t^\$(n)\right)$ be the log price and $y_t^\$(n) = -\frac{1}{n}p_t^\$(n)$ the yield of an n-period nominal bond. The log prices of nominal bonds are linear in the state variables:

$$p_t^\$(n) = -B_0^\$(n) - B_x^\$(n)x_t - B_{gs}^\$(n)\sigma_{g,t}^2 - B_{xs}^\$\sigma_{x,t}^2 - B_z^\$(n)z_t.$$

The coefficients satisfy the following recursions:

$$\begin{aligned}
B_0^{\$}(n) &= B_0^{\$}(n-1) - m_0 + \mu_\pi - \frac{1}{2}\left[\sigma_\pi^2 + (B_z^{\$}(n-1)\sigma_z)^2\right] \\
&- \log\Psi_c(-\lambda_{gw} - B_{gs}^{\$}(n-1)) - \log\Psi_x(-\lambda_{xw} - B_{xs}^{\$}(n-1)) - \frac{1}{2}\lambda_\eta^2\sigma^2 \\
B_x^{\$}(n) &= \rho B_x^{\$}(n-1) + \alpha_z B_z^{\$}(n-1) - m_x \\
B_{gs}^{\$}(n) &= \nu_g B_{gs}^{\$}(n-1) - m_{gs} - \frac{1}{2}\left[\varphi_{\pi g} + \gamma + \varphi_{zg} B_z^{\$}(n-1)\right]^2 \\
B_{xs}^{\$}(n) &= \nu_x B_{xs}^{\$}(n-1) - m_{xs} - \frac{1}{2}\left[\varphi_{\pi x} + \lambda_e + B_x^{\$}(n-1) + \varphi_{zx} B_z^{\$}(n-1)\right]^2 \\
B_z^{\$}(n) &= \alpha_z B_z^{\$}(n-1) + 1.
\end{aligned}$$

The one-period nominal interest rate is:

$$\begin{aligned}
y_t^{\$} &= -\left(m_0 + m_x x_t + m_{gs}\sigma_{g,t}^2 + m_{xs}\sigma_{x,t}^2 - \mu_\pi - z_t\right) \\
&- \frac{1}{2}(\lambda_\eta + \varphi_{\pi g})^2\sigma_{g,t}^2 - \frac{1}{2}(\lambda_e + \varphi_{\pi x})^2\sigma_{x,t}^2 - \frac{1}{2}\sigma_\pi^2 - \log\Psi_c(-\lambda_{gw}) - \log\Psi_x(-\lambda_{xw}).
\end{aligned}$$

Equity Returns Next, I turn to stock prices. Like the wealth-consumption ratio, the price-dividend ratio of the claim to aggregate dividends is affine in the same three state variables.

The return on the market portfolio is : $r_{t+1}^m = \kappa_0^d + \kappa_1^d pd_{t+1} - pd_t + \Delta d_{t+1}$, where the linearization constants κ_0^d and κ_1^d are non-linear functions of the unconditional mean log price-dividend ratio μ_{pd}:

$$\kappa_1^d = \frac{e^{\mu_{pd}}}{1+e^{\mu_{pd}}} < 1 \text{ and } \kappa_0^d = \log\left(1+e^{\mu_{pd}}\right) - \frac{e^{\mu_{pd}}}{1+e^{\mu_{pd}}}\mu_{pd}.$$

The price-dividend ratio is linear in the state variables: $pd_t = D_0 + D_x x_t + D_{gs}\sigma_{g,t}^2 + D_{xs}\sigma_{x,t}^2$

The mean log price-dividend ratio is:

$$E(pd) = D_0 + D_{gs}\sigma_g^2 + D_{xs}\sigma_x^2 = \log\left(\frac{\kappa_1^d}{1-\kappa_1^d}\right).$$

Using the Euler equation and setting all coefficients equal to zero leads to:

$$\begin{aligned}
D_x &= \frac{m_x + \phi}{1 - \kappa_1^d \rho} \\
D_{gs} &= \frac{m_{gs} + \frac{1}{2}\lambda_\eta^2 + \frac{1}{2}\varphi_{dg}^2}{1 - \kappa_1^d \nu_g} \\
D_{xs} &= \frac{m_{xs} + \frac{1}{2}(-\lambda_e + \kappa_1^d D_x)^2}{1 - \kappa_1^d \nu_x}
\end{aligned}$$

The constant terms implicitly define κ_1^d.

$$m_0 + \frac{1}{2}\lambda_\eta^2\sigma^2 + \kappa_0^d - D_0 + \mu_d + \kappa_1^d D_0 + \frac{1}{2}\varphi_d^2\sigma_d^2 + \log\Psi_c(-\lambda_{gw} + \kappa_1^d D_{gs}) + \log\Psi_x(-\lambda_{xw} + \kappa_1^d D_{xs}) = 0.$$

This expression simplifies to:

$$\log \kappa_1^d = m_0 + \frac{1}{2}\lambda_\eta^2\sigma^2 + \mu_d + \frac{1}{2}\varphi_d^2\sigma_d^2 + \log\Psi_c(-\lambda_{gw} + \kappa_1^d D_{gs}) + \log\Psi_x(-\lambda_{xw} + \kappa_1^d D_{xs})$$
$$+ \quad (1-\kappa_1^d)\left(D_{gs} * \sigma_g^2 + D_{xs} * \sigma_x^2\right).$$

Appendix C.3 Calibration

Table 13 reports the model parameter values. Most preference and endowment parameters are those proposed in Bansal and Shaliastovich (2012). The calibration differs in risk-aversion, which varies from 4 to 6, instead of 10 in Bansal and Shaliastovich (2012). The inflation mean (2.5% instead of 3%), the inflation shock volatility (0.5% instead of 1.07%), and the expected inflation volatility (0.03% instead of 0.058%) are lower than in Bansal and Shaliastovich (2012) in order to reproduce the characteristics of aggregate inflation in the sample.

The model is simulated for 100,000 months.

[Table 13 about here.]

Table 14 reports regression tests on simulated data from the Long Run Risk model: countries differ only by their risk-aversion coefficient. Table 15 reports similar results when countries differ only by the volatility of their country-specific consumption growth component.

[Table 14 about here.]

[Table 15 about here.]

Table 11: Lustig et alii's (2012) Model: Regression Tests on Simulated Data

Country	α	β	γ	δ	τ	R^2	W	N
				Panel A				
Low Delta	0.28	−1.48				0.17	∗	3359
	[0.11]	[0.68]				(0.20)		
Med. Delta	0.07	−1.92				0.35	∗∗	3359
	[0.06]	[0.70]				(0.27)		
High Delta	−0.03	−1.16				0.11		3359
	[0.11]	[0.67]				(0.18)		
				Panel B				
Low Delta	0.22	−0.59	3.92	−0.20		25.52	∗ ∗ ∗	3359
	[0.10]	[0.55]	[0.16]	[0.03]		(1.55)		
Med. Delta	0.06	−0.61	4.41	0.03		21.38	∗ ∗ ∗	3359
	[0.05]	[0.58]	[0.17]	[0.02]		(1.51)		
High Delta	0.10	0.78	4.19	0.30		23.69	∗ ∗ ∗	3359
	[0.10]	[0.55]	[0.16]	[0.03]		(1.49)		
				Panel C				
Low Delta	0.16	−0.47	2.18	0.10	0.86	53.21	∗ ∗ ∗	3359
	[0.08]	[0.42]	[0.17]	[0.03]	[0.02]	(1.32)		
Med. Delta	0.00	−0.78	2.27	0.08	0.92	61.15	∗ ∗ ∗	3359
	[0.04]	[0.35]	[0.15]	[0.02]	[0.02]	(1.16)		
High Delta	−0.00	0.31	2.32	0.12	0.90	55.24	∗ ∗ ∗	3359
	[0.07]	[0.37]	[0.12]	[0.02]	[0.02]	(1.23)		

Notes: This table reports results from the following set of 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, and $i_t^\star - i_t$ 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, the adjusted R^2 of this regression, as well as the number of observations N. W denotes the result of a Wald test on the joint significance of γ and δ. 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 a monthly frequency using the model and parameter values of Lustig et al. (2013). The sample has 3,360 periods. 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 12: Heterogeneity in the Long-Run Risk Model

	Differences in Risk-aversion			Differences in Volatilities		
Country / Portfolio	1	2	3	1	2	3
			Panel I: Parameters			
γ	6.00	5.03	4.00	5.00	5.00	5.00
σ	2.10	2.10	2.10	2.42	1.96	1.47
σ_g	1.29	1.29	1.29	0.48	1.50	1.98
			Panel II: Consumption Growth			
$E(\Delta c)$	1.93	1.94	1.93	1.93	1.94	1.93
$\sigma_{\Delta c}$	2.58	2.59	2.58	2.57	2.59	2.58
Share: LRR x (common)	0.03	0.03	0.03	0.03	0.03	0.03
Share: η (common)	0.26	0.26	0.26	0.04	0.35	0.62
Share: ϵ	0.71	0.70	0.71	0.93	0.61	0.35
$Corr(\Delta c, \Delta c^\star)$	100.00	33.52	33.20	100.00	17.96	21.07
			Panel III: Equity			
$E(\Delta d)$	1.78	1.90	2.00	1.75	1.91	2.01
$\sigma_{\Delta d}$	12.53	12.54	12.49	12.53	12.54	12.52
$E(r^m - r^f)$	3.85	2.81	1.36	2.63	2.79	2.88
$\sigma_{r^m - r^f}$	24.27	25.64	27.73	25.66	25.69	25.64
			Panel IV: Bonds and Inflation			
$E(r^f)$	1.91	2.01	2.12	2.02	2.02	2.02
σ_{r^f}	0.29	0.29	0.29	0.29	0.29	0.29
$E(\pi)$	2.30	2.30	2.30	2.30	2.30	2.30
σ_π	3.92	3.93	3.92	3.92	3.93	3.92
$E(r^{f,\$})$	4.24	4.34	4.44	4.34	4.34	4.34
$\sigma_{r^{f,\$}}$	1.96	1.96	1.96	1.96	1.96	1.96
$E(y^5)$	5.84	5.62	5.38	5.61	5.61	5.61
σ_{y^5}	1.61	1.61	1.61	1.61	1.61	1.61
			Panel V: Exchange Rates			
$\sigma_{\Delta q}$	17.69	17.48	19.38	17.03	16.49	16.20
Share: η (common)	0.00	0.57	1.76	1.14	11.92	23.64
Share: ϵ	99.95	87.58	61.33	98.87	87.85	76.45
Share: LRR e (common)	0.03	11.66	36.29	0.00	0.00	0.00
$Corr(\Delta q, \Delta c^\star - \Delta c)$		51.01	45.95		65.21	78.94
			Panel VI: Systematic Risk			
R^2_{FX}	47.21	65.55	75.42	47.92	66.88	77.16
$R^2_{Equity,\$}$	70.56	82.63	88.78	67.05	80.40	86.80
R^2_{Equity}	81.85	83.88	86.07	76.27	86.30	90.89
$E(Carry)$	1.35	1.80	2.21	-0.02	-0.11	-0.12
$E(Dollar)$	0.50	0.84	1.21	-0.21	-0.14	-0.26

Notes: This table reports simulation moments of the long run risk model. The model is simulated at monthly frequency. There are 36 countries and 100,000 observations per country. Countries differ either by their risk-aversion coefficient (left-hand side of the table) or by the share of their country-specific volatility (right-hand side of the table). The first country is the domestic country. The table presents results for the first, middle, and last country (or first, middle, and last portfolios for the carry and dollar returns). Panel I reports the risk-aversion (γ), along with the volatility of country-specific and global consumption growth shocks (σ and σ_g). Panel II reports the volatility of aggregate consumption growth (σ) and the shares of the variance explained by the long-run risk component x_t, the common and country-specific short-term shocks (η_{t+1} and ϵ_{t+1}), as well as the cross-country correlation of consumption growth rates. Panel III reports the first two moments of real dividend growth rates Δd and real equity excess returns $r^m - r^f$. Panel IV reports the first two moments of real risk-free rates (r^f), inflation (π), one-period nominal interest rates ($r^{f,\$}$), and five-year interest rates (y^5). Panel V reports the volatility of exchange rates, and the shares of the variance explained by the common and country-specific short-term shocks (η_{t+1} and ϵ_{t+1}), and the long-run risk shocks e_{t+1}, as well as the correlation of real exchange rates with relative consumption growth rates ($Corr(\Delta q, \Delta c^\star - \Delta c)$). Panel VI reports the share of systematic currency and equity risk (R^2_{FX}, $R^2_{Equity,\$}$ for returns expressed in dollars, and R^2_{Equity} for returns in local currencies). Currency systematic risk is measured with the carry and dollar factors, while equity risk is measured with the world equity return. The last two lines report the mean currency excess returns of portfolios sorted by interest rates ($E(Carry)$) or by time-varying dollar betas ($E(Dollar)$).

Table 13: Long-Run Risk Model: Parameter Values

Parameter		*Value*
Preference Parameters:		
Subjective discount factor	δ	0.999
Intertemporal elasticity of substitution	ψ	1.5
Risk aversion coefficient	γ	4/6
Consumption Growth Parameters:		
Mean of consumption growth	μ_g	1.92
Long-run risk persistence	ρ	0.897
Short-run volatility level (country-spec.)	σ	2.42/1.47
Short-run volatility level	σ_g	0.48/1.98
Short-run volatility persistence	ν_g	0.069
Short-run volatility of volatility	σ_{gw}	$5.4e-4$
Long run-risk volatility level	σ_x	0.058
Long run-risk volatility persistence	ν_x	0.784
Long run-risk volatility of volatility	σ_{xw}	$2e-7$
Dividend Growth Parameters:		
Mean of dividend growth	μ_d	1.92
Dividend leverage	ϕ_x	5
Volatility loading of dividend growth	φ_{dg}	5
Volatility loading of dividend growth	φ_d	5
Inflation Parameters:		
Mean of inflation rate	μ_π	2.50
Inflation sensitivity to short-run news	$\varphi_{\pi g}$	0.0
Inflation sensitivity to long-run news	$\varphi_{\pi x}$	-2.0
Inflation shock volatility	σ_π	0.5
Expected inflation persistence	α_π	0.188
Expected inflation leverage on long-run news	α_x	-0.34
Expected inflation leverage on short-run news	φ_{zg}	0.0
Expected inflation leverage on long-run news	φ_{zx}	-1.0
Expected inflation shock volatility	σ_z	0.03

This table reports the calibrated parameters values for the simulation. Countries differ along their risk aversion coefficient and their country-specific short-run volatilities. The model is simulated at the monthly frequency. The parameter values in this table are annualized: consumption and inflation means (μ_g, μ_d, and μ_π) are multiplied by 12×100, the persistence parameters (ρ, ν_g, ν_x, α_x, and α_z) are raised to the power 12, and the volatility parameters (σ_g, σ_{gw}, σ_x, σ_{xw}, σ_π, and σ_z) are multiplied by $\sqrt{12} \times 100$

Table 14: Long-Run Risk Model with Differences in Risk-Aversion

Country	α	β	γ	δ	τ	R^2	W	N
				Panel A				
High R.A.	0.01	0.46				−0.00		99999
	[0.02]	[0.74]				(0.00)		
Med. R.A.	−0.14	1.37				0.00		99999
	[0.02]	[0.74]				(0.00)		
Low R.A.	−0.31	1.30				0.00		99999
	[0.02]	[0.82]				(0.00)		
				Panel B				
High R.A.	0.00	0.78	8.85	−0.11		0.76	$***$	99999
	[0.02]	[0.74]	[0.37]	[0.01]		(0.05)		
Med. R.A.	−0.13	1.44	6.01	0.34		2.51	$***$	99999
	[0.02]	[0.73]	[0.38]	[0.01]		(0.10)		
Low R.A.	−0.28	1.37	5.35	0.73		8.41	$***$	99999
	[0.02]	[0.79]	[0.41]	[0.01]		(0.17)		
				Panel C				
High R.A.	0.12	0.63	9.73	−0.39	0.87	47.21	$***$	99999
	[0.01]	[0.53]	[0.28]	[0.01]	[0.00]	(0.22)		
Med. R.A.	0.01	0.73	5.75	0.02	1.00	65.55	$***$	99999
	[0.01]	[0.43]	[0.23]	[0.01]	[0.00]	(0.18)		
Low R.A.	−0.12	0.81	3.97	0.39	1.14	75.42	$***$	99999
	[0.01]	[0.41]	[0.21]	[0.01]	[0.00]	(0.13)		

Notes: This table reports results from the following set of 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, and $i_t^\star - i_t$ 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, the adjusted R^2 of this regression, as well as the number of observations N. W denotes the result of a Wald test on the joint significance of γ and δ. 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 a monthly frequency from the Long Run Risk model described in Section 5. The sample has 100,000 periods. 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 risk-aversion (R.A.) coefficient. Risk-aversions range from 4 to 6; it is the only source of heterogeneity in the model.

Table 15: Long-Run Risk Model with Differences in Volatilities

Country	α	β	γ	δ	τ	R^2	W	N
				Panel A				
High σ	0.01	0.36				−0.00		99999
	[0.02]	[0.71]				(0.00)		
Med. σ	0.03	1.26				0.00		99999
	[0.02]	[0.70]				(0.00)		
Low σ	−0.00	0.91				0.00		99999
	[0.01]	[0.69]				(0.00)		
				Panel B				
High σ	0.02	−0.29	11.97	0.01		0.71	$*\!*\!*$	99999
	[0.02]	[0.71]	[0.45]	[0.01]		(0.05)		
Med. σ	0.03	0.79	8.32	−0.01		0.36	$*\!*\!*$	99999
	[0.02]	[0.69]	[0.45]	[0.01]		(0.04)		
Low σ	−0.00	0.55	6.84	−0.01		0.25	$*\!*\!*$	99999
	[0.01]	[0.69]	[0.44]	[0.01]		(0.03)		
				Panel C				
High σ	0.01	−0.73	13.52	0.06	0.88	47.92	$*\!*\!*$	99999
	[0.01]	[0.51]	[0.34]	[0.01]	[0.00]	(0.22)		
Med. σ	0.02	0.09	7.95	0.05	1.01	66.88	$*\!*\!*$	99999
	[0.01]	[0.40]	[0.26]	[0.01]	[0.00]	(0.17)		
Low σ	−0.01	0.32	5.39	0.06	1.07	77.16	$*\!*\!*$	99999
	[0.01]	[0.33]	[0.21]	[0.00]	[0.00]	(0.13)		

Notes: This table reports results from the following set of 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, and $i_t^\star - i_t$ 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, the adjusted R^2 of this regression, as well as the number of observations N. W denotes the result of a Wald test on the joint significance of γ and δ. 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 a monthly frequency from the Long Run Risk model described in Section 5. The sample has 100,000 periods. 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 volatility of the country-specific consumption growth shocks σ. The volatilities range from 2.4% to 1.5%; they are the only source of heterogeneity in the model.

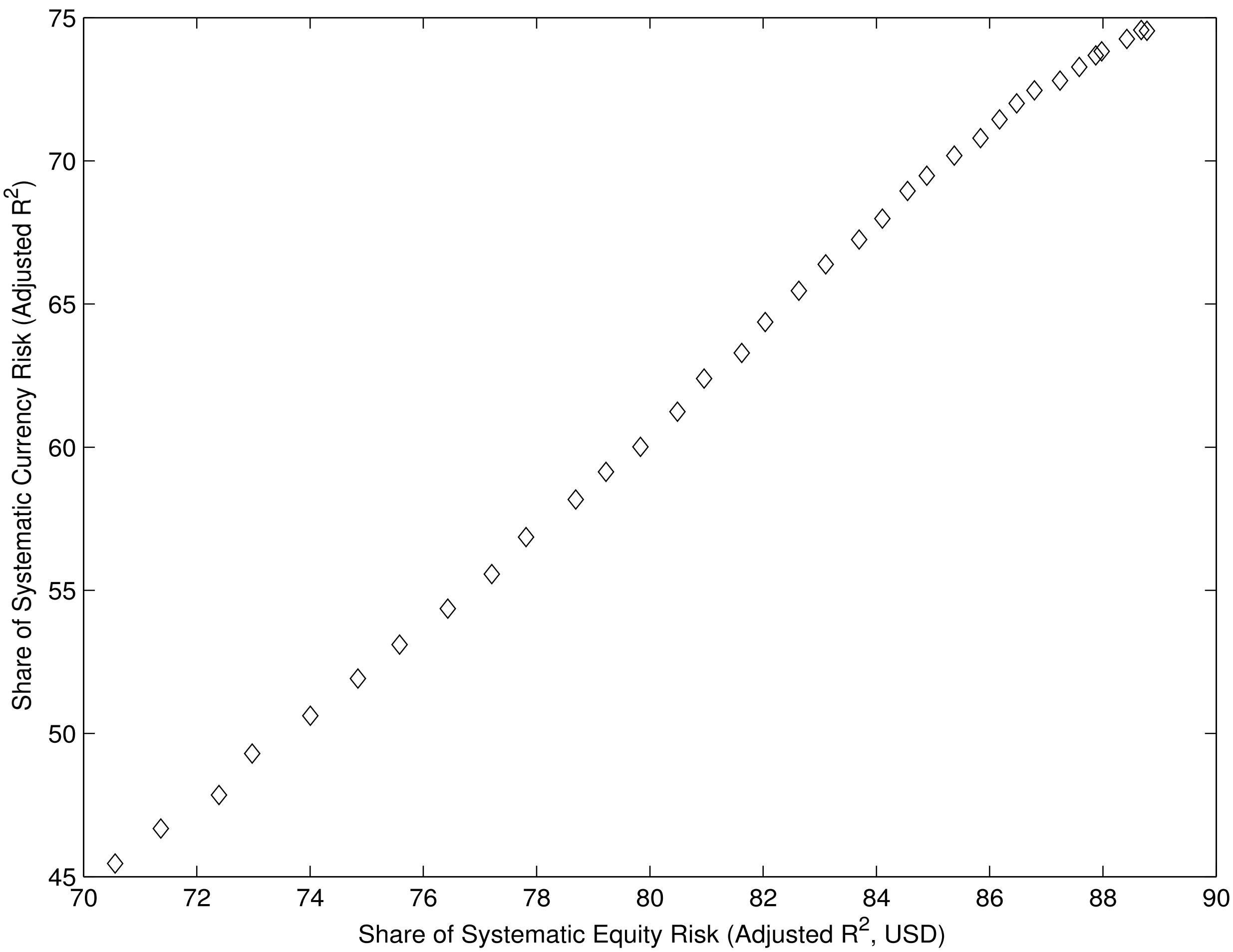

Figure 7: Systematic Equity and Currency Risk in the Long-Run Risk Model

The figure plots adjusted R^2s on currency markets as a function of adjusted R^2s on equity markets. 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:

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

where r_{t+1}^m denotes the returns on a foreign country's stock market index, $r_{t+1}^{m,world}$ corresponds to returns on the world equity index (obtained as the average of all stock market returns). Data are simulated at the monthly frequency. The sample has 60,000 observations.