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. They point to large shares of global shocks in the dynamics of exchange rates, as well as large differences across countries. The different shares of systematic currency risk are related to the comovement of international capital flows. The results offer new challenges for international finance models.

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The correlation structure of bilateral exchange rates can be summarized by a small number of principal components, but those principal components offer a purely statistical description of exchange rates and are difficult to interpret in any macro-finance model. In this paper, to the contrary, I report that two risk factors — the carry and the dollar factors — account for a substantial share of individual exchange rate time-series. These factors are priced in currency markets and the shares of systematic currency risk have implications for any no-arbitrage model in international finance.

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. All exchange rates are defined here with respect to the U.S. dollar. 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. With the carry factors, the adjusted R^2s range from 0% to 23% among developed countries. While a lot of research focuses on the carry trade, the dollar factor appears as a more important driver of exchange rates. It accounts for 13% to 88% of the monthly exchange rate variation. When the two factors are combined, the adjusted 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 distribution of R^2s on the factor regressions is quite stable across frequencies; similar distributions appear at daily, monthly, quarterly, and annual frequencies. 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.

Large R^2s can naturally be obtained by using three or more principal components. The dollar factor is actually close to the first principal component, while the carry factor is different from any of them — the information contained in short-term interest rates matters. Both factors deliver a more stable description of exchange rates than the principal components. More crucially, principal components do not imply that risks are priced. To the contrary, both the carry and the dollar factors are priced in currency markets. They 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.

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 start with rational, preference-free interpretation and implications, and then turn to a reduced-form model.

When markets are complete, 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). Without loss of generality, each pricing kernel can be decomposed into country-specific and world shocks. Bilateral exchange rates thus depend on (home minus foreign) differences in country-specific and world shocks. In large baskets of currencies, assuming that the law of large numbers applies, foreign country-specific shocks average out. The carry factor, defined as a difference in baskets of exchange rates, is dollar-neutral and therefore 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.

How many world shocks are necessary to describe exchange rates? The findings in this paper suggest at least two. As already noted, if markets are complete and the law of large numbers applies, the carry factor depends only world shocks — indeed, in the data, a measure of global volatility on equity markets is a good proxy for the carry factor. But, again, the carry factor does not explain the cross-section of dollar beta portfolios, thus suggesting the role of a second kind of global shocks. These global shocks can be extracted with a simple long-short strategy: the difference between high and low dollar beta portfolios, which eliminates U.S.-specific shocks to the U.S. pricing kernel, focuses on the global component of the dollar factor. At the annual frequency, this global component appears related to the world business cycle. The role of the dollar factor at higher frequencies, however, suggests that liquidity-based interpretations of the global shocks are very plausible.

The reduced-form, no-arbitrage model of Lustig, Roussanov, and Verdelhan (2013) suggests a potential difference between the two global shocks, and a potential interpretation of the findings in this paper. In their model, each pricing kernel responds to country-specific shocks, as well as two kinds of global shocks, either priced locally or globally. Since long-short carry trade excess returns are similar for all domestic and foreign investors, they mostly compensate them for global shocks that are priced in the same way in all countries. Thus, as a first approximation, the carry factor accounts for global shocks that are priced globally, while the dollar factor accounts for U.S.-specific and global shocks that are priced locally. Sorting countries by their dollar betas is similar to sorting them by their country-specific prices of risk. When the average forward discount 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. In this case, the dollar factor co-moves positively with global shocks that are priced locally. Bilateral exchange rates respond to the same global shocks, in proportion of their relative (home minus foreign) country-specific prices of risk. Currencies with large dollar betas are then currencies with low country-specific prices of risk. In times of bad global shocks, these currencies depreciate. They thus offer large excess returns on average to compensate investors for taking on global risks that are priced locally. The reduced-form model of Lustig, Roussanov, and Verdelhan (2013) thus offers a potential interpretation of the carry and dollar factors, and their associated cross-section of average excess returns. But this paper reports two empirical results that are more general and far-reaching than this particular model.

The relative importance of the local and global shocks in exchange rate movements can be measured precisely, without any assumption on preferences. In the data, the global component of the dollar factor is highly correlated with the average change in exchange rates expressed in U.S. dollars, thus its name. 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 turns out to be 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.

The cross-country differences in systematic currency risk offer a novel and useful characteristic of exchange rates: accounting for those differences point to international capital flows, not trade flows. Capital outflows and inflows are recorded in the balance of payments, and scaled by GDP. The share of systematic variation of total capital outflows (or inflows) for a given country is measured as the R^2 of a regression of that country's total capital outflows (inflows) on the first three principal components of all the other countries' capital outflows (or simply their mean). I find that a high share of systematic variation in exchange rates corresponds to a high share of systematic variation in total capital outflows, inflows, and their averages. Differences in capital flows account for up to 53% of the differences in systematic risk across currencies. The share of systematic variation in exports and imports account for much less of the differences in exchange rates. Among the capital flow components, portfolio and other investments are much more informative than foreign direct investments. The paper describes but does not explain exchange rate changes, for example by linking them directly to macroeconomic variables. The cross-country differences in systematic currency risk simply suggest that most of exchange rate variations are linked to trade in financial assets, not goods.

The paper is organized as follows. Section 1 reviews the related literature. Section 2 provides a general framework and a specific model example in order to define systematic risk and global factors in bilateral exchange rates. Section 3 shows that the dollar and carry factors explain a large share of bilateral exchange rates. Section 4 uncovers a new cross-section of currency excess returns that is explained by the dollar risk factor, thus showing that dollar risk is priced. Section 5 revisits the volatility puzzle and shows that cross-country differences in systematic currency risk are related to comovement in international capital flows. 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 many robustness checks and extensions, as well as model simulations.[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

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

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 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

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[2] Following Lustig and Verdelhan (2005, 2007), DeSantis and Fornari (2008), Jurek (2008), Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009), Galsband and Nitschka (2010), Verdelhan (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.

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 3% to 17% of daily changes in exchange rates among developed countries, while the dollar factor accounts for 20% to 84% 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 Framework

This section lays down a simple framework to think about global shocks in exchange rates, starting with some preference-free definitions before moving to the example of a simple factor model.

2.1 Systematic and Idiosyncratic Shocks to Exchange Rates

If the law of one price applies, the change in the nominal exchange rate, Δs^i, 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 projections on the space of traded assets of the nominal stochastic discount factors (SDF) of the domestic and country i investors.[3] An increase in s^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. Without loss of generality, each SDF can be decomposed into country-specific and world shocks:

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

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 SDF, 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. For that investor, the systematic component of exchange rate changes corresponds to the U.S.-specific shocks, as well as the impact of global shocks on the U.S. and foreign pricing kernels. In this general framework, let us define the dollar and carry factors.

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[3] This result derives from the Euler equations of the domestic and foreign investors buying any asset R^i that pays off in foreign currency: $E_t[M_{t+1}R^i S_t/S_{t+1}] = 1$ 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 SDFs 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 SDF 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 SDFs on the space of traded assets.

Dollar Risk Factor The dollar risk factor is the average of all exchange rates 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. 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). As a result, the dollar risk factor may depend on both U.S.-specific and world shocks, but not on foreign-specific shocks. The covariance between the change in exchange rate for country i 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, and thus cannot explain any empirical difference in the slope coefficients of bilateral exchange rates on the dollar risk factor. Yet, as we shall see, countries differ strongly in their loadings on the dollar factor. Such difference must come from the third term above, i.e., from different exposures of the foreign pricing kernels to world shocks. For the third term to be non-zero, the U.S. SDF exposure to world shocks must be different from the average exposure of the other countries' SDFs. In this case, the dollar factor does depend on world shocks, not only on U.S.-specific shocks.

Intuitively, a simple way to focus on the global component of the dollar factor is to sort currencies by their exposure to the factor and consider a long-short investment strategy. Going long the high dollar beta countries and short the low dollar beta countries eliminates the U.S.-specific component. A similar logic is behind the definition of the carry factor.

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. Defined as a difference in exchange rates, the carry factor is therefore dollar-neutral. As Lustig et al. (2011) find, the carry factor accounts for the cross-section of carry trade excess returns in portfolios of countries sorted by interest rates: in the data, the higher the interest rate, the larger the loading on the carry factor. Global volatility risk (as measured for example on world equity markets, as in Lustig, Roussanov, and Verdelhan, 2011, or measured on currency markets, as in Menkhoff, Sarno, Schmeling, and Schrimpf (2012a)) is a good proxy for such world risk. In any no-arbitrage model, pricing kernels must thus differ in their exposure to world shocks — without heterogeneity, the carry factor would not exist.

How Many Global Shocks? Carry and dollar risk factors reflect global shocks, but not necessarily the same shocks. A natural question therefore arises: how many global shocks drive exchange rate changes? This paper argues that two kinds of global shocks are priced in currency markets.

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 eliminates the U.S.-specific component of the U.S. pricing kernel and focuses on the global component of the dollar factor. Empirically , as we shall see, the global component of the dollar factor appears uncorrelated to the carry trade factor. Any model in international finance must then feature at least two kinds of global shocks.

I turn now to one example of such a model, using Lustig, Roussanov and Verdelhan (2013) to illustrate the potential difference between two global shocks.

2.2 A Reduced-Form Model

Stochastic Discount Factors Building on Cox, Ingersoll and Ross (1985) and Backus, Foresi and Telmer (2001), Lustig, Roussanov, and Verdelhan (2011, 2013) start from the law of motion of the log SDF m^i, which follows a two-factor conditionally-Gaussian process:

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

In this model, there are two kinds of priced risk: country-specific shocks (denoted u^i, uncorrelated across countries) and world shocks (denoted u^w and u^g). All shocks are *i.i.d* gaussian, with zero mean and unit variance. The risk prices of country-specific shocks depend only on the country-specific factors (z^i_t), but the risk prices of world shocks depend either on world (z^w_t) or country-specific factors (z^i_t).[4] 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 are governed by autoregressive square root processes:

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

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.[5] The zero average forward discount and the low correlation between the dollar

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[4] The SDFs are heteroscedastic because, as Bekaert (1996), Bansal (1997), and Backus et al. (2001) have shown, expected currency log excess returns depend on the conditional variances of the home and foreign (lognormal) SDFs. If SDFs were homoscedastic, expected excess returns would be constant and the UIP condition would be valid. Backus et al. (2001) show that this result generalizes to non-Gaussian SDFs. If SDFs are not lognormal, expected currency excess returns depend on the higher cumulants, some of which must be time-varying. Moreover, Engel (2011) shows that risk-based explanations of carry trades need to include at least two sources of risk.

[5] Three minor comments are in order. First, the model combines insights from the two papers. In the first paper, the global shock is absent. In the second paper, the global shocks u^w are priced globally: $\lambda = 0$. Second, in the Lustig et al. (2013) paper, the SDF is a real variable, and inflation in each country is defined as $\pi^i_{t+1} = \pi_0 + \eta^w z^w_t + \sigma_\pi \epsilon^i_{t+1}$. Since inflation risk is not priced, the model can be as well defined in terms of nominal SDFs as above. Second, there is no direct relation between the symbols in the model and the symbols used to describe

and carry factors imply additional restrictions on the model.

Interest Rate Difference The interest rate difference, or forward discount, between currency i and the U.S is equal to:

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

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: $\chi - \frac{1}{2}(\gamma + \kappa + \lambda) < 0$ 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., $N \to \infty$) by the law of large numbers. Note that, in practice, the number of currencies is small: the dataset used in this paper contains at most 39 currencies. As a result, the law of large numbers is only an approximation used here to provide intuition; the model can naturally be simulated without such approximation. Assuming that the law of large numbers hold, the average forward discount is:

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

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the slope coefficients in the regressions of the next sections. I keep the exact same notation and model as in Lustig et al. (2013) for the reader's convenience.

The last equality assumes that the U.S. SDF's exposure to world shocks priced globally (u^w) is equal to the average exposure to world shocks across countries: $\overline{\delta^i} = \delta$. This assumption implies that the time-series mean of the average forward discount among developed countries is zero, a close approximation to the data.

Risk Factors and Bilateral Exchange Rates In this case, the dollar factor is approximately:

$$\begin{aligned} Dollar_{t+1} &= \chi\left(\theta - z_t\right) - \sqrt{\gamma z_t} u_{t+1} \\ &+ \left(\overline{\sqrt{\delta^i z_t^w + \lambda z_t^i}} - \sqrt{\delta z_t^w + \lambda z_t}\right) u^w_{t+1} + \sqrt{\kappa}\left(\overline{\sqrt{z_t^i}} - \sqrt{z_t}\right) u^g_{t+1}, \\ &\simeq \chi\left(\theta - z_t\right) - \sqrt{\gamma z_t} u_{t+1} + \sqrt{\kappa}\left(\overline{\sqrt{z_t^i}} - \sqrt{z_t}\right) u^g_{t+1}, \end{aligned}$$

where the approximation relies on the additional assumption that most of the variation in the price of the global shocks u^w is global ($\delta^i z_t^w \gg \lambda z_t^i$ and $\overline{\delta^i} = \delta$, such that $\overline{\sqrt{\delta^i z_t^w + \lambda z_t^i}} \simeq \sqrt{\delta z_t^w + \lambda z_t}$).

The carry factor corresponds to the average change in exchange rates between portfolios of high and portfolios of low interest rate countries. 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 because of the values of their market prices of risk z^i and their exposure δ^i to world shocks. When most cross-country interest rate differences are driven by their exposure to world shocks, then baskets of high and low interest rate currencies exhibit the same level of country-specific volatilities ($\overline{\sqrt{z_t^i}}^H = \overline{\sqrt{z_t^i}}^L$). In that case, the carry factor only depends on the global shocks u^w, not u^g, and the correlation between the two factors is zero. In the data, the correlation between the dollar and carry factors is low (below 0.1). For expositional purpose, let us consider the special case of zero correlation. The carry factor then captures world shocks u^w perfectly:

$$
\begin{aligned}
Carry_{t+1} &= \chi\left(\overline{z_t^i}^H - \overline{z_t^i}^L\right) + \left(\overline{\sqrt{\delta^i z_t^w + \lambda z_t^i}}^H - \overline{\sqrt{\delta^i z_t^w + \lambda z_t^i}}^L\right) u_{t+1}^w, \\
&\simeq \chi\left(\overline{z_t^i}^H - \overline{z_t^i}^L\right) + \left(\overline{\sqrt{\delta^i}}^H - \overline{\sqrt{\delta^i}}^L\right) \sqrt{z_t^w} u_{t+1}^w,
\end{aligned}
$$

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. Finally, the change in bilateral exchange rates is:

$$
\begin{aligned}
\Delta s_{t+1}^i &= \chi(z_t^i - z_t) + \sqrt{\gamma z_t^i} u_{t+1}^i - \sqrt{\gamma z_t} u_{t+1} \\
&+ \left(\sqrt{\delta^i z_t^w + \lambda z_t^i} - \sqrt{\delta z_t^w + \lambda z_t}\right) u_{t+1}^w + \sqrt{\kappa}\left(\sqrt{z_t^i} - \sqrt{z_t}\right) u_{t+1}^g,
\end{aligned}
$$

where the second line presents the global components of exchange rates.

Exchange Rate Betas The reduced-form model provides a rationale for the two risk factors and two cross-sections of currency returns. A regression of the changes in exchange rates on the dollar and carry factors captures the systematic shocks that matter to a U.S. investor. Formally, the conditional dollar and carry betas are equal to:

$$
\begin{aligned}
\frac{cov_t(\Delta s_{t+1}^i, Dollar_{t+1})}{var_t(Dollar_{t+1})} &= \frac{\sqrt{z_t^i} - \sqrt{z_t}}{\overline{\sqrt{z_t^i}} - \sqrt{z_t}} \simeq \frac{\sqrt{z_t^i} - \sqrt{z_t}}{\sqrt{\theta} - \sqrt{z_t}}, \\
\frac{cov_t(\Delta s_{t+1}^i, Carry_{t+1})}{var_t(Carry_{t+1})} &= \frac{\sqrt{\delta^i + \lambda z_t^i / z_t^w} - \sqrt{\delta + \lambda z_t / z_t^w}}{\overline{\sqrt{\delta^i}}^H - \overline{\sqrt{\delta^i}}^L} \\
&= \frac{\sqrt{\delta^i} - \sqrt{\delta}}{\overline{\sqrt{\delta^i}}^H - \overline{\sqrt{\delta^i}}^L} \text{ when } \lambda = 0.
\end{aligned}
$$

The loading on the dollar factor depends on the U.S.-specific and foreign volatilities or market prices of risk. The loading on the carry factor is constant in the special case where the global shocks u^w are priced globally; if they are priced both locally and globally, then the loadings on the carry factor depend on the U.S., foreign, and global volatilities, which also govern the interest rate difference between the two countries.

As is well-known, sorting countries by their interest rates leads to a large cross-section of average currency excess returns in the data. Low (high) interest rate currencies offer low (high) average excess returns. In the model, as Lustig et al. (2011) show, sorting countries by their interest rates can be interpreted as 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 (z_t^i), 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 ($\theta < z_t$). 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: in case 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 in case of 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.

A measure of the global component of the dollar factor can be obtained by going long in a set of high dollar-beta-currencies and short in a set of low dollar-beta-currencies. Formally, the resulting exchange rate change is:

$$\begin{aligned}
Dollar\ Global_{t+1} &= \chi\left(\overline{z_t^i}^{H\beta} - \overline{z_t^i}^{L\beta}\right) + \left(\overline{\sqrt{\delta^i z_t^w + \lambda z_t^i}}^{H\beta} - \overline{\sqrt{\delta^i z_t^w + \lambda z_t^i}}^{L\beta}\right) u_{t+1}^w, \\
&+ \left(\overline{\sqrt{\kappa z_t^i}}^{H\beta} - \overline{\sqrt{\kappa z_t^i}}^{L\beta}\right) u_{t+1}^g, \\
&\simeq \chi\left(\overline{z_t^i}^{H\beta} - \overline{z_t^i}^{L\beta}\right) + \left(\overline{\sqrt{\kappa z_t^i}}^{H\beta} - \overline{\sqrt{\kappa z_t^i}}^{L\beta}\right) u_{t+1}^g,
\end{aligned}$$

where $\overline{x^i}^{H\beta} = \frac{1}{N_{H\beta}} \sum_{i \in H\beta} x^i$, $\overline{x^i}^{L\beta} = \frac{1}{N_{L\beta}} \sum_{i \in L\beta} x^i$, and where $N_{H\beta}$ and $N_{L\beta}$ denote the number of currencies in the high ($H\beta$) and low ($L\beta$) dollar beta portfolios. When most of the variation in the price of the global shocks u^w is global ($\delta^i z_t^w \gg \lambda z_t^i$), then the high and low dollar beta portfolios do not differ in terms of exposures to the carry-like global shocks u^w, and the high-minus low dollar beta investment strategy simply reflects the global shocks u^g.

3 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.

3.1 Data

Notation 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.[6]

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[6] 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

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 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.

In my data set, as in the rest of the literature, UIP slope coefficients are always below one, and most of them are negative. All but one are statistically insignificant. 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. Interest rates explain little of the changes in exchange rates. A more interesting view of exchange rates emerges when relying on contemporaneous risk factors.

3.2 Carry and Dollar Factors

In order to extract risk factors from currency markets, I build six *portfolios* of currencies, following Lustig and Verdelhan (2005, 2007), and like Lustig et al. (2011). All developed and emerging countries are sorted 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 ver-

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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.

sus all the other currencies; it corresponds to the average change in exchange rate across all six portfolios at each point in time.

Developed Countries Table 1 reports country-level results from the following regression:

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

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 1 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 1 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.).[7] 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) 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 1 about here.]

Emerging Markets To explore exchange rate dynamics further, and as an initial robustness check, Table 2 reports similar tests on a set of 18 developing countries (using the same factors as

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[7] 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 1 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.

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 2 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 2 about here.]

3.3 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.[8]

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 3 is the counterpart to Table 1: 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

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[8] I consider additional robustness checks (other factors, like momentum; rolling window estimations; bid-ask spreads; and different base currencies). The results are presented and commented in the separate online Appendix. They all reinforce the findings presented in the main text.

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 3 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.

3.4 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.

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 by 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.

Moreover, loadings on the carry and dollar factors appear more stable than loadings on principal components. To quantify this point, I conduct a pseudo-predictability exercise, in the spirit of the seminal Meese and Rogoff (1983) experiment.[9] Loadings on the carry and dollar factors are estimated over rolling windows of 60 months. Then, the one-month ahead 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. A similar test is run by estimating the loadings on the first three principal components, or a simple random walk with drift.

The square root of mean squared errors (RMSE) compares favorably for the carry and dollar factors, attesting the persistence of the factor loadings. To save space, results are reported in the online Appendix. 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. The carry and dollar factors also beat the random walk benchmark easily. The pseudo-predictability experiment therefore highlight another comparative advantage of the carry and dollar factors over principal components.

Focusing on the benchmark carry and dollar factors (instead of the principal components) has therefore 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. No meaningful closed-form expression for the principal components could be obtained in the simple model of Section 2 for example. Third, the loadings on the carry and dollar factors appear more stable than those of the principal

---

[9] Meese and Rogoff (1983) estimate multivariate regressions that link changes in exchange rates to macro variables. They assume that such macroeconomic variables are known one period in advance and compare the predicted value of the exchange rate with the one implied by a random walk. The random walk leads to lower mean squared error than any macroeconomic variable.

components. But I turn now to the most important characteristic of the carry and dollar factors, a key feature that distinguishes them from other statistical description of bilateral exchange rates: the corresponding risks are priced in currency markets

4 Dollar Risk

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.

4.1 Portfolios of Countries Sorted by Dollar Exposures

Lustig et al. (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.[10]

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 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

---

[10] Formally, the aggregate conditional dollar excess return is equal to $\left(-Dollar_{t+1}+\overline{r_t^i}-r_t\right)\times sign\left(\overline{r_t^i}-r_t\right)$.

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.

4.2 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.[11] 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 1 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 1 clearly shows that predicted

---

[11] 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 $E[R^e_{Dollar}] = \lambda$.

excess returns are aligned with their realized counterparts. An investor who takes on more dollar risk is rewarded by higher excess returns on average. The dollar risk is intuitive. 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 1 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.

At the annual frequency, 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. the different potential interpretation of those global shocks are interesting research avenues beyond the scope of this paper. Instead, the next section shows that the two risk factors offer a new set of stylized facts on exchange rates.

5 Implications and Additional Tests

This section builds on the previous empirical results and establishes three novel facts. First, global shocks account for a large share of bilateral exchange rate variations. This finding deepens the exchange rate volatility puzzle. Second, the carry and dollar factors describe exchange rate volatility changes, as implied by the model introduced in Section 2. Third, the share of systematic currency risk is a useful characteristic of exchange rates: it uncovers new links between co-movement in macro variables (like consumption and GDP growth) and exchange rates, as well as between capital flows and exchange rates.

5.1 Global Risk

I first estimate the share of dollar-based exchange rates driven by global shocks. In the data, the global shocks can be measured using long-short strategies. As noted in in Section 2, 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. Other base currencies offer a simple robustness check of this method: if the long-short strategies were not driven by global shocks, their associated return would not matter for non-dollar-based exchange rates.

Global Systematic Shocks in Bilateral Exchange Rates In order to focus on global risk factors in exchange rates, I therefore regress the changes in bilateral exchange rates on the conditional and unconditional carry factors and the global component of the dollar factor. Table 5 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 5 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 6 reports regression results similar to those in Table 5 but obtained for exchange rates expressed in Japanese Yen and in U.K. pound.

[Table 6 about here.]

Table 6 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 the Volatility 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 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 source of these differences, along with their impact on exchange rates, is the subject of ongoing research in international finance and international economics. 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, and Ready, Roussanov and Ward (2013) study different exposures to international commodity trade. All these papers offer interesting models to think about macroeconomic cross-country differences and exchange rate properties. The shares of systematic currency variation presented in this paper appear as a powerful link between exchange rates and macroeconomic quantities.

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[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: $Var[\Delta q^i_{t+1}] = Var[m^{real}_{t+1}] + Var[m^{real,i}_{t+1}] - 2cov(m^{real}_{t+1}, m^{real,i}_{t+1})$.

5.2 Systematic Currency Risk and World Comovement

The differences in currency systematic risk are indeed related to measures of comovement in macroeconomic quantities, such as real consumption and GDP growth rates, and even more strongly related to measures of comovement in capital flows.

Comovement of GDP and consumption In the language of the model in Section 2 , the share of world shocks vs country-specific shocks in each SDF is governed by the relative prices of the global (u^w and u^g) and local (u) shocks. In the international real business cycle literature, those shocks are related to fundamental macroeconomic variables: e.g., consumption growth or GDP growth. In such models, the importance of global shocks would therefore be linked to the comovement of output and consumption growth rates across countries. While direct links between bilateral changes in exchange rates and macroeconomic variables are difficult to establish empirically, the shares of systematic currency risk appear related to measures of comovement based on consumption and output growth.

As for exchange rates, the measure of comovement across countries is obtained as a simple adjusted R^2s on consumption and output growth rates or trade flows, derived from the following regression:

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

where Δy_{t+1} denotes the annual growth rate of real foreign consumption (or output) and Δy_{t+1}^{world} corresponds to the annual growth rate of the world consumption or output (e.g., measured as the sum of all consumption or output in OECD countries). The GDP and consumption series, measured at purchasing power parity, as well as the exports and imports, scaled by GDP, come from the World Bank and are available at an annual frequency. Adjusted R^2s on trade flows are derived similarly. The country averages of exports and imports divided by GDP, a measure of trade openness, are regressed on their world counterpart (obtained as the average across countries).

The different shares of systematic currency risk across countries appear significantly related to measures of 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, and $R_i^{2,X}$ denotes the share of systematic variation measured with macroeconomic variables. Panel I of Table 7 reports the slope coefficients (β) on this cross-country regression. The slope coefficients are all positive and significant. A large share of systematic variation in output or consumption growth is associated with a large share of systematic currency risk. Slope coefficients range between 0.45 and 0.6 across macroeconomic measures of comovement. The R^2s on the cross-country regressions, however, remain low. Differences in GDP, consumption and trade comovement explain only a limited part of the differences in the share of systematic currency risk.[13]

[Table 7 about here.]

Comovement of Capital Flows To the contrary, comovement among capital flows appear strongly related to the shares of systematic currency risk.

Capital flows are reported in the balance of payments of each country, more precisely in their financial accounts. Such accounts decompose capital flows into foreign direct investments, portfolio investments, other investments, and reserve assets. Other investments correspond to trade credits, loans, currencies and deposits, and other assets not classified elsewhere. Reserve assets correspond to gold, I.M.F. drawing rights and reserve positions, as well as currencies all held by monetary authorities. For each category, balance of payments report gross inflows and gross outflows: the former are net sales of domestic financial instruments to foreign residents,

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[13] The link between comovement in consumption growth and comovement in exchange rates can be interpreted in the reduced-from model of Section 2. Assuming that the reduced-form model starts from the SDF of representative agent with constant relative risk-aversion, then the log SDF is simply equal to the risk-aversion coefficient multiplied by consumption growth; SDF shocks are then related to consumption growth shocks (GDP growth shocks in an endowment economy). A consumption growth process in country i that is mostly driven by global consumption growth may correspond to a large loading (κ^i in the model) on global shocks. A high share of comovement in consumption growth would then relate to a high share of currency systematic risk.

while the latter are net purchases of foreign financial instruments by domestic residents.

A recent literature in international economics shows that gross outflows and inflows are more informative than net flows (see Lane and Milesi-Ferretti, 2007, Obstfeld, 2012, Forbes and Warnock, 2012, and Broner et al., 2013). Notably, Rey (2013) shows that gross outflow and inflows are highly correlated across countries, while net flows are not. I follow this literature and study the comovement among gross capital inflows and outflows, scaled by GDP.

The share of systematic variation of total capital outflows for a given country is measured as the R^2 of a regression of that country's total capital outflows on the first three principal components of all the other countries' capital outflows (excluding the U.S.). Similar shares of systematic variation are obtained for inflows, and for each category of capital inflows and outflows. Using the mean of all capital flows instead of the first three principal components leads to similar results. Averaging the capital inflows and outflows leads to a measure of financial openness, which is the counterpart to trade openness. Data come from the I.M.F. database and are compiled by Bluedorn, Duttagupta, Guajardo and Topalova (2013).[14] The series are quarterly, over the same 1983–2010 sample as the exchange rates.

The shares of systematic capital flow variation appear strongly related to the shares of systematic currency variation: Panel II of Table 7 reports the results from cross-country regressions of one on the other. The standard errors are obtained by bootstrapping the two stages of the estimation, using quarterly non-overlapping data. All the slope coefficients are positive and significant. A high share of systematic variation in exchange rates corresponds to a high share of systematic variation in total capital outflows, inflows, and their averages. Differences in capital flows account for up to 53% of the differences in systematic risk across currencies. As Figure 2 shows, this strong link is pervasive across countries; it is not driven by a few outliers. The U.K. actually appears as a sole outlier; U.K. capital flows are much more correlated with world flows than the pound is correlated with world currency factors. The singularity of the U.K.

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[14] The data set is built from balance of payments statistics (version 5), supplemented with other IMF and country sources. The data set does not include the Euro area, but includes its members. It does not report outflows and inflows related to the changes in reserves, but only the net flows. For this reason, they are not included in the subsequent analysis.

seems naturally linked to its role as world financial hub.

[Figure 2 about here.]

The strong link between capital flows and exchange rates can be traced back to the broad components of capital flows. While comovement in foreign direct investment does not explain much of the cross-country differences in systematic currency risk, comovement in portfolio and, particularly, other investments does. These findings are intuitive, as moments of prices should be related to moments of quantities. Yet, such simple relationships have been difficult to establish for exchange rates.

5.3 Systematic Variation in Exchange Rate Changes and Volatilities

This paper ends with a novel look at the reduced-form model presented in Section 2. While the model implied link between changes in exchange rates and their volatilities is not rejected in the data, some other aspects of the model need to be refined.

The findings in this paper imply large differences in the loadings of each bilateral exchange rates on the dollar factor. In the model, since the only source of heterogeneity is in the price of the global carry-related shocks (u^w), loadings on the dollar factor are very similar across countries. Simulations suggest that the loadings range from 0.86 to 0.9 with the calibration proposed in Lustig et al. (2013), while they range from 0.34 to 1.51 in the data for developed countries. Additional heterogeneity in the prices of the dollar-related global shocks (u^g) is needed. Moreover, the volatility of the dollar factor appears correlated to the volatility of the carry factor (0.5 in the data), suggesting that the price of dollar-related global shocks (u^g) must also exhibit a common component. These changes are simple to implement, but would obfuscate the model's intuition.

The model implies a strong link between shocks on exchange rate levels and shocks on exchange rate volatilities.[15] In the model, changes in volatilities are driven by the same shocks

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[15] Recall that the unexpected component of the change in bilateral exchange rates is:

$$\sqrt{\gamma z_t^i} u_{t+1}^i - \sqrt{\gamma z_t} u_{t+1} + \left(\sqrt{\delta^i z_t^w + \lambda z_t^i} - \sqrt{\delta z_t^w + \lambda z_t} \right) u_{t+1}^w + \sqrt{\kappa} (\sqrt{z_t^i} - \sqrt{z_t}) u_{t+1}^g .$$

u, u^i, and u^w that affect the changes in exchange rates. The global shocks u^g that are priced locally and account for a large share of the dollar factor do not impact the volatilities. The carry and conditional carry, as well as the changes in the volatilities of the carry and dollar factors, should be significantly linked to exchange rate volatilities. I check these predictions of the model. The monthly volatility of the exchange rate is obtained as the standard deviation of the daily changes in exchange rates. Since volatilities are persistent, changes in volatilities are regressed either on the carry and dollar factors (similar to the exchange rate level regressions) or on the change in the dollar and carry volatilities. In both cases, the tests control for the past value of the exchange rate volatility.

The carry and conditional carry factors appear jointly significant in 12 out of 13 developed countries at the 10% significance level. The dollar factor appears significant in only 2 cases. The R^2s range from 14% to 34%. The changes in volatilities of the dollar and carry factors, which exhibit a correlation of around 0.5, are jointly significant in all 13 cases. The share of systematic risk measured on exchange rate levels appear clearly related to the share of systematic risk measured on exchange rate volatilities. This result is consistent with previous findings: if the factors are orthogonal and exchange rate changes are *i.i.d*, then the significant factor decomposition on exchange rate changes at the daily frequency implies a similar decomposition in terms of exchange rate volatilities. The key assumption of the model — the same shocks driving both the state variables and the pricing kernels — is not rejected by the data. This assumption is a key element of most term structure models, suggesting that they constitute a potentially interesting starting point for modeling currency markets.

The conditional variance of the exchange rate changes, $E_t\left(\Delta s^i_{t+1} - E_t(\Delta s^i_{t+1})\right)^2$, is thus:

$$\sigma^2_{t,\Delta s^i_{t+1}} = \gamma(z^i_t - z_t) + \left(\sqrt{\delta^i z^w_t + \lambda z^i_t} - \sqrt{\delta z^w_t + \lambda z_t}\right)^2 + \kappa\left(\sqrt{z^i_t} - \sqrt{z_t}\right)^2.$$

6 Conclusion

This paper shows that bilateral exchange rates are driven by country-specific shocks, as well as two global risk factors. 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. Cross-currency differences in the shares of systematic variation appear related to the comovement of capital flows.

The findings are important for both academics and practitioners. For practitioners, they imply the need for global currency risk management. The decomposition of exchange rates in two risk factors simplifies optimal global 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.

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Table 1: 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:

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

where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i^\star_t - i_t$ is the interest rate difference 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 2: 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 1 for additional information.

Table 3: 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:

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

where where Δs_{t+1} denotes the bilateral exchange rate in foreign currency per U.S. dollar, and $i^{\star}_t - i_t$ is the interest rate difference 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 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 4 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: 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 4 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 6: 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 5 for the definition of the variables and the list of parameters reported. Note that, as in Table 5 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.

Table 7: Shares of Currency Systematic Variation and World Comovement

	Panel I: GDP , Consumption, and Trade		
	GDP	Consumption	Trade
β	0.61	0.44	0.45
s.e	[0.16]	[0.20]	[0.10]
R^2	23.68	11.26	17.32
s.e	[10.27]	[7.60]	[6.54]
N	36	35	38
	Panel II: Capital Flows		
	Outflows	Inflows	Average
	Foreign Direct Investment		
β	0.73	0.40	0.59
s.e	[0.11]	[0.10]	[0.10]
R^2	9.95	3.34	9.33
s.e	[7.85]	[5.93]	[6.40]
	Portfolio Investment		
β	0.90	0.27	0.73
s.e	[0.11]	[0.13]	[0.12]
R^2	32.91	1.56	24.55
s.e	[7.63]	[7.65]	[8.07]
	Other Investment		
β	0.81	1.04	0.98
s.e	[0.09]	[0.09]	[0.09]
R^2	33.72	43.94	46.78
s.e	[7.39]	[7.82]	[7.67]
	Total		
β	1.02	0.95	1.03
s.e	[0.10]	[0.11]	[0.10]
R^2	52.95	38.62	48.29
s.e	[9.13]	[9.06]	[9.14]
N	35	35	35

Notes: The table reports results from the following second-stage cross-country regressions:

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

In the first stage, $R_i^{2,FX}$ is obtained as the share of systematic variation in the exchange rate of country i measured by the carry and dollar factors as in Tables 1 and 2. Likewise, $R_i^{2,X}$ are obtained in tests of world comovement, using either GDP growth, consumption growth, trade openness (Panel I), or measures of capital flows (Panel II): each country's R^2 corresponds to a regression of that country's macroeconomic variable on a world aggregate (the OECD total in Panel I and the first three principal components in Panel II). Consumption and GDP series are expressed in purchasing power parity (PPP) dollars. Trade openness is measured as the average of imports and exports divided by GDP. Capital flows are expressed as percentages of GDP. The table reports the slope coefficients β, the standard errors, the cross-sectional R^2s (in percentage points), as well as the numbers of observations N (i.e., countries) of the second stage regression described above. R^2s on currencies are obtained on monthly series, while R^2s on capital flows are obtained on quarterly series. R^2s on macroeconomic variables (consumption and output) are obtained on annual series. The sample period is 11/1983–12/2010. The standard errors (s.e., reported between brackets) are obtained by bootstrapping the entire estimation (i.e., the two stages) on either annual (Panel I) or quarterly (Panel II) data.

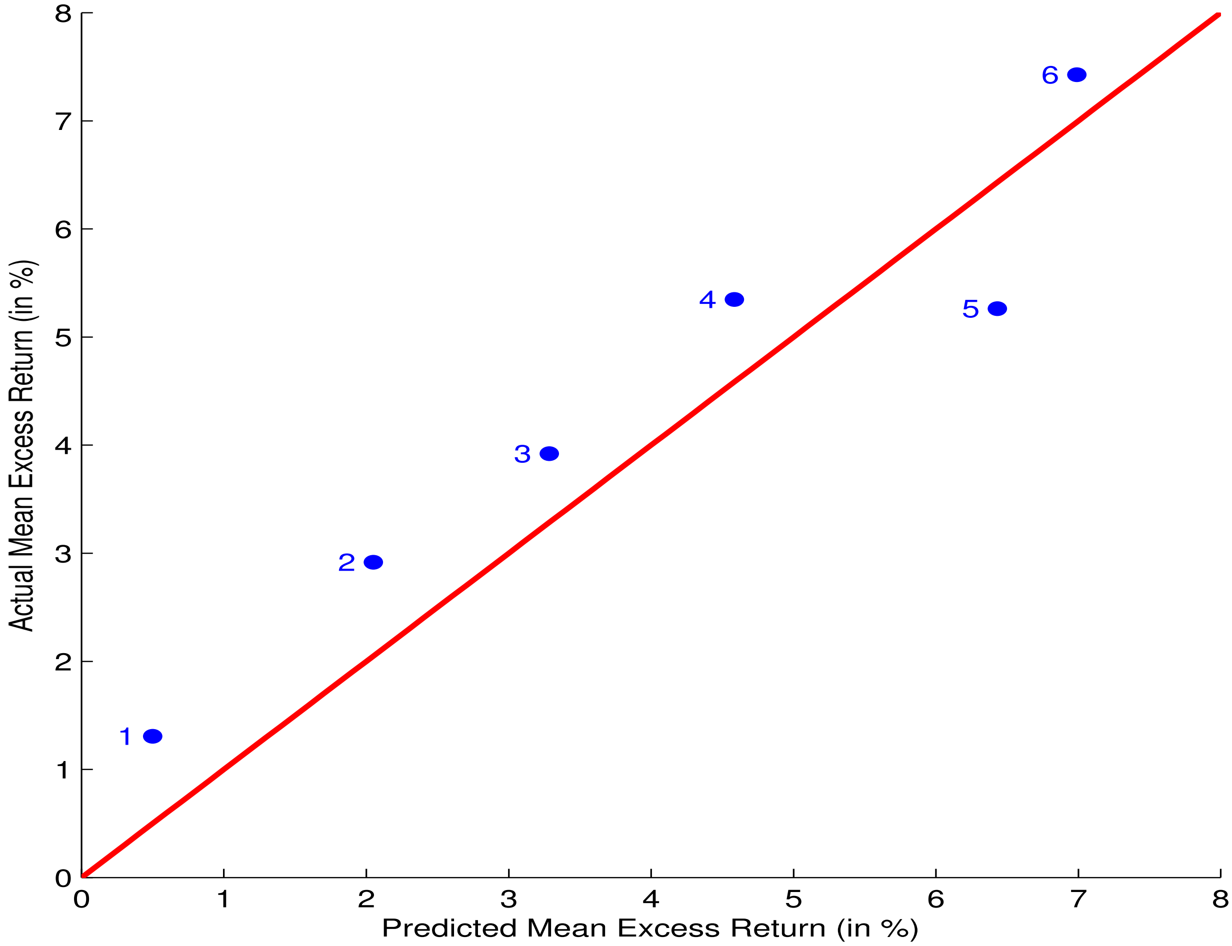

Figure 1: Realized vs. Predicted Excess Returns: Portfolios of Countries Sorted on Dollar Exposures

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.

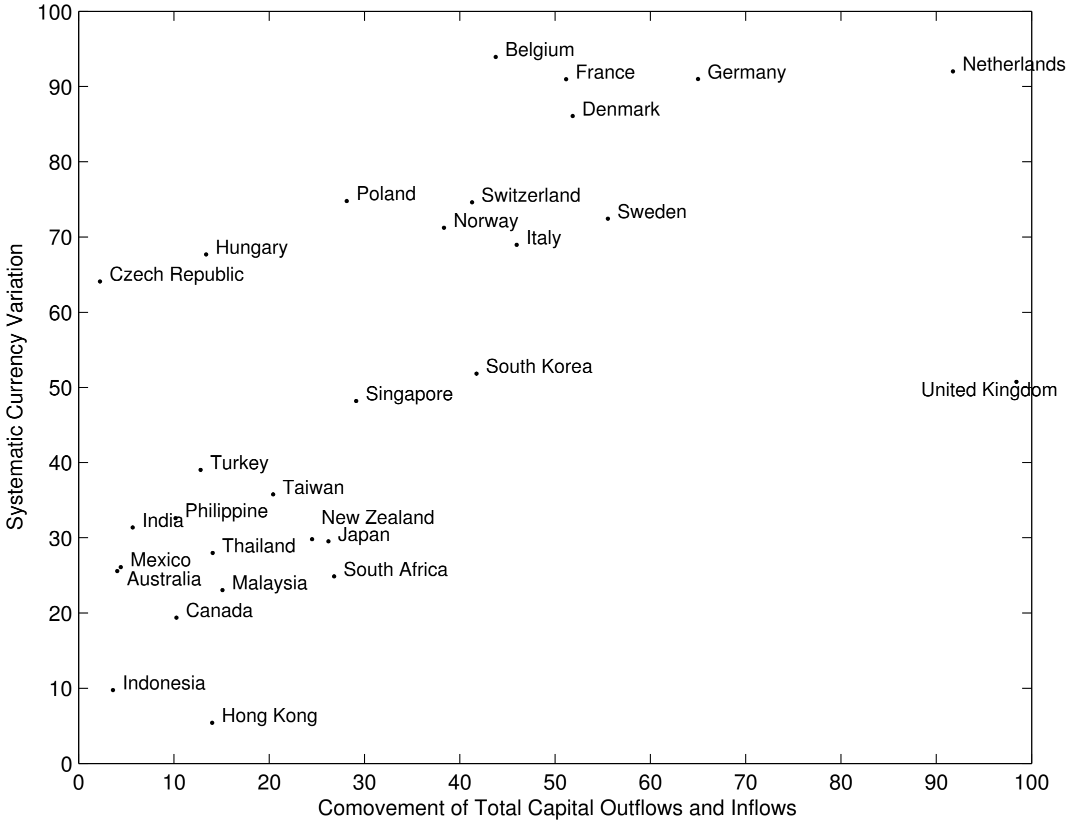

Figure 2: Systematic Currency Variation and International Capital Flows Comovement

The figure plots the share of systematic variation in the exchange rate of each country (on the vertical axis) as a function of the comovement of that country's capital flows with aggregate capital flows (on the horizontal axis). The shares of systematic variation in the exchange rates correspond to the R^2s of regressions of bilateral exchange rates on the carry and dollar factors, as reported in Tables 1 and 2. Comovement in capital flows for country i is measured as the R^2 of a regression of country i's capital flows on the first three components of all capital flows series (excluding the U.S.). Measures of capital flows correspond to the average of total inflows and total outflows scaled by GDP. Exchange rate data are monthly, while capital flows are quarterly. The sample period is 11/1983–12/2010.

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, 5, and 6 report regressions results for 13 developed countries, while Table 2 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.