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Huang, Huichou and MacDonald, Ronald

Adam Smith Business School, University of Glasgow

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Huichou Huang[†] Ronald MacDonald[‡]

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Abstract

This is the first study that employs option pricing model to measure the position-unwinding risk of currency carry trade portfolios, which covers moment information as the proxy for crash risk. I show that high interest-rate currencies are exposed to higher position-unwinding risk than low interest-rate currencies. I also investigate the sovereign CDS spreads as the proxy for countries' credit conditions and find that high interest rate currencies load up positively on sovereign default risk while low interest rate currencies provide a hedge against it. Sovereign credit premia as the dominant economic fundamental risk, together with position-unwinding likelihood indicator as the market risk (non-neutrality) sentiment, captures over 90% cross-sectional variations of carry trade excess returns. I identify sovereign credit risk as the impulsive country-specific risk that drives market volatility, and also the global contagion channels. Then I propose an alternative carry trade strategy that is immunized from crash risk, and a composite story of sovereign credit premia, global liquidity imbalances and liquidity reversal/spiral for explaining the forward premium puzzle.

JEL classification: F31, F37, G12, G13, G15.

Keywords: Carry Trades; Position-unwinding Risk; Sovereign CDS Spreads; Currency Options; Forward Premium Puzzle.

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[†]Corresponding author; Email: huichou.huang@exeter.oxon.org.

[‡]Department of Economics, Adam Smith Business School, University of Glasgow, Glasgow, G12 8QQ, United Kingdom.

1. Introduction

According to the Uncovered Interest Parity (UIP), if investors have rational expectations and are risk neutral, the changes in the bilateral exchange rates will eliminate the profit arising from the interest rate gap between these two countries. However, a substantive number of empirical studies show that the appreciations of low interest rate currencies do not compensate for the interest rate differentials. Instead, the high interest rate currencies tend to appreciate rather than depreciate. Carry trades, as one of the most popular trading strategies in foreign exchange (FX) market, explores the profits from the violation of UIP by investing in high interest rate currencies while financing in low interest rate currencies. The excess returns of carry trades give rise to the "forward premium puzzle" (Hansen and Hodrick, 1980; Fama, 1984), which is well documented for nearly 30 years. Given the high liquidity in global FX market and dismantling of international capital flow barriers, it's difficult to justify the unreasonably sustainable profits of carry trade strategies[1]. Time-varying risk premia is a straightforward and theoretically convincing solution towards this puzzle in the economic sense that high interest-rate currencies deliver high returns merely as a compensation for high risk exposures during the turmoil periods (Fama, 1984; Engel, 1996; Christiansen, Ranaldo, and Söderlind, 2011). Verdelhan (2010) shows that agents with Campbell-Cochrane preferences (Campbell and Cochrane, 1999) can generate notable deviation from UIP due to the consumption habit. Burnside, Eichenbaum, and Rebelo (2009) argue from the perspective of market microstructure that it's the adverse selection from which the forward premium arises.

[1]Although this type of trading strategies had suffered substantial losses since the outbreak of sub-prime mortgage crisis during 2007 (particularly after the bankruptcy of Lehman Brothers in the mid of September 2008, see Figure B.1. in Appendix B), it recovered soon around the mid of 2009 and the losses are relatively small compared to its historical cumulative returns (Brunnermeier, Nagel, and Pedersen, 2009).

Bansal and Dahlquist (2000) are the first to examine the cross-section relations between currency risk premia and interest rate differentials. They show that UIP works better for currencies that experience higher inflation rates. In more recent empirical literature, Lustig, Roussanov, and Verdelhan (2011) originally introduce portfolio-sorting approach by forward discounts into the study of currency carry trades. Instead of analyses on individual currencies, they focus on currency portfolios for the reason that sorting currencies into portfolios allow us to eliminate a large amount of country idiosyncratic characteristics, to overcome the problem that these characteristics are potentially time-varying with countries, and to concentrate on their common characteristics. For those currencies that Covered Interest Parity (CIP) holds, sorting by forward discounts is equivalent to sorting by interest rate differentials. The first two principal components of the excess returns of the these portfolios account for most of the time series variations. The first principal component (PC_1) is essentially the average excess returns of all portfolios, which can be interpreted as the average excess returns of a zero-cost strategy that an investor borrows in USD for investing in global money market outside U.S., so-called "dollar risk factor" (GDR). It is an intercept (level) factor because each portfolio shares roughly the same exposure to it. The second principal component (PC_2) is a slope factor in the sense that the weight of each portfolio, from the one containing the highest interest-rate currencies to the one made up of low interest-rate currencies, decreases monotonically from positive to negative. And it is very similar to the excess returns of another zero-cost strategy with long positions in highest interest-rate currencies funded by short positions in lowest interest-rate currencies. Hence, I call it "forward bias risk factor", denoted by HML_{FB}.

These two common factors are first documented in their paper as the key ingredient for a risk-based explanation of currency carry trades' excess returns. The risk factors identified by the data-driven approach are in line with Arbitrage Pricing Theory by Ross (1976) while other standard risk factors, such as consumption growth (Lustig and Verdelhan, 2007) measured by durable Consumption-based CAPM (CCAPM) setting of Yogo (2006), Chicago Board Options Exchange's (CBOE) VIX index as the measure of volatility risk, T-Bill Eurodollar (TED) Spreads as the illiquidity risk indicator, Pastor and Stambaugh's (2003) liquidity measure, and Fama and French (1993) factors, do not covary enough with the currency excess returns to explain them (Burnside, 2011; Burnside, Eichenbaum, Kleshchelski, and Rebelo, 2011). Based on the theoretical foundations of Merton's (1973) Intertemporal CAPM (ICAPM)[2], Menkhoff, Sarno, Schmeling, and Schrimpf (2012) propose the global volatility (innovation) risk (GVI) of FX market instead of HML_{FX} as the slope factor that, along with GDR as the level factor, also successfully explains the cross sectional excess returns of currency carry trades. They show that high interest-rate currencies deliver low returns in the times of high unexpected volatility while low interest-rate currencies offer a hedge against high volatility risk by yielding positive returns. However, none of these studies bridges the gap between currency risk premia and macroeconomic fundamentals.

One contribution of my research to asset pricing of currency carry trades is that I rationalize the carry trades' excess returns from the perspective of sovereign credit risk as the dominant macroeconomic fundamental (country-specific) risk, which is strongly supported by my empirical results. The investigation is well based on the theory of a country's external adjustment to the global imbalances through the valuation channel of exchange rates

[2]The ICAPM model assumes that investors are concerned about the state variables, which exert evolutionary influences on the investment opportunities set. Market-wide volatility (not the idiosyncratic volatility) is a good proxy for the investment sentiment of market states. As the result, a risk-averse agent wishes to hedge against unexpected changes (innovations) in market volatility, especially during the period of high unexpected volatility the hedging demand for assets that have negative exposures to systematic volatility risk drives up the prices of these assets. Campbell (1993), Ang, Hodrick, Xing, and Zhang (2006), Adrian and Rosenberg (2008) have made remarkable extensive researches on the volatility risk of stock markets.

(Gourinchas and Rey, 2007; Caballero, Farhi, and Gourinchas, 2008). Global imbalances are believed to be the crucial macroeconomic determinant of sovereign credit risk (Baek, Bandopadhyaya, and Du, 2005; Wu and Zhang, 2008; Hilscher and Nosbusch, 2010; Durdu, Mendoza, and Terrones, 2013) and therefore are priced in the term structure of sovereign CDS spreads (Pan and Singleton, 2008; Longstaff, Pan, Pedersen, and Singleton, 2011). Following this economic logic, I link the implicit sovereign default and recovery closely to the term structure of interest rates (Cox, Ingersoll, and Ross, 1985) to explain the forward premium anomalies (Backus, Foresi, and Telmer, 2001; Bekaert, Wei, and Xing, 2007; Ang and Chen, 2010). I name it "Joint (Affine) Term Structure Model", which shows that the short-term interest rates imply short-run market liquidity risk component and short-run sovereign credit risk components reflected by the corresponding CDS spreads. The sovereign component represents the short-term rollover risk of maturing debt and refinancing constraint (see Acharya, Gale, and Yorulmazer, 2011; He and Xiong, 2012 for the analyses of stock market). The currencies of debtor-countries offer risk premia to compensate foreign creditors who are willing to finance the domestic defaultable borrowings, such as current account deficits. The advantage of tracing sovereign risk by a country's CDS spreads rather than its Net International Investment Position[3] (NIIP) is that we cannot observe the net foreign assets in monthly frequency, but we can trade currencies on their sovereign CDS spreads daily. And the CDS market is very liquid, thereby is well-known for their efficiency in price discovery. The empirical findings of this paper also shed some light on the dynamic general equilibrium asset pricing model of exchange rates[4] that incorporates the global imbalances framework (Gourinchas and Rey, 2007; Caballero, Farhi, and Gourinchas, 2008) into the business cycle theory of sovereign default risk (Mendoza and Yue; 2008, 2012).

[3]The data are available from Lane and Milesi-Ferretti's (2007) website, and can be updated from IMF's official reported series in *International Financial Statistics* database.

[4]I name it Foreign Exchange Pricing Model, "FXPM" for abbreviation.

Furthermore, I argue that using a different slope factor instead of the forward bias risk constructed directly from the currency carry portfolios with a persistent monotonic excess returns pattern can remove the constraints on the intercept betas that $\beta_{g,1} = \beta_{g,5}$, and on the slope betas that $\beta_{c,5} - \beta_{c,1} = 1$. As the result, we are able to observe more reliable and accurate estimates on risk exposures of the lowest and highest interest-rate currencies portfolios. I will provide the evidence that we detect the higher interest-rate currencies are exposed to higher global (crash) risk by relaxing those two constraints. Sovereign credit risk is a even better alternative slope factor because it not only relaxes the estimation restrictions, but also itself possesses a traceable characteristic of risk against which we are able to hedge.

Another contribution of my research is that I originally use the extended version of classical option pricing model (Black and Scholes, 1973; Merton, 1974) for foreign exchanges by Garman and Kohlhagen (1983) to compute the position-unwinding likelihood indicator of carry trade portfolios, as motivated by Brunnermeier, Nagel, and Pedersen's (2009) story about the liquidity spirals and crash risk[5] of currency carry trades. That the crash (jump) risk is priced in currency excess returns is also stressed in other scholars' recent studies, such as Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009), Chernov, Graveline, and Zviadadze (2012). Moreover, in Farhi and Gabaix's (2008) theoretical model that option prices might in principle uncover latent disaster risk of exchange rates, I thereby adjust the position-unwinding likelihood indicator for skewness and kurtosis by Gram-Charlier expansion for standard normal distribution density function. The position-unwinding risk factor is highly correlated with the dollar risk factor, which may suggest

[5] Carry trades inject the liquidity into high interest-rate currencies that generates negative skewness of them relative to low interest-rate currencies. Plantin and Shin (2011) build a strategic games framework to demonstrate the destabilizing effect of currency speculative positions. As the result, when the liquidity eventually dries up, the high interest-rate currencies inevitably crash (dramatic depreciations relative to the low interest-rate currencies) as the bubble-correcting behavior of the market (Abreu and Brunnermeier, 2003).

that we model crash risk in the pricing of currency options. My position-unwinding likelihood indicator may also be deemed as additional supportive evidence for Brunnermeier, Nagel, and Pedersen's (2009) liquidity spiral story. Carry trade excess returns portray the "self-fulfilling[6]" story that investors boost the price (appreciation of a currency) and realize their profits by taking up carry positions. The liquidity will keep injecting into the high interest-rate currencies and create the negative skewness phenomenon against the low interest-rate currencies (and that's why the position-unwinding likelihood indicator is closely associated with the global skewness factor I constructed) as long as the position-unwinding likelihood does not exceed a critical value of sustainable "global liquidity imbalances", which is intimately related to the market sentiment and economic fundamentals, e.g. short-term and otherwise maturing external debts and the pledgeable value of external assets of a nation. When the line is crossed over, investors begin to unwind their positions as bubble correction behavior (Abreu and Brunnermeier, 2003), followed up by abrupt price reversal and liquidity withdrawal from the investors (Plantin and Shin, 2011). The liquidity will inevitably dries up, triggering the crash of a currency. This will be discussed in detail later in this paper. I develop an Intertemporal Trading Equilibrium Model (ITEM) in the other paper with skewness preference and learning behavior of a representative investor and show that betting against the UIP in an initial state of low position-unwinding likelihood can lead to excess but bounded accumulation of liquidity in a currency. The currency carry trades give rise to global liquidity transfer.

Furthermore, I show that the two-factor model of sovereign credit risk and position-unwinding risk has very well and robust performance in terms of cross-sectional pricing power in my data. Also following the economic intuition of the position liquidation story of currency crashes, I further con-

[6]It's similar to the concept of Obstfeld's (1996) currency-crisis model.

struct "semi-conditional[7]" skewness and kurtosis factors as proxy for crash risk. The global skewness factor again highly correlated with the dollar risk factor. The position-unwinding risk of carry trades is closely linked with the aggregate level of volatility and skewness risk in FX market. Position-unwinding likelihood indicator and global skewness risk as intercept factors[8] mutually confirm that crash risk is normally not the individual currency's behavior (unless there's a substantial idiosyncratic shock) but the systemic risk of the global market or the regionally integrated market that the currencies depreciate sharply against USD during the high volatility regime. Thus, I also suggest the position-unwinding likelihood indicator as the gauge of market risk appetite, and propose an alternative carry trade strategy that is immunized from crash risk by analyzing the threshold level of position-unwinding risk with a Smooth Transition Model (STR). This paper also leads to the development of a sovereign risk contagion model of exchange rates for dynamic hedging purpose that highlights the interactions between default arrival and systemic risk in a joint valuation framework of currency options and sovereign CDS contracts as the cross-sectional extension of Carr and Wu's (2007, 2010) pioneering work.

I also examine the robustness of my main findings in various specifications without altering their qualitative features: (i) Besides measuring the sovereign credit risk implied in currencies, I also use alternative measure by the government bonds, which explains the excess returns of currency carry trades as well as the factor directly measured by the currencies. (ii) I show that equity risk premium is not priced in currency carry trades by double sorting of the currencies on both sovereign CDS spreads and equity premia. (iii) I winsorize the sovereign credit series at 95% and 90% levels, and confirm that this factor does not represent a peso problem, even though the factor price of sovereign credit is statistically significant, about 3.3% per an-

[7] It assumes zero (unconditional) mean alike the realized volatility approach.

[8] Their correlations with PC_2 are consistently very low, see Table B.2..

num. (iv) I show that sorting currencies on their betas with sovereign credit risk is quite similar but not identical to those sorted on forward discounts. Currency portfolios doubly sorted on betas with both sovereign credit risk and position-unwinding risk also exhibit monotonic patterns in returns in both dimensions and are more close to currency carry portfolios. (v) Because the position-unwinding risk is not a return-based series, by building a factor-mimicking portfolio, I'm able to confirm its validity and reliability as an arbitrage-free traded factor. (vi) I verify that position-unwinding likelihood indicator is a good proxy for global crash risk by introducing two additional (moment) factors, global skewness and kurtosis risk. Moreover, I shows it's trivial to adjust the standard normal probability distribution for skewness and kurtosis in the option pricing model to compute the position-unwinding likelihood indicator of carry trade positions. (vii) I further check the quadratic effect of position-unwinding (crash) risk in pricing currency carry trades and find little improvement in cross-sectional R^2 of the factor model with a quadratic term. (viii) I compare the cross-sectional asset pricing power of my slope factor with volatility and liquidity factors (also as the country-specific risk) and show that the sovereign credit risk dominates both of them. (ix) I assess the abrupt changes in risk exposures of the currency carry portfolios in a two-state Markov regime-switching model with smoothed transition probabilities and find that linear factor model is good enough and nonlinearity does not matter much for cross-sectional asset pricing. (x) I investigate if my factors are capable of pricing the international bond and stock portfolios, and find that my factors also play pivotal roles in driving the risk premia across asset classes that position-unwinding risk of currency carry trades represents global crash risk while sovereign default risk not only is the dominating country-specific fundamental risk of both money and bond markets, but also closely linked to the global equity premia. This may imply that sovereign credit risk reflects the quality of the local investment opportunities and policy environment for the firms. (xi) I use both linear and nonlinear Granger causality test to analyze the dynamics among risk factors, and identify not only the sovereign credit risk as the impulsive factor that drives other country-specific factors, such as volatility and liquidity risk, but also the spillover channel of the contagious country-specific risk to the global economy, and accordingly propose the practice of a currency trading strategy that carry positions are immunized from crash risk through the analysis of the threshold level of position-unwinding likelihood indicator.

This paper is organized as follows: Section 2 introduces the measure of position-unwinding risk of carry trades by crash-risk adjusted currency option pricing model. Section 3 bridges the affine term structure model of interest rates and that of sovereign CDS spreads, and provides the theoretical foundation for sovereign credit premia based on existing theories of global imbalances and international external adjustments. Section 4 provides the information about the data set used in this paper, the approach for currency portfolio-sorting, and the construction of risk factors. In Section 5, I introduce the linear factor model and the estimation methodologies. In Section 6, I show and discuss the empirical results, including alternative measure of sovereign credit risk, and factor-mimicking portfolio of position-unwinding risk. I also compare the asset pricing performance of my risk factors with other factors, such as equity premium risk, volatility risk, and liquidity risk. A composite story of sovereign credit premia, global liquidity imbalances, and liquidity reversal/spiral is proposed for explaining forward premium puzzle. Section 7 contains several additional robustness checks for my findings, including Markov regime-switching risk exposures, peso problem in sovereign default risk, beta-sorted portfolios, quadratic effect of position-unwinding risk, and investigation in international bond and equity markets. In Section 8, I then test the factor dynamics by both linear and nonlinear Granger causality tests. A financial application of currency trading strategy is also shown in this section. Conclusions are drawn in Section 9. The main findings of this paper are delegated to Appendix A while Appendix B is complementary for additional interests in the intermediates of the empirical tests.

2. Measuring Position-unwinding Risk

Carry trades as a very popular strategy in FX market, have experienced several times[9] of "dramatic position-unwinding" in the past 30 years. Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) find that standard business cycle risk factors are unable to account for these major shortfalls of carry trades. Using the currency options to protect the downside risk, they construct hedged carry positions and show that the payoffs to this hedged strategy are very close to those of the unhedged carry trades. This result may imply the mispricing of currency options (particularly those trading away from money) used for hedging the carry positions as pointed out by Farhi and Gabaix (2008) that option might in principle uncover latent disaster risk. Because if the crash risk of the underlying is ignored or underestimated, a currency option would be significantly undervalued, and in this situation the payoffs to the hedged carry trades could be different from those of the unhedged positions. This difference in the between unhedged and hedged carry trade portfolios can be justified as the variance risk premium (Carr and Wu, 2009; Londono and Zhou, 2012), the skewness risk premium (Kozhan, Neuberger, and Schneider, 2012), or even the kurtosis risk premium[10]. Jurek (2007) shows that the excess returns of a crash-neutral currency carry position are statistically indistinguishable from zero. In this sense, I put forward a measure of position-unwinding risk of currency carry trades from the option pricing model and argue that one way to understand the excess returns of

[9]They're around the second quarter of 1986 - the mid of 1986, the last quarter of 1987 - the first quarter of 1988, the mid of 1992 - the mid of 1993, the first quarter of 1995, the mid of 1997 - the mid of 1998, the mid of 2008 - the mid of 2009.

[10]Moment risk premia are measured as the differences between the realized moments and the option-implied risk neutral moments (see Breeden and Litzenberger, 1978).

the carry trades lies in the changes in the non-risk-neutral market sentiment of the probability that the positions might be unwound.

I build the position-unwinding likelihood indicator in the similar way to Vassalou and Xing's (2004) for evaluating the default risk premia in equity returns. The differences are: First, they use Black-Scholes option pricing formula (Black and Scholes, 1973) while my computation is based on Garman and Kohlhagen's (1983) version for currency option valuation. Second, their strike prices are the book value of firm's liabilities as in Merton's (1974) paper while I set the strike prices to be the forward rate so that both of the CIP and UIP are embodied in the Garman-Kohlhagen currency option pricing model. Third, the higher moments, such as skewness and kurtosis are ignored in these option pricing models. However, for the currency carry trades, Brunnermeier, Nagel, and Pedersen (2009) show a negative cross-sectional correlation between interest rate differentials and empirical skewness, also the implied (risk neutral) skewness of the out-of-money option "risk reversals". The tail risk is of paramount importance for illuminating currency crash premia (Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan, 2009) and the jump risk account for 25% of the total currency risk, and as high as 40% during the turmoil periods (Chernov, Graveline, and Zviadadze, 2012). They also show that the probability of depreciation jump of a currency is positively associated with the increase in its interest rate. Moreover, that agents are averse to kurtosis, which measures the dispersion of the extreme observations from the mean, is shown consistent with Dittmar's (2002) nonlinear pricing kernel framework. Hence, I adjust Garman-Kohlhagen currency option pricing model in an economically intuitive way by introducing the third and fourth moments as the higher order terms expansion.

2.1. Currency Option Pricing Model

It is assumed that the spot rates S_t of a currency pair (indirect quotes[11]) follows a geometric Brownian motion (GBM) of the form with an instantaneous drift μ and an instantaneous volatility σ:

$$\mathrm{d}S_t = \mu\, S_t\, \mathrm{d}t + \sigma\, S_t\, \mathrm{d}W \tag{1}$$

where W is the standard Wiener process. Then the value of the spot rates at any time $t{+}T$ is given by:

$$\ln S_{t+T} = \ln S_t + \left(\mu - \frac{\sigma^2}{2}\right) T + \sigma\, \sqrt{T}\, \varepsilon_{t+T} \tag{2}$$

where

$$\varepsilon_{t+T} = \frac{W(t+T) - W(t)}{\sqrt{T}} \quad \text{and} \quad \varepsilon_{t+T} \sim \mathcal{N}(0,1) \tag{3}$$

$\mathcal{N}(0,1)$ is the Gaussian *i.i.d.* standard normal distribution. The value of a call option for a currency pair with the strike price of X_t and the time to maturity of T at time t is:

$$c_t = S_t\, \exp(-r_{d,t}\, T)\, \mathbb{N}(d_1) - X_t\, \exp(-r_{f,t}\, T)\, \mathbb{N}(d_2) \tag{4}$$

For the put option:

$$p_t = X_t\, \exp(-r_{f,t}\, T)\, \mathbb{N}(-d_2) - S_t\, \exp(-r_{d,t}\, T)\, \mathbb{N}(-d_1) \tag{5}$$

where

$$d_1 = \frac{\ln(S_t/X_t) + \left(r_{d,t} - r_{f,t} + \frac{1}{2}\, \sigma^2\right) T}{\sigma\, \sqrt{T}} \quad \text{and} \quad d_2 = d_1 - \sigma\, \sqrt{T} \tag{6}$$

[11] Units of foreign currency per unit of domestic currency (USD).

$r_{d,t}$, $r_{f,t}$ denotes domestic (U.S.) risk-free interest rate, and foreign risk-free interest rate, respectively. $\mathbb{N}(\cdot)$ is the cumulative density function of standard normal distribution. Now, we turn to the application of this model for evaluating the position-unwinding risk.

2.2. Position-unwinding Likelihood Indicator

Under the condition that CIP holds, we have:

$$1 + r_{d,t} = (1 + r_{f,t})\,\frac{S_t}{F_t} \tag{7}$$

F_t is the forward rate with the same maturity of T as $r_{d,t}$ and $r_{f,t}$. Therefore, $\ln F_t - \ln S_t \simeq r_{f,t} - r_{d,t}$. When $r_{f,t} > r_{d,t}$, implying $F_t > S_t$, that a U.S. investor takes a carry position to short USD for longing foreign currencies is equivalent to betting on $S_{t+T} < F_t$. This means the future sport rate of USD will not appreciate as much as the CIP predicts or even will depreciate because of the failure of UIP, which claims that $S_{t+T} = \mathbb{E}_t[S_{t+T}|S_t] = F_t$. If the U.S. investor does not enter a forward contract for the carry position he's already taken, the amount of the assets in USD on his wealth balance sheet will be $(1 + r_{f,t})\,S_t/S_{t+T}$ while $1 + r_{d,t}$ is the amount of USD-denominated liabilities that he has to pay back at $t{+}T$. Thus, if it turns out $S_{t+T} \geq F_t$ at time $t{+}T$, the U.S. investor will go bankrupt and have to liquidate his carry position. Then, the position-unwinding probability of a currency pair i at t is the probability that the S_{t+T} will be greater than the F_t.

$$\psi_{t+T} = \Pr\,(S_{t+T} \geq F_t \mid S_t) = \Pr\,(\ln S_{t+T} \geq \ln F_t \mid \ln S_t) \tag{8}$$

We can rewrite position-unwinding risk for any long position of carry trades by plugging Equation (2) into Equation (8):

$$\psi_{t+T} = \Pr\left(\ln S_t - \ln F_t + \left(\mu - \frac{\sigma^2}{2}\right)T + \sigma\sqrt{T}\,\varepsilon_{t+T} \geq 0\right) \tag{9}$$

Equation (9) can be rearranged as below:

$$\psi_{t+T} = \Pr\left(-\frac{\ln(S_t/F_t) + \left(\mu - \frac{1}{2}\,\sigma^2\right) T}{\sigma\,\sqrt{T}} \leq \varepsilon_{t+T} \right) \tag{10}$$

Similarly, the position-unwinding probability for any short position in a currency pair i at t is given by:

$$\psi_{t+T} = \Pr\left(-\frac{\ln(S_t/F_t) + \left(\mu - \frac{1}{2}\,\sigma^2\right) T}{\sigma\,\sqrt{T}} \geq \varepsilon_{t+T} \right) \tag{11}$$

I define the distance to "bankrupt" (DB) for a FX trader, then the position-unwinding risk for a single currency pair is computed as follows::

$$DB_{t+T} = -\frac{\ln(S_t/F_t) + \left(\mu - \frac{1}{2}\,\sigma^2\right) T}{\sigma\,\sqrt{T}} \tag{12}$$

$$\psi_{t+T} = \begin{cases} 1 - \Pr\left(DB_{t+T}\right) & \text{if the currency is in long position;} \\ \Pr\left(DB_{t+T}\right) & \text{if the currency is in short position.} \end{cases} \tag{13}$$

where $\Pr\left(DB_{t+T}\right) = \mathbb{N}(DB_{t+T})$. DB_{t+T} tells us by how many standard deviations the log of the ratio of S_t/F_t needs to deiate from its mean in order for the "bankruptcy" to occur. Notice that value of the currency option does not depend on μ but DB_{t+T} does. This is because DB_{t+T} is determined by the future spot rates given in Equation (6). At time $t{+}T$, I use the conditional mean μ_{t+T} over a period of T from time t for the estimation of μ, and the realized volatility (conditional σ_{t+T}) over a period of T from time t for the estimation of σ, as we allow for time-varying risk premia (Fama, 1984; Engel, 1996; Christiansen, Ranaldo, and Söderlind, 2011).

So far, I use the theoretical distribution implied by classical option pricing models, which is standard normal distribution. However, $\mathbb{N}(\cdot)$ does not represent the true probability distribution of the currency returns because the tail risk of the currencies (skewness and kurtosis) is considerably significant. Noting that the first four moments of the underlying asset's distribution should capture most of the information for option valuation (Jarrow and Rudd, 1982), the standard definition of Hermite Polynomials (Stuart and Ord, 2009) series is truncated after its fourth term for the skewness-and-kurtosis augmented probability density function of standard normal distribution (see Backus, Foresi, and Wu, 2004):

$$h(z) = n(z)\left[1 - \frac{\varsigma}{3!}\,H_3(z) + \frac{\kappa}{4!}\,H_4(z)\right] \tag{14}$$

where

$$H_a(z)\,n(z) = (-1)^a\,\frac{\mathrm{d}^a n(z)}{\mathrm{d}z^a} \tag{15}$$

Equation (14) can be rewritten as:

$$h(z) = n(z)\left[\,1 - \frac{\varsigma}{3!}(z^3 - 3z) + \frac{\kappa}{4!}(z^4 - 6z^2 + 3)\,\right] \tag{16}$$

$n(z)$ is the probability density function of standard normal distribution. a represents the order of the moment. ς, κ denotes the excess skewness, and excess kurtosis, respectively. They're estimated by the methods of "realized" moments, assuming zero (unconditional) mean of daily returns, which is similar to realized volatility (see e.g. Andersen, Bollerslev, Diebold, and Labys, 2001). The details will be discussed in Section 5. z here is actually the values of DB_{t+T}. Hence, the skewness-and-kurtosis adjusted $\Pr(DB_{t+T})$ is:

$$\Pr(z) = \int_{-\infty}^{z} h(z)\mathrm{d}z = \mathbb{N}(z) + \left[\,\frac{\varsigma}{3!}(z^2 - 1) + \frac{\kappa}{4!}(3z - z^3)\,\right]\cdot n(z) \tag{17}$$

As the historical observations of the position-unwinding behavior of carry trades is a collapse across these currency portfolios, we then compute the aggregate level of the position-unwinding risk for the whole FX market:

$$PUW_{t+T} = \frac{1}{K_{t+T}} \sum_{i=1}^{K_{t+T}} \psi_{i,t+T} \tag{18}$$

where K_{t+T} is the number of the currencies available at time $t+T$. Strictly speaking, PUW_{t+T} is not a "bankruptcy" probability faced by the FX traders because it does not correspond to the true probability of unwound positions in large observations across business cycles. Therefore, I call PUW_{t+T} the "position-unwinding likelihood indicator", which corresponds to the excess returns of currency carry trades over the period of T from time t. Reassuringly, I will show that it's a good proxy for currency crash risk in Section 5, confirmed by the global skewness (GSQ) factor. And it's robust to the unadjusted PUW since the adjustment for both skewness and kurtosis is trivial compared with the magnitude of probability distribution. Global kurtosis (GKT) risk seems to be a unique factor containing information that is not covered by crash risk factors but useful for understanding the cross-sectional carry trade excess returns.

3. Sovereign Credit Premia

In this section, I provide the theoretical foundations that link the excess returns of currency carry trades to the sovereign credit premia through two ways. I develop a joint (affine) term structure model of interest rates and sovereign CDS spreads that not only decomposes (short-term) interest rates into short-run and medium-run components, but also embeds a sovereign credit risk element into the classical affine term structure model. I also count on an economic methodology from existing literature on global imbalances that underscores the valuation channel of a nation's net foreign asset holdings towards exchange rate adjustments.

3.1. A Joint Term Structure Model

There are two types of term structure models: One is affine for interest rates, which is commonly harnessed for explaining forward premium anomaly (the failure of UIP); another is for credit spreads, which is rarely linked to the study of forward premium anomaly.

3.1.1. Interest Rates

Backus, Foresi, and Telmer (2001) characterize the forward premium anomaly in the context of affine term structure of interest rates and reveal that several alternative models all have serious shortcomings in depicting the behavior of both exchange rates and interest rates. Bekaert, Wei, and Xing (2007) show that imposing the Expectation Hypothesis of Term Structure affects the currency risk premium. Clarida, Sarno, Taylor, and Valente (2003) propose a Markov (Regime)-Switching Vector Equilibrium Correction Model (MS-VECM) that captures the nonlinearity of exchange rate dynamics, which is forecast by the term structure of interest rates. The model is shown outperforming both random walk and linear VECM.

3.1.2. Credit Spreads

Diebold, Li, and Yue (2008) propose a global dynamic version of Nelson-Siegel term structure model (Nelson and Siegel, 1987) of sovereign spreads which also allows for country-specific factor and explains a large fraction of the yield curve dynamics. Pan and Singleton (2008) explore the nature of the default arrival and recovery/loss implicit in the term structure of sovereign CDS spreads and find positive evidence for informational efficiency and the close linkage between the unpredictable component of the credit events and the measures of global risk aversion, financial market volatility, and macroeconomic policy. Wu and Zhang (2008) reveal the determinants of the term structure of the credit spreads (both sovereign and corporate), such as macroeconomic fundamental and financial market volatility. Positive inflation and real output growth shocks increases the sovereign spreads. But those of the low credit-rating classes are suppressed by the shocks.

All these literature suggests the implicit sovereign credit risk component in the interest rates. Because sovereign credit premia not only is the medium to long run risk but also more importantly represent the short run rollover risk of maturing debt and refinancing constraint (see Acharya, Gale, and Yorulmazer, 2011; He and Xiong, 2012 for the analyses of stock market), the short-term interest rate thereby can be decomposed into the short-term market liquidity premium component and short-term sovereign credit premium component for bridging the global liquidity imbalances (first component) and sovereign default risk (second component) with the excess returns of currency carry trades. Introducing the model is not the purpose of this paper, thereby it is not formulated and discussed in detail here.

3.2. Valuation Channel of Global Imbalances

Gourinchas and Rey (2007) show that the external imbalances must predict either future portfolio returns on net foreign assets and/or future current account surplus (net export growth). A country currently running net external debt will inevitably experience a depreciation in its currency that is attributable to international financial adjustments through the balance of sheet effect of intertemporal budget constraint. Exchange rates not only adjust through bilateral trade channel (Obstfeld and Rogoff, 1995) but also open a valuation channel on the external assets and liabilities (e.g. Net International Investment Position) that transfer wealth from creditor countries to debtor countries. They find that external imbalances predict the exchange rates at 1-quarter horizon ahead and beyond. Abhyankar, Gonzalez, and Klinkowska (2011) manage to price a large proportion of the variation in the cross-sectional excess returns (quarterly) of currency carry portfolios using conditioning information of a forward-looking net foreign assets via a standard C-CAPM.

Moreover, some recent studies reveal that market attitude towards crash risk (e.g. Baek, Bandopadhyaya, and Du, 2005), macroeconomic fundamentals (e.g. the volatility of terms of trades; see also Hilscher and Nosbusch, 2010) and financial fragility (e.g. Ang and Longstaff, 2011) are well embodied by sovereign debt/CDS spreads (Borri and Verdelhan, 2011) in terms of statistical and economic significance. Durdu, Mendoza, and Terrones (2013) also show that the solvency of nations responds sufficiently to the external adjustments, suggesting that sovereign spreads plays a role of "meta information"[12] about external imbalances. Caceres, Guzzo, and Segoviano Basurto (2010) further accentuate the proper management of the debt sustainability and sovereign balance sheets as the necessary conditions for preventing the sovereign credit risk from feeding back into broader financial instability. Sovereign spreads thereby contain complex information for the valuation of currency risk premia in response to external adjustments of a nation. Caballero, Farhi, and Gourinchas (2008) propose another analytical framework of global imbalances that emphasizes the countries' ability to produce financial assets for global savers/insurers. Alvarez, Atkeson, and Kehoe (2009) point out that the risk premium of a currency pair is approximately equal to its interest rate differential. All these further suggest a plausible linkage between currency premia and sovereign credit risk that a domestic country with high sovereign default risk inclines to offer higher interest rate to attract foreign savings for funding its external deficit. Following this logic, we would expect a strong relationship between the premia of carrying a currency and the sovereign credit risk.

[12] It refers to the concept of the information on information in informatics.

4. Data, Portfolio Sorting and Risk Factors

My data set, obtained from Bloomberg and Datastream, consists of spot rates and 1-month forward rates with bid, middle, and ask prices, 1-month interest rates, 5-year sovereign CDS spreads, at-the-money (ATM) option 1-month implied volatilities, 25-delta out-of-the-money (OTM) option 1-month risk reversals and butterflies of 35 currencies: EUR (EMU), GBP (United Kingdom), AUD (Australia), NZD (New Zealand), CHF (Switzerland), CAD (Canada), JPY (Japan), DKK (Denmark), SEK (Sweden), NOK (Norway), ILS (Israel), RUB (Russia), TRY (Turkey), HUF (Hungary), CZK (Czech Republic), SKK (Slovakia), PLN (Poland), RON (Romania), HKD (Hong Kong), SGD (Singapore), TWD (Taiwan), KRW (South Korea), CNY (China), INR (India), THB (Thailand), MYR (Malaysia), PHP (Philippines), IDR (Indonesia), MXN (Mexico), BRL (Brazil), ZAR (South Africa), CLP (Chile), COP (Colombia), ARS (Argentina), PEN (Peru), all against USD (United States); and corresponding countries' equity indices (MSCI) and government bond total return indices (Bank of American Merrill Lynch and J.P. Morgan TRI)[13] in USD.

My sample period is restricted by the availability of sovereign CDS historical data which only dates back to 2004 for my sample countries, according to CMA Datavision[14]. Although the data from Markit[15] date back to 2001, they're unavailable to academia yet. To keep the best consistency of time frame across assets, the sample period is chosen from September 2005 to

[13]There are 26 countries' data available: EMU, Great Britain, Australia, New Zealand, Canada, Switzerland, Norway, Sweden, Denmark, Russia, Turkey, Hungary, Czech Republic, Poland, Japan, South Korea, Hong Kong, Taiwan, Singapore, China, India, Malaysia, Thailand, Indonesia, South Africa, and Mexico. China and India are only available from July 2007.

[14]CMA Datavision is the world's leading source of independent accurate OTC market pricing data and technology provider, typically specializing in the sovereign CDS pricing.

[15]Markit is also a leading global financial information services provider of independent data, valuation and trading process across all asset classes, also with a specialization in CDS data.

January 2013 in daily frequency. Furthermore, there is no existing sovereign CDS for EMU as the whole, thus I calculate its proxy spread as the external-debt weighted sovereign CDS spreads of EMU's 13 main member countries, Germany, France, Italy, Spain, Netherland, Belgium, Austria, Greece, Portugal, Ireland, Slovenia, and Luxembourg, which account for over 99% of the EMU's GDP on average in my sample period.

4.1. Portfolio Sorting

All currencies are sorted by forward discounts from low to high, and allocated to five portfolios, e.g. Portfolio 1 (C_0) consists of the short position of currencies with lowest 20% interest-rate differentials (lowest forward discount) while Portfolio 5 (C_5) is the long position of currencies with highest 20% interest-rate differentials (highest forward discounts). The portfolios are rebalanced at the end of each forward contract according to the updated forward rate. The average monthly turnover ratio of five portfolios is about 25%, thereby the transaction costs should be considered for evaluating carry trade excess returns. The log excess returns of a long position xr^L_{t+1} at time $t+1$ is computed as:

$$xr^L_{t+1} = r_{f,t} - r_{d,t} + s^B_t - s^A_{t+1} = f^B_t - s^A_{t+1} \tag{19}$$

f, s is the log forward rate, and spot rate, respectively; Superscript B, A denotes bid price, and ask price respectively. Similarly, for short position the log excess returns xr^S_{t+1} at the time $t+1$:

$$xr^S_{t+1} = -f^A_t + s^B_{t+1} \tag{20}$$

Currencies that largely deviate from CIP are removed from the sample for the corresponding periods[16]: IDR from the end of December 2000 (September

[16] ZAR from the end of July 1985 to the end of August 1985, MYR from the end of August 1998 to the end of June 2005, TRY from the end of October 2000 to the end of

2005 in my data) to the end of May 2007, THB from the end of October 2005 to March 2007, TWD from March 2009 to January 2013. And due to the managed floating exchange rate regime of CNY, I also exclude it for the whole sample periods. Table A.1. below shows the descriptive statistics of currency carry portfolios.

[**Insert Table A.1. about here**]

C_1 is C_0 is long position. The statistics of portfolio mean, median, and standard deviation in excess returns all exhibit monotonically increasing patterns. We also see a monotonically decreasing skewness from C_1 to C_5, except that the skewness of C_4 is a little bit higher than that of C_5, probably due to the time span limitation. I will show in the empirical tests section that the position-unwinding risk matches with the skewness of excess returns of each carry trade portfolios. The unconditional average excess returns is 2.33% per annum from holding the equally-weighted foreign-currency portfolio, reflecting the low but positive risk premium demanded by the U.S. investors for investing in foreign currencies. There is a sizeable spreads of 7.33% per annum between C_5 and C_0. The currency carry portfolios are adjusted for transaction costs which is quite high for some currencies (Burnside, Eichenbaum, and Rebelo, 2007). Monthly excess returns and factor prices are annualized by 12, and standard deviation by $\sqrt{12}$. All return data are in percentages unless specified. The Sharpe ratios are not as high as usual because my data span the recent financial crunch period. Please also refer to Figure B.1. for the cumulative excess returns of five currency carry portfolios (long positions) in the sample period. The cumulative excess returns of carry trades plummeted during the 2008 crisis but the positions recovered soon after a few months, especially for the high interest-rate countries.

November 2001, UAE (United Arab Emirates) from the end of June 2006 to the end of November 2006. These currencies or periods are not included in my data.

4.2. Risk Factors

I also follow Lustig, Roussanov, and Verdelhan (2011) to construct the dollar risk factor (GDR) and forward bias risk factor (HML_{FB}):

$$GDR = \frac{1}{5}\sum_{j=1}^{5} PFL_{FB,j} \tag{21}$$

$$HML_{FB} = PFL_{FB,5} - PFL_{FB,0} \tag{22}$$

GDR has a correlation of 0.99 with PC_1 and is almost uncorrelated with PC_2 in my data. HML_{FB} is 0.90 correlated with PC_2, however, remains a considerable correlation of 0.39 with PC_1[17]. Therefore, strictly speaking, it's not a pure slope factor. However, its correlated part may offer valuable information about the contagious country-specific risk that may spill over and contaminate the global economy.

In addition, I demonstrate the construction of other risk factors used in this paper, including the factors of sovereign credit risk, equity premium risk, currency crash risk, volatility risk, and liquidity risk.

4.2.1. Sovereign Credit

Foreign investors require a compensation for a sudden devaluation of the local currency when default on government bond occurs. If the sovereign credit risk explains the cross-section of the excess return of currency carry trades, then high sovereign CDS-spread currencies are expected to be associated with high interest rates and tend to appreciate against low sovereign CDS-spread currencies that are expected to accompanied with low interest rates. The sovereign CDS spreads data are of 5-year (medium-term) duration. This implies that the short-term interest rates may embody the both

[17]See Table B.1. for principal component analysis of currency carry portfolios, and Table B.2. for the correlations between risk factors and principle components.

short-run and medium-run risk components of sovereign credit conditions reflected in corresponding CDS spreads[18] (see my Joint Affine Term Structure Model), which are well-known for the efficiency in price discovery since the CDS market is very liquid. The currencies of debtor-countries offer risk premia to compensate foreign creditors who are willing to finance the domestic defaultable borrowings, such as current account deficits. I evaluate sovereign default risk by the excess returns of a strategy that invests in the highest $\frac{1}{3}$ sovereign default risk currencies funded by the lowest $\frac{1}{3}$ sovereign default risk currencies as Fama and French (1993) did for their size (market capitalization) factor:

$$HML_{SC} = PFL_{SC,H} - PFL_{SC,L} \tag{23}$$

Sovereign credit risk has a correlation of 0.71 with PC_2, and is almost orthogonal to PC_1 (with a correlation of 0.08); Thereby, it can be regarded more rigorously as a slop factor. Since it is positively correlated with the slope factor, the factor price of sovereign credit risk is expected to be positive. And ideally, high interest-rate currencies are positively exposed to sovereign credit risk while low interest-rate currencies with negative exposures provide a hedge to it (see principal component analysis of currency carry portfolios in Table B.1.).

4.2.2. Equity Premium

Foreign investors require a compensation for the risk of possible poor economic performance in the future to hold the local-currency denominated stock shares in a distressed market, which is usually accompanied with low interest rate. To check if any compensation for this type of risk is implied in currency excess return as well, it's necessary to probe into the average

[18] The sovereign credit story does not necessarily suggest the comovement of short-term interest rates with the medium-term interest rates, which are supposed to covary with the medium-term sovereign CDS spreads to eliminate any arbitrage opportunity.

excess return differences among the portfolios that are doubly sorted on both sovereign CDS spreads and equity premia over U.S. market. Constrained by the availability of the currencies, I sort the currencies into 3×3 portfolios. Each dimension is partitioned into three portfolios, containing the currencies with the sort base in ascending order, denoted by "L" for low level, "M" for medium level, and "H" for high level of either sovereign CDS spreads or equity premia. This approach matches the currency sorting on sovereign default risk above:

$$HML_{EP} = PFL_{EP,H} - PFL_{EP,L} \tag{24}$$

Figure B.2. shows a very intriguing pattern that the equity premium risk seems to be priced in currency excess returns. A U.S. investor is compensated in terms of the appreciation of the local currency, not only for holding equities in a distressed market but also for investing in a boom equity market, which might be rationalized as a compensation for the crash risk of bubbles in a overheated economy. As the result, we do not see any favourable monotonic pattern of excess returns in equity premia dimension. These also provide additional supportive evidence for U.S. investors to at least fully hedge or probably overhedge the currency exposures of their international equity holdings (see Campbell, Serfaty-de Medeiros, and Viceira, 2010). Clearly, on the other hand, we observe a monotonic increase in excess returns of the currency portfolios sorted by sovereign CDS spreads in ascending order.

4.2.3. Position-unwinding Risk and Currency Crashes

In the research of Andersen, Bollerslev, Diebold, and Labys (2001) and Menkhoff, Sarno, Schmeling, and Schrimpf (2012), volatility risk is measured with "realized" or "semi-conditional" feature that assumes zero unconditional mean of daily returns. This assumption embeds the martingale properties in daily return series. I follow this method to construct two factors that measure the crash risk in FX market. At time $t+T$, the realized moments, realized volatility ($\hat{\sigma}_{t+T}$), realized (excess) skewness ($\hat{\varsigma}_{t+T}$), and realized (excess) kurtosis ($\hat{\kappa}_{t+T}$) over the period of T (time-to-maturity of the forward contract) for individual currency i are modelled as:

$$\hat{\sigma}_{i,t+T} = \sqrt{\frac{1}{T_\tau}\sum_{\tau=t}^{T_\tau} r_{i,\tau}^2} \tag{25}$$

$$\hat{\varsigma}_{i,t+T} = \frac{1}{T_\tau}\frac{\sum_{\tau=t}^{T_\tau} r_{i,\tau}^3}{\sigma_{i,t}^3} \tag{26}$$

$$\hat{\kappa}_{i,t+T} = \frac{1}{T_\tau}\frac{\sum_{\tau=t}^{T_\tau} r_{i,\tau}^4 - 3}{\sigma_{i,t}^4} \tag{27}$$

where $r_{i,\tau}$ represents daily returns and T_τ is the number of trading days available over the period of T from t. We substitute the annualized values[19] of $\hat{\sigma}_{i,t+T} \cdot \sqrt{N_\tau}$ and $\hat{\mu}_{i,t+T} \cdot N_\tau$ in to Equation (12) for the calculation of distance to "bankrupt", which is then the input of Equation (13). By combining it with the adjusted values of $\hat{\varsigma}_{i,t+T} \,/\, \sqrt{T_\tau}$ and $\hat{\kappa}_{i,t+T} \,/\, T_\tau$ as the inputs[20] of Equation (17), we get the position-unwinding likelihood indicator $\hat{\psi}_{i,t+T}$ for individual currency. Finally, we can compute the aggregate level of position-unwinding risk PUW by Equation (18). As shown in Figure A.1., position-unwinding likelihood indicator is closely associated with dollar risk (with a high negative correlation of -0.92) and with forward bias risk (with a correlation of -0.42). Therefore, I expect negative exposures of currency carry portfolios to PUW and a negative factor price.

[Insert Figure A.1. about here]

There are amplitude of literature that stresses the role of skewness in asset pricing exercise. Kraus and Litzenberger (1976) show that investors

[19] N_τ is the number of trading days in a year and then $T = \frac{1}{12}$ in Equation (12).

[20] Time-aggregation scaling adjustments are necessary to match the statistical moment estimates with the option pricing model over the forward contract maturity T, based on the assumption of *i.i.d.* returns.

are in favour of positive return skewness under most preferences. As the result, it's rational to require more compensation for assets with negative return skewness. Grounded in Merton's (1973) ICAPM where skewness is also viewed as state variable that characterize investment opportunities, **?** (2009), and Chang, Christoffersen, and Jacobs (2013) find strong evidence in the cross-sectional pricing power of skewness on excess returns in stock market. Now I apply their thoughts to FX market.

Emphasized by Harvey and Siddique (2000) that the skewness of the returns distribution is also important for asset pricing, typically the crash risk for currency carry trades (Brunnermeier, Nagel, and Pedersen, 2009; Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan, 2009), I also construct two other moment factors for measuring currency crash risk (besides the position-unwinding likelihood indicator) in the way that is grounded in the theories of moment risk premia developed by Carr and Wu (2009), Neuberger (2012). We can simply take the average of individual currency's skewness and the changes in kurtosis at aggregate level as Equation (18) does.

$$GSQ_{t+T} = \frac{1}{K_{t+T}} \sum_{i=1}^{K_{t+T}} \left(\frac{\hat{\varsigma}_{i,t+T}}{\sqrt{T_\tau}} \right) \tag{28}$$

and

$$GKT_{t+T} = \frac{1}{K_{t+T}} \sum_{i=1}^{K_{t+T}} \left(\frac{\Delta\hat{\kappa}_{i,t+T}}{T_\tau} \right) \tag{29}$$

The skewness does not need to be signed by the interest rate differentials or equivalently to forward premium/discount, because skewness is associated with interest rate differential (Brunnermeier, Nagel, and Pedersen, 2009). For instance, the excess returns of low interest-rate currencies[21] exhibit negative skewness and vice versa for high interest rate currencies. If crash risk explains

[21] The exchange rates are in indirect quotes against USD, hence they have negative interest rate differentials.

carry trade excess returns, the portfolios are expected to have negative exposures to the global skewness factor and the factor price should be negative. The global kurtosis factor is constructed to match the concept of crash risk. Positive excess kurtosis is also called Leptokurtic distribution (characterized by high peak and fat tail relative to standard normal distribution) in which volatility is driven by a few extreme events, and vice versa for Platykurtosis (negative excess kurtosis). Table A.2 below shows the comovement of global skewness and kurtosis risk with dollar risk. PUW has a high positive correlation with GSQ of 0.85. Since GSQ directly measures the tail risk associated with the implied position, PUW possesses the consistent economic intuition of crash risk. Because the position-unwinding risk is closely associated with the skewness of the portfolio excess returns which is shown highly related to the interest rate differentials (see Brunnermeier, Nagel, and Pedersen, 2009), it's straightforward to expect portfolio with higher interest-rate currencies has higher exposure to PUW. GKT is regarded as the volatility of volatility, and hence constructed as the complementary measure to volatility risk gauged by the second moment.

[**Insert Figure A.2. about here**]

I also construct the aggregate-level moment risk premium factors, i.e. variance risk premium, skewness risk premium, and kurtosis risk premium, as the difference between the realized moments (ex-post realizations) and its corresponding option-implied risk neutral moments (ex-ante expectations)[22]. They reflect the risk premia charged by investors on the relevant risk exposures. But I find little evidence of the cross-sectional pricing power by these moment risk premium factors at aggregate level. The result for moment risk premia is not reported in this paper but I will be glad to provide on request.

[22]The implied skewness $\tilde{\varsigma} \approx 4.4478 \cdot RR_{25\Delta} \,/\, IV_{ATM}$, and the implied kurtosis $\tilde{\kappa} \approx 52.7546 \cdot BF_{25\Delta} \,/\, IV_{ATM}$, where $RR_{25\Delta}$, $BF_{25\Delta}$, and IV_{ATM} denotes 25-delta (OTM) risk reversals, 25-delta (OTM) butterflies, and ATM implied volatility (see Breeden and Litzenberger, 1978).

4.2.4. *Volatility and Liquidity*

I employ Menkhoff, Sarno, Schmeling, and Schrimpf's (2012) innovations of an AR(1) process (GVI) in the global FX volatility (GVL) as the proxy for volatility risk in FX market, and compare it with the simple changes in Chicago Board Options Exchange's (CBOE) VIX index (ΔVIX) that is adopted e.g. by Ang, Hodrick, Xing, and Zhang (2006).

$$GVL_{t+T} = \frac{1}{T}\sum_{\tau \in T}\left(\frac{1}{K_\tau}\sum_{i \in K_\tau}|r_{i,\tau}|\right) \tag{30}$$

where K_τ denotes the number of currencies available on day τ. I then resort to a market microstructure approach that measures illiquidity risk in FX market as the global relative FX bid-ask spreads (GLR) (see also Menkhoff, Sarno, Schmeling, and Schrimpf, 2012), and compare it with the changes in T-Bill Eurodollar (TED) Spreads Index (ΔTED)[23] as used e.g. by Brunnermeier, Nagel, and Pedersen (2009).

$$GLR_{t+T} = \frac{1}{T}\sum_{\tau \in T}\left[\frac{1}{K_\tau}\sum_{i \in K_\tau}\left(\frac{S^A_{i,\tau} - S^B_{i,\tau}}{S^M_{i,\tau}}\right)\right] \tag{31}$$

Superscript M denotes mid price of spot rates. This measure is grounded in Glosten and Milgrom's (1985) theory that is the first to investigate the adverse selection behavior in transactions. They show that informational asymmetry leads to positive bid-ask spreads. Amihud and Mendelson (1986) further set forth a model that predicts the market observed expected returns as an increasing and concave function of the bid-ask spreads, wherein expected holding periods play a vital role. Amihud (2002) show that expected excess returns in equity markets represents an illiquidity premium[24].

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[23] Originally, it is a 3-month index. Thus, it has to be divided by $\frac{1}{3}$ to match the monthly excess returns.

[24] The difference is that he measures illiquidity as the average daily ratio of absolute return to dollar volume across stocks. But measurement is not exploitable for FX market since it is a highly liquid market with massive daily trading volume. Instead, I adopt

5. Linear Factor Model and Methodology

In this section, I introduce the linear factor model for time-series and cross-sectional analyses of the tested assets, and the econometrics methodology to estimate the model.

5.1. Linear Factor Model

This section briefly summarizes the methodologies used for risk-based explanations of the currency carry trades' excess returns. The benchmark asset pricing Euler equation with a stochastic discount factor (SDF) implies the excess returns must satisfy (Cochrane, 2005) the no-arbitrage condition:

$$\mathbb{E}_t[m_{t+1} \cdot xr_{j,t+1}] = 0 \tag{32}$$

$\mathbb{E}[\,\cdot\,]$ is the expectation operator with the information available at time t. The unconditional moment restrictions is given by applying the law of iterated expectations to Equation (32):

$$\mathbb{E}[m_t \cdot xr_{j,t}] = 0 \tag{33}$$

The SDF takes a linear form of:

$$m_t = \xi \cdot [\,1 - (f_t - \mu^*)'\,b\,] \tag{34}$$

where ξ is a scalar, f_t is a $k \times 1$ vector of risk factors, $\mu^* = \mathbb{E}[f_t]$, and b is a conformable vector of factor loadings. Since ξ is not identified by Equation (34), I set it equal to 1, implying $\mathbb{E}[m_t] = 1$. Rearranging Equation (33) with Equation (34) gives:

$$\mathbb{E}[xr_t] = \mathrm{cov}[xr_t\, f_t'] \cdot b \tag{35}$$

relative bid-ask spread approach.

or

$$\mathbb{E}[xr_{j,t}] = \underbrace{\text{cov}[xr_{j,t}, f_t]\,\Sigma_{f,f}^{-1}}_{\beta_j} \cdot \underbrace{\Sigma_{f,f}\, b}_{\lambda} \tag{36}$$

where $\Sigma_{f,f} = \mathbb{E}[(f_t - \mu^*)(f_t - \mu^*)']$. Equation (36) is the beta representation of the asset pricing model. β_j is the vector of exposures of portfolio j to n risk factors, it varies with the portfolios. λ is a $k \times 1$ vector of factor prices associated with the tested risk factors, and all portfolios confront the same factor prices. The beta representation of the expected excess returns by my two-factor linear model can be written as:

$$\mathbb{E}[xr_{j,t}] = \beta_{j,PUW} \cdot \lambda_{PUW} + \beta_{j,SC} \cdot \lambda_{SC} \tag{37}$$

The subscripts denote the corresponding risk factors. Theoretically s-peaking, the higher position-unwinding risk (PUW), the lower expected excess returns of the currency carry trades. Thereby, we expect negative betas (β_{PUW}) and negative factor price (λ_{PUW}) across all portfolios. However, the exposures to the sovereign credit risk (HML_{SC}) vary across the portfolios. If its factor price (λ_{SC}) is positive, high expected excess-return portfolios should have a positive beta (β_{SC}) while low expected excess-return portfolios with a negative beta provide a hedge against sovereign credit risk.

5.2. Estimation Methodology

I reply on two procedures for the parameter estimates of the linear factor model: Generalized Method of Moments (Hansen, 1982), as known as "GMM", and Fama-MacBeth (FMB) two-step OLS approach (Fama and MacBeth, 1973).

5.2.1. Generalized Method of Moments

In the first procedure, I estimate the parameters of the SDF, b, and μ^* using the GMM and the moment restrictions in Equation (35) which can be rewritten as:

$$\mathbb{E}\{xr_t \cdot [\,1 - (f_t - \mu^*)'\, b\,]\} = 0 \tag{38}$$

The GMM estimators of μ^* and b are $\hat{\mu}^* = \bar{f}$ and:

$$\hat{b} = \left(\hat{\Sigma}'_{xr,f}\, W_N\, \hat{\Sigma}_{xr,f}\right)^{-1} \hat{\Sigma}'_{xr,f}\, W_N\, \overline{xr} \tag{39}$$

where $\hat{\Sigma}_{xr,f}$ is the sample covariance matrix of xr_t and f_t, W_N is a weighting matrix, $\overline{xr}$ is the sample mean of excess returns. Then the estimates of factor prices λ are $\hat{\lambda} = \hat{\Sigma}_{f,f}\, \hat{b}$, where $\hat{\Sigma}_{f,f}$ is the sample covariance matrix of f_t. Following Burnside (2011), I include an additional set of corresponding moment restrictions on the factor mean vector and factor covariance matrix:

$$g(\phi_t, \theta) = \begin{bmatrix} xr_t \cdot [\,1 - (f_t - \mu^*)'\, b\,] \\ f_t - \mu^* \\ (f_t - \mu^*)(f_t - \mu^*)' - \Sigma_{f,f} \end{bmatrix} = 0 \tag{40}$$

where θ is a parameter vector containing $(b, \mu^*, \Sigma_{f,f})$, ϕ_t represents the data (xr_t, f_t). By exploiting the moment restrictions $\mathbb{E}[g(\phi_t, \theta)] = 0$ defined by Equation (40), the estimation uncertainty[25] is thus incorporated in the standard errors of λ, and this method of point estimates is identical to that of Fama-MacBeth two-pass OLS approach (as discussed in Burnside, 2011). The standard errors are computed based on Newey and West's (1987) VARHAC procedure with the data-driven approach of Andrews's (1991) optimal number of lags selection in a Bartlett kernel. In the first stage of GMM estimator, $W_N = I_n$; In the subsequent stages of GMM estimator, W_N

[25] It is due to the fact that factor mean vector and covariance matrix have to be estimated.

is chosen optimally. The empirical results for the first stage GMM and the iterate-to-convergence GMM are reported.

5.2.2. Fama-MacBeth Approach

Additionally, I report the empirical results from the second procedure of FMB estimates. The first step is a time-series regression of each portfolio's excess returns on proposed risk factors to obtain corresponding risk exposures:

$$xr_{j,t} = \alpha_j + \beta_{j,PUW}\, PUW_t + \beta_{j,SC}\, HML_{SCt} + \varepsilon_{j,t} \tag{41}$$

where $\varepsilon_{j,t}$ is $i.i.d.$ $(0, \sigma^2_{j,\varepsilon})$. The second step is a cross-sectional regression of each portfolio's average excess returns on the estimated betas from the first step to get the risk prices:

$$\overline{xr}_j = \hat{\beta}_{j,PUW} \cdot \hat{\lambda}_{PUW} + \hat{\beta}_{j,SC} \cdot \hat{\lambda}_{SC} \tag{42}$$

Since PUW has no significant cross-sectional relation with the currency carry portfolios, it seems to serve as a constant that allows for a common mispricing term[26]. Therefore, I do not include a constant in the second pass of FMB. The estimates of the risk prices from FMB is numerically identical to those from GMM. The standard errors adjusted for measurement errors by Shanken's (1992) approach are also reported besides Newey and West (1987) VARHAC standard errors with automatic lag length selection (Andrews, 1991).

The predicted expected excess returns by the model is thereby $\hat{\Sigma}_{xr,f}\, \hat{b}$ and the pricing errors are the model residuals $\hat{\varepsilon} = \overline{xr} - \hat{\Sigma}_{xr,f}\, \hat{b}$. Then a statistic for over-identifying restrictions $N\, \hat{\varepsilon}'\, V_N^{-1}\, \hat{\varepsilon}$ can be constructed to test the null hypothesis that all pricing errors across portfolios are jointly zero, where N is

[26] See also Burnside (2011); Lustig, Roussanov, and Verdelhan (2011) on the issue of whether or not to include a constant.

the sample size, V_N is a consistent estimate of asymptotic covariance matrix of $\sqrt{N}\,\hat{\varepsilon}$ and its inverse form is generalized. The test statistic is asymptotic distributed as χ^2 with $n-k$ degrees of freedom. I report its p-values based on both Shanken (1992) adjustment and Newey and West's (1987) approach for FMB procedure, and the simulation-based p-values for the test of whether the Hansen-Jagannathan (Hansen and Jagannathan, 1997) distance ($HJ-dist$) is equal to zero[27] for the GMM procedure. The cross-sectional R^2 and Mean Absolute Errors (MAE) are also reported. When factors are correlated, we should look into the null hypothesis test $b_j = 0$ rather than $\lambda_j = 0$, to determine whether or not to include factor j given other factors. If b_j is statistically significant (different from zero), factor j helps to price the tested assets. λ_j only asks whether factor j is priced, whether its factor-mimicking portfolio carries positive or negative risk premium (Cochrane, 2005).

6. Empirical Results

In this section, I show and discuss the empirical results from the asset pricing tests. Beware of the factor prices that are all annualized. By using a different slope factor rather than the forward bias risk constructed directly from the currency carry portfolios with a persistent monotonic excess returns pattern, we no longer need to constrain the intercept betas that $\beta_{g,1} = \beta_{g,5}$, and the slope betas that $\beta_{c,5} - \beta_{c,1} = 1$. As the result, we are able to observe more objective estimates on risk exposures of the lowest and highest interest-rate currencies portfolios. The following paragraphs will reveal that the higher interest-rate currencies are exposed to higher global (crash) risk, which is not detectable when imposed with above two constraints.

[27]For more details, see Jagannathan and Wang (1996); Parker and Julliard (2005).

6.1. *Sovereign Credit As the Dominant Fundamental Risk*

The top panel of Table A.2. shows the asset pricing results with GDR and HML_{SC}. The highest interest-rate currencies are positively exposed to sovereign credit risk and the low interest-rate currencies offer a hedge against it. The risk exposures are monotonically increasing with the interest rate differentials. The cross-sectional R^2 is very high, about 0.933[28]. The coefficients of β, b and λ are all statistically significant. The price for sovereign credit risk is 3.287% per annum, and the Mean Absolute Error (MAE) is about 30 basis points (bps), which is very low. The $p-values$ of χ^2 tests from Shanken (1992) and Newey and West (1987) standard errors, and those of the $HJ-dist$ (Hansen and Jagannathan, 1997) all suggest to accept the model. By using alternative slope factor to relax the constraints on βs of the lowest and highest interest-rate currencies portfolios, we are able to detect that the exposures to the global risk increase with the interest rate differentials. Since the interest rate differentials covary with skewness of the portfolio excess returns, the global risk represents the crash risk and this can be confirmed by my other two risk factors PUW and GSQ.

[**Insert Table A.2. about here**]

Table A.3. below shows the the asset pricing results with GDR and HML_{PC}, which is the principal component of HML_{SC} and HML_{FB}. So HML_{PC} can be deemed as the proxy for sovereign credit risk as well. The empirical results are very similar to those obtained from using the direct sovereign credit risk measure, except for a little higher factor price of 5.695% per annum and an even higher R^2 of 0.968. This might mean that there is informational "noise" captured by HML_{SC} that is not valuable for explaining currency carry trade excess returns. However, I will verify that this noisy component is not useless in the next test. The model is also confirmed correct

[28]So do the time-series R^2s that are persistently over 0.90 across portfolios.

by χ^2 and $HJ - dist$ tests, with a MAE of about 19 bps. The price of the dollar risk almost remains the roughly same, 2.388% per annum.

[Insert Table A.3. about here]

To circumvent the multicollinearity problem, I add the orthogonal component ($HML_{SC_\perp}$) of HML_{SC} to HML_{PC} into above model. As shown in Table A.4., I get an R^2 of nearly 1.00 with a MAE of only 8 bps, and a smaller price of HML_{PC} (3.96% per annum), which is normal when including an additional factor $HML_{SC_\perp}$ that is not correlated with the existing factors and simultaneously has additional explanatory power. Intriguingly, the orthogonal component is priced cross-sectionally with a negative (-1.25% per annum) and statistical significant factor price. This means HML_{SC} has additional valuable information that is not captured by HML_{FB}. Isolating the "noisy" component ($HML_{SC_\perp}$) from HML_{SC} better explains the currency carry trade excess returns because the portfolios do not share the same degree of sensitivity to each component of HML_{SC}, i.e. HML_{PC} and $HML_{SC_\perp}$, in terms of risk exposures.

[Insert Table A.4. about here]

When I substitute $HML_{SC_\perp}$ with the orthogonal component ($HML_{FB_\perp}$) of HML_{FB} to HML_{PC}, I again get very similar results, which suggest there is no additional valuable information in HML_{FB} that is not captured by HML_{SC} for cross-sectional explanation of currency carry trade excess returns. These findings confirms that sovereign credit risk is a good substitutive slope factor. It's even better than the forward bias risk because it not only relaxes the estimation restrictions, but also has a traceable characteristic of risk against which we are able to hedge. A theoretical ground to rationalize these findings is that the short-term interest rates imply both short-run and medium-run risk components of sovereign credit conditions reflected in the corresponding CDS spreads as described in my Joint Affine Term Structure

Model, which are well-known for the efficiency in price discovery since the CDS market is very liquid. The currencies of debtor-countries offer risk premia to compensate foreign creditors who are willing to finance the domestic defaultable borrowings, such as current account deficits.

6.2. Alternative Measure of Sovereign Credit Risk

Clarida, Davis, and Pedersen (2009) find a significant comovement between currency risk premia and yield curve risk premia that drive the bond yields of the countries comprising the currency pairs in the carry trade portfolios. Therefore, I also resort to government bond for alternative measure of sovereign credit risk by sorting government bond total return indices into five portfolios based on their respect redemption yields. By doing this, I not only can form the government bond portfolios for robustness test later, but also can evaluate the sovereign credit risk from the excess returns of a total-return-index investment strategy that holds long positions in the highest 20% sovereign default risk government bonds funded by the lowest 20% sovereign default risk government bonds:

$$HML_{GB} = PFL_{GB,H} - PFL_{GB,L} \tag{43}$$

In Figure A.3. as shown below, we can see the inextricably tied-up fluctuations of the three factors, HML_{FB}, HML_{SC}, and HML_{GB}, implying that the forward premia may, to some degree, represent sovereign credit risk, which could be the dominant source of country-specific fundamental risk priced in cross section of currency carry trade excess returns[29]. The correlation between HML_{SC} and HML_{GB} is 0.96, which mutually manifests that my measures are valid for evaluating sovereign credit risk and the short-term

[29] In time-series analysis, both HML_{SC} and HML_{GB} cannot outperform HML_{FB} in pricing the currency carry portfolios since the forward bias risk is directly constructed from the portfolios themselves. And these portfolios already shows a persistently monotonic pattern in excess returns.

exchange rates move in the directions to compensate for sovereign credit risk.

[**Insert Figure A.3. about here**]

The bottom panel of Table A.2. shows the asset pricing results with GDR and HML_{GB}. Again, we can see monotonic exposures of the currency carry portfolios to HML_{GB}. My alternative measure of sovereign credit risk from government bonds total return indices has slightly higher cross-sectional pricing power (an R^2 of 0.952). There is prevailing practice among the investors to fully hedged the currency exposures implicit in their international bond holdings. In my case, when holding high sovereign default risk currency denominated bonds, the investors still confronts a high probability of large currency devaluations that may not yet be compensated by the bond yields. However, it seems that in short run the demand for the government bond holders to hedge currency devaluation risk is small because high sovereign default risk currency tends to appreciate in short run, according to the high correlation between HML_{SC} and HML_{GB}. This is consistent with Campbell, Serfaty-de Medeiros, and Viceira's (2010) findings. Again, the coefficients of β, b and λ are all statistically significant. The price for sovereign credit risk implied in government bond is much higher, 9.544% per annum; and the Mean Absolute Error (MAE) is still low, about 27 bps. The $p-values$ of χ^2 tests from Shanken (1992) and Newey and West (1987) standard errors, and those of the $HJ-dist$ (Hansen and Jagannathan, 1997) all suggest to accept the model correct. These results add additional credibility on the measure of sovereign credit risk and its cross-sectional pricing power.

Since my two-factor model explains over 90% of the cross-sectional variance of the currency carry trade excess returns, it's reasonable to believe that one solution towards forward premium puzzle is sovereign credit premia, even in short run. Because sovereign credit premia not only reflect a country's medium to long run risk, but also indicate the short-run rollover risk of maturing sovereign debt, which would particularly be exacerbated during the market liquidity deterioration (see Acharya, Gale, and Yorulmazer, 2011; He and Xiong, 2012 for the analyses of stock market). From a bilateral angle, a high forward-premium currency (home currency) does not depreciate as much as predicted by UIP, or even tends to appreciate because it relatively high interest rate implies higher sovereign credit risk than that of the foreign currency. So I propose to measure the effective interest rate of a currency, which equals to the observed interest rate subtracted by the sovereign credit risk in terms of a rate, instead of using the observed interest rate directly. If the sovereign credit story holds, a high interest-rate currency may actually have a smaller "effective" interest rate differential so that it does not appreciate as much as UIP predicts, or may even have a negative "effective" interest rate differential so that it depreciates against what we view as a low interest-rate currency. The corresponding effective forward premium is the observed forward premium minus the relative sovereign default risk, then it might become a good predictor of future spot rate movements. Meanwhile, the excess liquidity (or the insufficient liquidity on the other side of a currency pair) arises from the carry trade activities, namely "global liquidity imbalances", is also priced in the short-term observed interest rates.

6.3. Forward Position-unwinding Premia

To show that the position-unwinding likelihood indicator is a good measure of global (crash) risk, I run time-series and cross-sectional regressions of currency carry portfolios on PUW and HML_{SC}, which is my benchmark model.

[Insert Table A.5. about here]

As shown in Table A.5. above, the higher skewness (crash risk) of the excess returns' distribution (see Table A.1.), the higher position-unwinding risk of the corresponding carry trade position, in terms of factor exposures. Brunnermeier, Nagel, and Pedersen (2009) find a strong correlation between the interest rate differential and the crash risk measured by skewness of individual currency, which is further conformed by the carry trade portfolios conducted in asset pricing literature, e.g. Lustig, Roussanov, and Verdelhan (2011), Menkhoff, Sarno, Schmeling, and Schrimpf (2012). My data also exhibits very similar results except that the skewness of the fourth currency carry portfolio is slightly higher than that of the fifth one, possibly owing to the fact that the time span of my data is not long enough. Nevertheless, we may still reach a quite robust conclusion that the higher interest-rate currencies are exposed to higher position-unwinding risk when allocated into the carry trade portfolios, as the correlation between interest rate differentials and the skewness of the excess returns' distribution is well established. I will show that this conclusion is also robust to using the global skewness factor (GSQ) as the proxy for crash risk (in the horse race section), and the PUW_{CR} that is unadjusted for skewness and kurtosis (see the top panel of Table A.6.).

[**Insert Table A.6. about here**]

In both cases, the coefficients of β, b and λ are all statistically significant. The prices for position-unwinding risk are consistently negative as expected, -19.019% per annum for PUW and -19.156% per annum for PUW_{CR}, respectively. The R^2s are 0.924 and the MAEs are also approximately the same, about 32 bps. The $p-values$ of χ^2 tests from Shanken (1992) and Newey and West (1987) standard errors, and those of the $HJ-dist$ (Hansen and Jagannathan, 1997) all suggest to accept the model, suggesting that the model is correct. These empirics add additional credibility on the measure of position-unwinding risk and its cross-sectional pricing power.

My position-unwinding risk factor is concordant with the liquidity spiral story of Brunnermeier, Nagel, and Pedersen (2009). Investors boost the price (appreciation of a currency) and realize their profits by taking up carry positions. The liquidity will keep injecting into the high interest-rate currencies and create the negative skewness phenomenon against the low interest-rate currencies (and that's why the position-unwinding likelihood indicator is closely associated with the global skewness factor I constructed) as long as the position-unwinding likelihood does not exceed the critical value for global liquidity imbalances to sustain, which is intimately related to market sentiment and economic fundamentals, e.g. short-term and otherwise maturing external debts and the pledgeable value of external asset of a nation. When the line is crossed over, investors begin to unwind their positions as bubble correction behavior (Abreu and Brunnermeier, 2003), followed up by price reversal and liquidity withdrawal (Plantin and Shin, 2011). The liquidity will inevitably dry up, triggering the crash of a currency. My Intertemporal Trading Equilibrium Model (ITEM) shows that a representative investor with learning behavior and a skewness term (besides the first two moments) in the utility function prefer to betting against UIP at an initial state of low position-unwinding risk and this in turn leads to excess but bounded accumulation of liquidity in a currency. The currency carry trades give rise to global liquidity transfer and imbalances. The forward premium anomaly, to some extent, can be explained by this "meso" theory, which is also concordant with the decomposition of short-run interest rates into market liquidity premium component and sovereign credit premium component. I further suggest a Smooth Transition Model (STR) for the analysis of the threshold level and accordingly propose a simple trading strategy that the currency carry positions are immunized from unwinding risk.

6.4. Factor-mimicking Portfolio

To better scrutinize the factor price of the position-unwinding risk in a natural way, it's necessary to convert it into a return series by following Breeden, Gibbons, and Litzenberger (1989), Ang, Hodrick, Xing, and Zhang (2006) to build a factor-mimicking portfolio of position-unwinding likelihood indicator. If this factor is a traded asset, its risk price should be equal to the mean return of the traded portfolio for satisfying the no-arbitrage condition.

I regress PUW on the vector of excess returns of five carry trade portfolios xr_t to obtain the factor-mimicking portfolio $xr_{FMP,t}$:

$$PUW_t = \alpha + \beta' \, xr_t + \upsilon_t \tag{44}$$

where $\upsilon_{j,t}$ is $i.i.d.$ $(0, \sigma^2_{j,\upsilon})$. The factor-mimicking portfolio $xr_{FMP,t} = \hat{\beta}' \, xr_t$ is given by:

$$xr_{FMP,t} = -0.259 \cdot xr_{1,t} - 1.833 \cdot xr_{2,t} - 0.206 \cdot xr_{3,t} - 2.091 \cdot xr_{4,t} - 0.967 \cdot xr_{5,t} \tag{45}$$

The factor-mimicking portfolio of position-unwinding risk (PUW_{FMP}) is -0.99 correlated with dollar risk factor. It is natural to expect this high correlation since PUW is already highly correlated with GDR. The estimated annualized factor price of the position-unwinding risk $\lambda_{PUW_{FMP}} = -14.480\%$ per annum (from the regression with slope factor, HML_{FB}; see also the bottom panel of Table A.6. for the regression with HML_{SC}), which is very close to the average annual excess return of the factor-mimicking portfolio $\overline{xr}_{FMP} = -14.061\%$ per annum, only 3.5 basis points monthly nuance. These results confirm that the risk price of my factor, position-unwinding likelihood indicator, is arbitrage-free and has economically meaningful implications for dynamic hedging against currency crash risk, especially during the turmoil periods.

6.5. Horse Races

Firstly, I add the HML_{EP} into my benchmark model ($PUW + HML_{SC}$) to test if equity premium risk is priced in the cross-section of currency excess returns. The empirical results are shown in Table A.7. below. I find little improvement on the cross-sectional R^2, and the coefficients of β, b, and λ are statistically insignificant given other factors, whose parameter estimates remain statistically significant.

[Insert Table A.7. about here]

Secondly, I run a horse race of the position-unwinding likelihood indicator (PUW) with the global skewness factor (GSQ) as the proxy for crash risk. As shown in the top panel of Table A.8., the cross-sectional R^2 remains very high and even slightly improved, at 0.934. And its coefficients of β, b, and λ are statistically significant. GSQ has a comparable factor price of -14.968% per annum to PUW. The null hypotheses of jointly zero pricing errors and zero $HJ - dist$ are accepted with a MAE of 30 bps. So the model is also correct. This implies that the position-unwinding risk is essentially the global crash (devaluation) risk against the U.S. dollar. These findings are affirmative evidence for Brunnermeier, Nagel, and Pedersen's (2009) liquidity spiral story that low position-unwinding likelihood (implying $S_{t+1} < F_t$) actually creates a sizeable speculative demand for the high interest-rate currencies, pushing S_{t+1} far away from F_t. This in turn leads to negative skewness distributions of excess returns against low interest-rate currencies.

Inspired by Harvey and Siddique (2000) who extended the classical CAP-M to a conditional three-moment model, I do an asset pricing test to examine if these three moments represent different time-series and cross-sectional information. Before that, it's necessary to run an additional horse race of GVI with GSQ because GSQ has a high correlation of 0.837 with PC_1 of the currency carry portfolios and the innovations in global volatility risk is also highly correlated (-0.629) with the PC_1[30], which may suggest the overlap of information between GSQ and GVI. The bottom panel of Table A.8. suggests the collinearity problem when put the second and third moment risk factors together in a linear model. The empirical results also reveal that the

[30]This is consistent with the observations that the currency crashes during the regime of high volatility.

exposures to GVI across five currency carry portfolios are no longer monotonic (see also Menkhoff, Sarno, Schmeling, and Schrimpf, 2012), which implies that the crash risk GSQ, to some extent, contains the "slope" information in GVI. This is not surprising because skewness is closely associated with interest rate differential (Brunnermeier, Nagel, and Pedersen, 2009) based on which the currencies are allocated into portfolios. Notwithstanding, GVI dominates in the cross-sectional analysis that the estimates of b and λ of GSQ becomes statistically insignificant.

[**Insert Table A.8. about here**]

Thirdly, I run two further horse races of the sovereign credit risk (HML_{SC} and HML_{GB}), one with volatility risk measures, i.e. global FX volatility (innovation) risk factor (GVI) by Menkhoff, Sarno, Schmeling, and Schrimpf (2012), and simple changes in Chicago Board Options Exchange's (CBOE) VIX index (ΔVIX); another one with illiquidity risk measures, i.e. global FX bid-ask spreads (GLR), and changes in T-Bill Eurodollar (TED) Spreads Index (ΔTED). My empirical results corroborate Bandi, Moise, and Russell's (2008) evidence that stock market volatility drives out liquidity in cross-sectional asset pricing exercises, FX market shares this similarity.

[**Insert Table A.9. about here**]

The empirical findings of Menkhoff, Sarno, Schmeling, and Schrimpf (2012) are reproduced in Table A.9. and Table A.10. that high interest-rate currencies load negatively on volatility risk while low interest-rate currencies provide a hedge against it, which confirmed by both measures of volatility risk. GVI works better than ΔVIX does, although the factor price of GVI, -0.323% per annum, is very small, compared with that of ΔVIX of -16.074% per annum. The same logic works for the illiquidity measure of ΔTED with a factor price of -2.488% per annum that high interest-rate currencies load negatively on illquidity risk while low interest-rate currencies provide a hedge against it. However, GLR performs poorly for pricing currency carry portfolios. Its model presents a non-monotonic risk exposure pattern and is rejected in terms of non-zero jointly pricing errors and non-zero $HJ - dist$. All above factor prices are estimated solely with GDR in two factor linear models (full results are not printed in table).

[Insert Table A.10. about here]

ΔVIX cannot dominate HML_{SC} and cross-sectional pricing power does not improve much (see Table A.9.). While as shown in Table A.10., when racing with GVI, the estimates of b and λ with respect to HML_{SC} become statistically insignificant in pricing the cross section of currency excess returns, although both factor exposures exhibit monotonic and statistically significant patterns in time-series regressions. This is caused by multicollinearity problem that GVI dominates HML_{SC} in cross-sectional regression. The rationale behind this suggests that there must be some other ingredients that drives the cross-sectional volatility in FX market, but sovereign credit risk already constitutes a major part of the FX volatility innovation because HML_{SC} and HML_{GB} as the proxy for sovereign default risk both possess very close cross-sectional pricing power to GVI. I employs both linear and nonlinear Granger causality tests to show that sovereign default risk leads to innovations in global FX volatility later in this paper.

[Insert Table A.11. about here]

Global kurtosis factor as a complementary measure of volatility risk and tail risk is added into Menkhoff, Sarno, Schmeling, and Schrimpf's (2012) linear factor model as discussed previously. Unlike Harvey and Siddique (2000) who extend the classical CAPM to a conditional three-moment model, I only add GKT given that GSQ and GVI are highly correlated, GVI dominates in cross-sectional analysis, and GKT has a low correlation with GVI. This alternative three-factor model work so well that it has a R^2 of almost 1.00 with a MAE of only 2 bps, and the null hypotheses of jointly zero pricing errors and zero $HJ - dist$ are all accepted (see Table A.11.), suggesting a correct model. Nonetheless, the estimates of b and λ with respect to GKT do not exhibit enough statistical significance. Yet, GKT seems to offer additional cross-sectional information on currency excess returns that GSQ does not cover.

[Insert Table A.12. about here]

GLR performs badly in terms of statistically insignificant parameter estimates when racing with HML_{SC} (see Table A.12.). While Table A.13. shows that HML_{SC} dominate ΔTED in both time-series and cross-sectional regressions. Unlike HML_{SC}, ΔTED loses its monotonic risk exposure pattern and its estimates of b and λ become very statistically insignificant. Again, this is not surprising because ΔTED is also an indicator of credit risk in the general economy while HML_{SC} is constructed directly from the currency excess returns, and accordingly it should be more specialized in gauging (sovereign) credit risk in money market. Given the fact that credit risk and liquidity risk are always the twins that interacts dynamically in the global economy, credit risk is usually the trigger of liquidity risk, and liquidity risk sequentially amplifies credit risk. So we should expect that HML_{SC} overwhelms ΔTED in terms of cross-sectional risk information.

[Insert Table A.13. about here]

To summarize, even though global volatility innovations in FX market dominates sovereign default risk in pricing the cross section of currency carry portfolios, sovereign default risk yet is the dominant country-specific fundamental risk in terms of persistent monotonic time-series factor exposures and very high cross-sectional pricing power. And follow the economic intuition, sovereign credit conditions should be the driver of volatility and illquidity risk in FX market and the reverse should not necessarily be true. These will be testified by linear and nonlinear Granger causality later in this paper.

7. Robustness

I stick to conditional risk premia, since it's more reasonable to look at the empirical results obtained from managed investments that in reality FX traders open, close, or adjust their positions based on daily updated interest-rate information. Given the sample period is not long enough, splitting sample by time and/or category (advanced economies[31] and emerging market) is not ideal because these will introduce measurement errors in betas in terms of smaller variations in their estimated values, which will in turn make the market prices appear higher and less accurately estimated than on full sample. However, my reported results still robust to state-dependent factor exposures, peso problem, beta-sorted portfolios and nonlinearity checks besides alternative measures of sovereign credit risk and crash risk, and unadjusted position-unwinding likelihood indicator, and factor-mimicking portfolio.

7.1. Regime-switching Exposures

Regime-switching models are popular among scholars for conducting time-series analysis, ranging from Hamilton's (1989) business cycle application to Ang and Bekaert's (2002) asset allocation application, and can be employed to evaluate the possibility of abrupt changes in risk exposures. I consider a simple two-state (η) Markov regime-switching model that uses the filtering procedure of Hamilton (1990) and followed by the smoothing algorithm of Kim and Nelson (1999, 2003):

$$xr_{j,t} = \begin{cases} \alpha_j^0 + \beta_{j,PUW}^0 \cdot PUW_t + \beta_{j,SC}^0 \cdot HML_{SCt} + \zeta_{j,t} & \text{if } \eta = 0; \\ \alpha_j^1 + \beta_{j,PUW}^1 \cdot PUW_t + \beta_{j,SC}^1 \cdot HML_{SCt} + \zeta_{j,t} & \text{if } \eta = 1. \end{cases} \quad (46)$$

[31] Although currencies of these countries are involved in over 90% of the daily transactions in FX markets, the average excess returns of their carry trade portfolios do not exhibit the monotonic patterns during the financial crunch because these positions were unwound in distinctive ways of collapse.

where $\zeta_{j,t}$ is $i.i.d.$ $(0, \sigma^2_{j,\zeta})$. The matrix Π consists of the transition probabilities, e.g. p_{10} denotes the transition probability from state 1 to state 0:

$$\Pi = \begin{bmatrix} p_{00} & p_{10} \\ p_{01} & p_{11} \end{bmatrix} \tag{47}$$

We reject the null hypothesis of linearity except for the portfolio with lowest interest-rate currencies. However, the validity of the LR-statistic for linearity test is questioned by Teräsvirta (2006) because it does not have a standard asymptotic χ^2 distribution. And the turmoil-state regime does not last for more three months except for the portfolio with high interest-rate currencies. The Wald test is employed for testing identical parameters and systematically alternating regimes (opposite to arbitrarily switching between two regimes) in terms of smoothed transition probabilities. And the Wald statistics are computed by asymptotic covariance matrix.

[**Insert Figure A.4. about here**]

Figure A.4. indicates the persistent low volatility regime (Regime 1) for portfolio C_1, C_3, and C_4, which rarely shifts into the alternative high volatility regime (Regime 0). Portfolio C_2 and C_5 appear more sensitive to the financial turbulence. Table A.14. below presents the estimates and tests for the Markov regime-switching model of currency carry portfolios. During the high volatility state, the alpha (α, constant terms) and the exposures (β) to position-unwinding risk are consistently and significantly higher across portfolios (except for C_4) than those in low volatility state, which however does not apply to the exposures to sovereign credit risk.

[**Insert Table A.14. about here**]

The Wald tests suggest us reject the null hypotheses of no difference in parameter estimates between two regimes, except for portfolio C_4, and the

β_{SC}s of portfolio C_2 and C_5. This means that the regime dependence is mainly driven by the assessment of systemic (position-unwinding) risk exposures (β_{PUW}). I argue that it's not necessary to consider regime-switching risk exposures in the cross-sectional asset pricing exercise for the following two reasons: (i) The average duration of high volatility regime for portfolio C_1, C_3, and C_4 is very short (1-month, 1-month, and 2.5-month, respectively), and the shifts only occur for four times on average. Comparing this to the time length of the data, we believe the impact of the shifts is trial on each portfolio. (ii) Even though portfolio C_2 and C_5 are substantially affected by the regime-switching, their exposures to sovereign default risk does not change, as indicated by the Wald tests. However, the slope factor plays a much more important role in the cross section of currency carry trades (see the factor loadings in Table B.1.). (iii) The linear factor models already perform quite well, with a cross-sectional R^2 consistently over 0.90. The remaining cross-sectional variance that can be captured by state-dependent risk exposures is limited. The cross-sectional R^2 obtained from regime-splitting regressions in the second stage of FMB approach does not improve much.

7.2. Peso Problem

To show that the sovereign credit risk does not represent a "peso problem" because sovereign default is a rare event, I winsorize the sample outliers of the "HML_{SC}" at 95% and 90% levels respectively to cut off the spikes, as Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) argue that the key characteristics of a peso state is a high value of SDF, not large losses in carry trades.

[Insert Table A.15. about here]

As shown in Table A.15., I still obtain very robust empirical results with R^2s of 0.924. The only change is the estimates of risk exposures and factor prices of HML_{SC}, and the price of the factor estimated with it. Due the the winsorization, the variance of HML_{SC} becomes smaller, hence λ_{SC} would naturally become smaller as well, 3.328% per annum with $b_{SC} = 0.804$ and a standard error of 0.768 when 5% of the extreme observations are excluded; 3.109% per annum with $b_{SC} = 0.907$ and a standard error of 0.850 when 10% of the extreme observations are excluded.

7.3. Beta-sorted Portfolios

I adopt 60-month rolling window for the estimation of betas as commonly used for the study in the field of stock markets, because it also yields stable parameter estimates in FX market in my data, so does the rank of the factor exposures across currencies. As the result, I do not need to dynamically rebalance my portfolios over the sample period. Instead, I sort the currencies into portfolios according to their average betas. Table A.16., Table A.17. shows the descriptive statistics of the currency portfolios sorted on betas with HML_{SC}, and doubly sorted on betas with both HML_{SC} and PUW, respectively.

[**Insert Table A.16. about here**]

CHF and JPY are the currencies with the lowest and the third lowest exposure to sovereign credit risk, their average β_{SC} over the sample period are -0.794 and -0.658 respectively. These results are coherent with Ranaldo and Söderlind's (2010) findings that CHF and JPY are characterized as "safe-heaven" currencies because they have negative exposures to risky assets and appreciates when market risk, volatility risk and illiquidity risk increase. Interestingly, JPY is also the currency with the lowest position-unwinding risk, it has a unique positive average β_{PUW} of 0.014, while other currencies all have average negative β_{PUW}s. This implies a weak hedge position of JPY for global currencies against position-unwinding risk. CHF's average β_{PUW} is -0.145, a medium position-unwinding risk exposure among the currencies in the sample.

[Insert Table A.17. about here]

Intriguingly, the countries with the highest exposures to HML_{SC} are "BRIC[32]", "MIST", and "CIVETS[33]" coined by Jim O'Neil in Goldman Sachs' "Global Economic Paper" series in order to differentiate among the variety of emerging markets. The corresponding average β_{SC}s of these currencies are shown in the parentheses in descending order: COP (1.107), TRY (1.102), ZAR (0.931), MXN (0.801), INR (0.559), BRL (0.489), IDR (0.452), KRW (0.471). The next group contains the currencies of the countries from "EAGLEs'[34] Nest" members, e.g. PHP, PEN, MYR, ARS. Nordic currencies, such as SEK, NOK, and DKK, feature safe assets with respect to low negative β_{SC}. All these countries do not have a common level of exposures to the PUW. AUD and NZD, among the most popular carry trade currencies, are in the group of high position-unwinding risk. HKD with a $\beta_{PUW} = -0.003$ seems to be isolated from the position-unwinding risk, as it is known pegged to USD, which provides additional supportive evidence that my position-unwinding likelihood indicator essentially substantiates the (global) dollar risk.

Furthermore, the excess returns and forward discounts "$f - s$" increase monotonically with both β_{SC} and β_{PUW} dimensions across portfolios[35], which confirms that my beta-sorted portfolios reproduces the cross section of currency carry portfolios' excess returns. However, the skewness of my beta-

[32]Except for China which is excluded in my currency portfolio, and Russia which ranks medium in the exposure to sovereign credit risk.

[33]Except for Vietman and Egypt which are not included in my sample.

[34]EAGLEs is a grouping acronym created by BBVA Research in late 2010, standing for Emerging and Growth-leading Economies, whose expected contribution to the world economic growth in the next 10 years is greater than the average of the G6 advanced economies (G7 excluding U.S.).

[35]Notice that in the top $\frac{1}{3}$ sovereign default risk portfolios group, the average excess returns of the portfolio with the lowest exposure to position-unwinding risk is just slightly higher than that of the portfolio with the medium exposure to position-unwinding. This is due to the much higher (nearly doubled) skewness of the medium crash risk exposure portfolio than the lowest crash risk exposure portfolio.

sorted portfolios exhibit very similar but not exactly the same pattern of those sorted on forward discounts. Moreover, unlike the volatility of of the currency carry portfolios, the portfolios sorted solely on β_{SC} does not show a monotonic pattern. These suggest that sorting currencies on β_{SC} alone is closely related to, but not utterly identical to the currency carry portfolios. Sorting currencies on both β_{SC} and β_{PUW} is much more close to the currency carry portfolios in terms of volatility and skewness patterns, because the position-unwinding risk drives volatility innovations in FX market. This suggests that forward bias risk reflects not only sovereign credit premia, but also forward crash premia.

7.4. Quadratic Effect of Position-unwinding Risk

I also examine the quadratic effect of position-unwinding risk and do not find notable improvement of this alternative factor model, though, in terms of cross-sectional pricing power (increased only by 0.024 to 0.948). The null hypotheses of jointly zero pricing errors and zero $HJ-dist$ again cannot be rejected. We still observe monotonic pattern in the time-series β_{SC}s and the sovereign credit risk price $\lambda_{SC} = 2.692\%$ per annum, which are very close to those estimated by the linear factor model.

[Insert Table A.18. about here]

Moreover, the factor price $\lambda_{PUW} = -15.090\%$ per annum, which does not differ much from that estimated by a linear factor model. The risk price of the level of position-unwinding risk $\lambda_{PUW^2} = -20.517\%$ per annum, is considerably high. However, both b_{PUW} and b_{PUW^2} becomes statistically insignificant, which is caused by the multicollinearity problem. The evidence suggest that quadratic effect may not exist or that the curvature of the function is not significant at all. Thus, the level (after taking the first differentiation) of position-unwinding likelihood is not essential for pricing the cross-sectional excess returns of currency carry trades.

[Insert Figure A.5. about here]

Figure A.5. shows the cross-sectional fitness of five currency carry portfolios of six different models. Apparently, the two three models work the best: "$PUW + HML_{PC} + HML_{SC_\perp}$" and "$GDR + GKT + GVI$". Both of them have a cross-sectional R^2 of 1.00, typically with very low MAE of only 8 bps, and 2 bps respectively.

7.5. International Bond and Equity Portfolios

In this section, the position-unwinding likelihood indicator (PUW) and global skewness factors (GSQ) as the proxy for currency crash risk, together with sovereign credit risk factors (HML_{SC} and HML_{GB}), will be shown robust to pricing the international government bond (total return indices) portfolios (sorted on redemption yields) and equity (composite indices) momentum portfolios (sorted on equity premia). Please refer to Table B.2. for whether to include a risk factor in the asset pricing test and whether the risk factor has an intercept feature or a slop feature.

I've already formed five government bond portfolios[36] for construction of an alternative measure of sovereign credit risk, as sorting government bonds by redemption yields is equivalent to sorting based on the information about sovereign credit risk (CDS spreads). Table A.19. shows the descriptive statistics that only the mean, median and standard deviation of government bond portfolios' excess returns increase monotonically. They do not exhibit the same skewness pattern as currencies.

[Insert Table A.19. about here]

As shown in Table A.20. that β_{GB}s exhibit prominently monotonic patterns from the the lowest redemption-yield bonds to the highest redemption-

[36]See Table B.1. for principal component analysis of government bond portfolios, and Table B.2. for the correlations between risk factors and principle components.

yield ones in the time-series regressions. However, like the circumstance of pricing currency carry portfolios, the PUW and GSQ both serve as a constant that allows for a common pricing error in government bond excess returns when tested with HML_{GB}. Therefore, it's not necessary to add a constant in any cross-sectional regression. Both model have very high cross-sectional R^2s (0.837 estimated with PUW and 0.924 estimated with GSQ), λ_{GB} is positive (3.755% per annum estimated with PUW 3.523% per annum estimated with GSQ) as expected and statistically significant, and the model is accepted correct by the jointly zero pricing error and zero $HJ-dist$ tests. The estimates of b and λ with PUW and those with GSQ are also statistically significant ($\lambda_{PUW} = -41.035\%$ per annum and $\lambda_{GSQ} = -32.406\%$ per annum). Obviously, position-unwinding risk of currency carry trades does not well present the global risk in government bond market, or general economy, but more specializes in the FX market. While the global FX skewness (crash) risk seems to mirror the global risk of cross-asset markets, at least that of the government bond market. On the other hand, the sovereign default risk implied in the FX market (HML_{SC}) does not possess the pricing power on the cross section of government bond excess returns.

[**Insert Table A.20. about here**]

The equity momentum portfolios[37] are built similarly according to the past performance (see Jegadeesh and Titman; 1993, 2001). Table A.21. shows the descriptive statistics that not only the mean of equity momentum portfolios' excess returns increase monotonically, but also the median, standard deviation, skewness, and kurtosis exhibit nearly monotonic patterns.

[**Insert Table A.21. about here**]

[37] See Table B.1. for principal component analysis of equity momentum portfolios, and Table B.2. for the correlations between risk factors and principle components.

The equity momentum factor is then given by the differences in the excess returns between the top 20% winner portfolio and the bottom 20% loser portfolio:

$$HML_{EM} = PFL_{EM,H} - PFL_{EM,L} \tag{48}$$

According to the correlations between the risk factors and principal components of portfolios in Table B.2., I firstly test sovereign default risk (both HML_{SC} and HML_{GB}) that acts as systematic risk to equity momentum portfolios, then crash risk (both PUW and GSQ) also as the intercept factor. The equity momentum risk is certainly used as the slope factor for pricing the corresponding stock portfolios.

[Insert Table A.22. about here]

Although we get very high level of R^2, consistently over 0.975 and a positive and statistically significant λ_{EM} as expected, about 7.50% per annum. The estimates of b and λ of all intercept factors are statistically insignificant, which suggests the failures of all intercept factors in pricing stock momentum excess returns given the slope factor HML_{EM}. These results are consistent with Jegadeesh and Titman's (1993, 2001) findings that the cross-sectional profitability of equity momentum strategies is not due to the systematic risk. A further robustness test will be included in the near future to investigate if sovereign credit risk and position-unwinding (crash) risk explains the cross-sectional excess returns of currency momentum strategies.

[Insert Table A.23. about here]

It would be interesting to check if equity momentum risk is also priced in currency carry portfolios as well.

[Insert Table A.24. about here]

Table A.24. shows seemingly confirmative results that the excess returns of currency carry trades, to some extent, reflect a sort of equity momentum premia, given the statistically significant estimates on b and λ, a good cross-sectional R^2 of 0.702, a small MAE of 63 bps, and a correct model accepted by the jointly zero pricing error and zero $HJ-dist$ tests. λ_{EM} is 15.899% per annum for currency carry portfolios, which is considerably high. However, the exposures to HML_{EM} do not exhibit a monotonic pattern and even some of them are statistically insignificant.

8. Factor Dynamics and Application

Existing literature in empirical asset pricing of currency carry trades do not highlight the spillover effect of country-specific fundamental risk to the global economy nor test the impulsive country-specific risk that drives others of its kind. The contagion channels can be international trade linkages (e.g. Krugman, 1979; Eichengreen, Rose, and Wyplosz, 1996), international bank lending (e.g. Kaminsky and Reinhart, 1999, 2000; Allen and Gale, 2000; van Rijckeghem and Weder, 2001), international portfolio holdings and re-balancing (e.g. Kodres and Pritsker, 2002; Pericoli and Sbracia, 2003), or more generally speaking, international capital flows, such as sudden stop and flight-to-quality (see Calvo, 1998; Forbes and Warnock, 2012). And follow an economic intuition that volatility risk and liquidity risk should be driven by either fundamental risk and market sentiment, and may feedback into investors' risk appetite. There are various econometric techniques that can be employed for testing factor dynamics, which, however, is not the main purpose of this paper. Therefore, I only choose Granger causality test (both linear and nonlinear) among them for the analysis of this section.

The interactions between the global risk factor (e.g. dollar risk "GDR", position-unwinding risk "PUW", and crash risk "GSQ") and country-specific factor (e.g. sovereign credit risk "HML_{SC}", forward bias risk "HML_{FB}", volatility risk "GVI", illiquidity risk "ΔTED", etc.) is the principal concern of testing contagion. Position-unwinding likelihood indicator is embedded with the global risk aversion since it is evaluated via the risk non-neutrality probability distribution. Caceres, Guzzo, and Segoviano Basurto (2010) shows that at the early stage of the financial crisis, global risk aversion is a significant factor influencing sovereign CDS spreads; and at the later stage, country-specific factor, such as short-term refinancing risk and long-term fiscal sustainability, becomes more important and begins to feed back into broader financial instability. Furthermore, hedging design of currency portfolios against idiosyncratic risk can be oriented by testing the stimulative source of risk among the country-specific factors.

I employ both linear and nonlinear Granger causality tests to identify which factor drives the cross-sectional risk, and to investigate the dynamic propagation between global risk and country-specific risk, especially the spillover of the country-specific risk to the global economy, because the degree of Granger causality in the asset return-based risk factors can also be viewed as a proxy for the spillover of information among market participants as suggested by some recent research in this field, e.g. Daníelsson, Shin, and Zigrand (2009), Battiston, Delli Gatti, Gallegati, Greenwald, and Stiglitz (2012), and Billio, Getmansky, Lo, and Pelizzon (2012). Hiemstra and Jones (1994) propose a nonparametric test for general (both linear and nonlinear) Granger non-causality (HJ-test), which is questioned by Diks and Panchenko (2006). They show that HJ-test tends to incur spurious discovery of nonlinear Granger causality, and the probability to reject the Granger non-causality increases with the sample size. Instead, they provide an alternative nonparametric test for nonlinear Granger causality that circumvents the problem in HJ-test through replacing the global statistic by the average of local conditional dependence measures. I follow their method to test the nonlinear Granger causality among risk factors. The bandwidth of 1.50 is chosen to accommodate the sample size. I adopt Akaike's Final Prediction Error (also as known as AIC) as the lag-length selection criterion because Anderson (2004) find that Akaike's Final Prediction Error[38] (also as known as AIC) works quite well for small samples even if the true model is nonlinear, and contrarily, Schwarz (Bayesian) Information Criterion (SIC) and Hannan-Quinn Information Criterion performs poorly unless the sample size is large enough.

8.1. Impulsive Country-specific Risk

Table A.25. shows that sovereign credit risk seems to be the impetus of other country-specific factors: HML_{SC} both linearly and nonlinearly Granger causes HML_{FB}, GVI, ΔVIX, and ΔTED. And the reverse is not true except that HML_{FB} and ΔTED feedback into HML_{SC} nonlinearly.

[**Insert Table A.25. about here**]

The relationship between HML_{SC} and GLR seems to be dynamical and nonlinear. From the aspect of market microstructure, liquidity spreads (bid-ask spreads) are endogenously set by the market makers, whose reaction function to perceived sovereign credit risk should be nonlinear to rationalize this nonlinear and dynamical Granger causality between HML_{SC} and GLR. All these vindicate my conclusion that sovereign credit risk is the dominant fundamental risk.

8.2. Global Contagion

Table A.26. reveals the spillover of country-specific risk to the global economy. Sovereign default risk are contagious to the global money market (GDR)and drives the currency crash risk (GSQ), which in turn amplifies the

[38]Although nonlinear techniques suggested by Tjøstheim and Auestad (1994) might improve the accuracy, they're very difficult to implement.

global volatility risk (both GVI and ΔVIX). The FX volatility innovation (GVI) is naturally triggered by the position-unwinding likelihood, which is believed to measure the risk attitude of the investors. PUW then feedbacks into broad market volatility (ΔVIX).

[**Insert Table A.26. about here**]

I also find that position-unwinding risk of the currency carry trades is only driven by the broad market volatility and by the forward bias risk. The development of a joint valuation framework of currency options and sovereign CDS contracts for dynamic hedging contagion risk of currency portfolios in my another paper is inspired by above findings, and thus it well calibrates the stylized facts of forward premium puzzle.

8.3. Threshold Trading

Given that the position-unwinding likelihood indicator measures the probability of the currency crashes against the speculative carry trade positions taken by the investors, and that it solely represents the global systematic risk in terms of high correlation with the equally loaded PC_1 of the currency carry portfolios and also with the global skewness risk (GSQ) while is nearly uncorrelated with the PC_2 that can be intensified by the (country-specific) forward bias risk (see Table A.26.), we can continue earning on the forward bias risk as long as the positions are not forced unwounded. However, once the currency crashes in the opposite direction of the carry trade positions, the risk reverses and we will suffer losses by taking up any forward bias risk. So focusing on the position-unwinding risk is the principal concern of currency carry trades.

In this section, I propose an alternative carry trade strategy that is immunized from currency crash risk by identifying the threshold level of the position-unwinding likelihood indicator. PUW does not measure the true probability of a position to unwind. Brunnermeier and Pedersen (2009), Clarida, Davis, and Pedersen (2009) reveal the regime-sensitivity of Fama regression parameters that the βs are much smaller than unity or even negative during the tranquil period and shift to positive values during the turmoil period. Thus, we can gain both statistical and economic significance by analyzing the transition dynamics between regimes, e.g. reverse the carry trade positions during the currency crashes. And according to the reality observed in my data, the position-unwinding behavior would be triggered when PUW exceeds a certain threshold, which represents investors' risk aversion at a certain high-volatility and negatively-skewed state. The procedure to search for the threshold level could be done by Smooth Transition Model (STR) specifying that the carry trade excess returns depend linearly on HML_{FB} and nonlinearly on GDR. The nonlinear relationship is dependent on the level position-unwinding likelihood. More generally, my model is given by:

$$xr_{j,t} = (\alpha_j^0 + \beta_j^0 \ f_t^0) + (\alpha_j^1 + \beta_j^1 \ f_t^1) \cdot \omega(\nu_t; \gamma_j, c_j) + \zeta_{j,t} \tag{49}$$

where $\zeta_{j,t}$ is $i.i.d.$ $(0, \sigma_{j,\zeta}^2)$. PUW acts as the transition variable ν_t and $\omega(\cdot)$ is the transition function which is conventionally bounded by zero and one. $\gamma_j > 0$ denotes the slope parameter that determines the smoothness[39] of the transition from one regime to the other. When γ_j approaches zero, the STR process reduces to a linear model; and as γ_j goes to infinity, the STR process becomes an absolute two-regime threshold model with abrupt transition (Tong, 1990). c_j is the threshold level of the abruptness in transitional dynamics. f_t^0 (f_t^1) is a vector of risk factors that enter the linear (nonlinear) part of the STR model. Two types of transition functions (Teräsvirta and Anderson, 1992) universally appeal to scholars are:

Logistic STR Model (LSTR):

$$\omega(\nu_t; \gamma_j, c_j) = \{1 + \exp[-\gamma_j(\nu_t - c_j)]\}^{-1} \tag{50}$$

[39] This implies that there exists a continuum of states between two polar regimes.

Exponential STR Model (ESTR):

$$\omega(\nu_t; \gamma_j, c_j) = 1 - \exp[-\gamma_j(\nu_t - c_j)^2] \tag{51}$$

Unlike the ESTR model, the LSTR specification accounts for asymmetric realizations of the transition variable at two sides of the threshold level. I follow Teräsvirta's (1994) methodology to choose the appropriate STR model and utilize $LM - test$ for examining the null hypothesis of no remaining non-linearity (Eitrheim and Teräsvirta, 1996). That no residual autocorrelation in the STR model is confirmed by Teräsvirta's (1998) procedure.

[**Insert Table A.27. about here**]

The threshold levels of the position-unwinding risk are revealed in Table A.27. that a PUW above 0.462 is suggested as a signal for reverse the positions of conventional carry trades. In my first trading rule, I use ex-ante 3-month moving average of PUW for comparison with the threshold level of 0.462. Moreover, that the PUW becomes very volatile during the recent financial crisis also caught my attention. So, I follow a second trading rule of the ex-ante 6-month PUW volatility, which suddenly exceeded 15% at the outbreak point and remains above this level in most of the aftermath of the financial crunch. If it drops below 15%, the positions are reversed back to the plain vanilla carry trade strategy.

[**Insert Figure A.7. about here**]

Figure A.7. show that the cumulative excess returns of the alternative carry trade strategy is immunized from currency crashes, in comparison with the plain vanilla one. The annualized (compounded) excess return of the threshold carry trading strategy is about 18.576%, which is much higher than that of the plain vanilla one (5.547%).

9. Conclusions

I argue that sovereign credit condition is the dominant fundamental risk that drives the cross-sectional excess returns of currency carry trades based on the striking and robust time-series and cross-sectional evidence. It impulsively drives other country-specific risk, such as volatility and liquidity risk in both linear and nonlinear Granger causality tests. High interest-rate currencies load up positively on sovereign default risk while the low interest-rate currencies provide a hedge against it, which is consistent with the external valuation adjustment story of Gourinchas and Rey (2007). This is robust to alternative measure of sovereign default risk by government bonds. Its cross-sectional pricing power does not reflect a "Peso problem". The sovereign credit premia not only reflect a country's medium to long run fundamental risk, but also response to short-run rollover risk of maturing debt and liquidity constraint of a nation (see Acharya, Gale, and Yorulmazer, 2011; He and Xiong, 2012 for the analyses of stock market). On the other hand, short-term interest rates imply short-term market liquidity premium component and short-term sovereign credit premium component, which should be taken into account for measuring the "effective" forward premia.

I also explain a "self-fulfilling" mechanism of currency carry trades according to the analysis of position-unwinding likelihood indicator. Its factor-mimicking portfolio confirms that the position-unwinding risk is an arbitrage-free traded asset. It is remarkably fed by the forward bias risk in both linear and nonlinear Granger causality tests, in which complicated global contagion channels is highlighted. It is also concordant with the liquidity spiral story of Brunnermeier, Nagel, and Pedersen (2009) as it measures the currency crash risk in terms of high correlation with the global skewness factor. I show high interest-rate currencies are exposed to higher position-unwinding (crash) risk than low interest-rate currencies owing to the global liquidity transfer. The global liquidity reversal/withdrawal of the investors triggers currency crashes. Accordingly, I propose an alternative carry trade strategy (using the technique of Smooth Transition Model for calculating the threshold level) that is immunized from currency crash risk and earns a much higher annualized excess return than the plain vanilla carry trade strategy. Furthermore, the quadratic effect of position-unwinding risk is not statistically significant.

Nonlinearity (Markov Regime-switching Model) does not capture much additional information about the risk exposures for cross-sectional analysis. Both single and double beta-sorted portfolios reproduce very similar excess returns pattern to that of currency carry trade portfolios in terms of mean, median, volatility and skewness. And my risk factors also excel in pricing government bond portfolios and the next step is to test on currency momentum portfolios. Forward premium seems to be a compounded but decomposable puzzle that sovereign credit premia constitute a major part of it and most of the remaining part can be attributed to global liquidity imbalances brought by carry trades themselves. Overall, these empirical results offer economically meaningful illustrations on risk-return relation in FX market and shed additional insights on hedging currency crash risk and contagion risk using financial derivatives.

References

Abhyankar, A., A. Gonzalez, and O. Klinkowska (2011). Salvaging the c-capm: Currency carry trade risk premia and conditioning information. *Available at SSRN No.1927265*.

Abreu, D. and M. Brunnermeier (2003). Bubbles and crashes. *Econometrica 71*(1), 173–204.

Acharya, V., D. Gale, and T. Yorulmazer (2011). Rollover risk and market freezes. *The Journal of Finance 66*(4), 1177–1209.

Adrian, T. and J. Rosenberg (2008). Stock returns and volatility: Pricing the short-run and long-run components of market risk. *The Journal of Finance 63*(6), 2997–3030.

Allen, F. and D. Gale (2000). Financial contagion. *The Journal of Political Economy 108*(1), 1–33.

Alvarez, F., A. Atkeson, and P. Kehoe (2009). Time-varying risk, interest rates, and exchange rates in general equilibrium. *Review of Economic Studies 76*(3), 851–878.

Amihud, Y. (2002). Illiquidity and stock returns: Cross-section and time-series effects. *Journal of Financial Markets 5*(1), 31–56.

Amihud, Y. and H. Mendelson (1986). Asset pricing and the bid-ask spread. *Journal of Financial Economics 17*(2), 223–249.

Andersen, T., T. Bollerslev, F. Diebold, and P. Labys (2001). The distribution of realized exchange rate volatility. *Journal of the American Statistical Association 96*(453), 42–55.

Anderson, H. (2004). Choosing lag lengths in nonlinear dynamic models. *Advances in Economics and Econometrics, Cheltenham: Edward Elgar Press*, 176–204.

Andrews, D. (1991). Heteroskedasticity and autocorrelation consistent covariance matrix estimation. *Econometrica 59*(3), 817–858.

Ang, A. and G. Bekaert (2002). International asset allocation with regime shifts. *Review of Financial Studies 15*(4), 1137–1187.

Ang, A. and J. Chen (2010). Yield curve predictors of foreign exchange returns. In *AFA 2011 Denver Meetings Paper*.

Ang, A., R. Hodrick, Y. Xing, and X. Zhang (2006). The cross-section of volatility and expected returns. *The Journal of Finance 61*(1), 259–299.

Ang, A. and F. Longstaff (2011). Systemic sovereign credit risk: Lessons from the US and Europe. *NBER Working Paper No.16982*.

Backus, D., S. Foresi, and C. Telmer (2001). Affine term structure models and the forward premium anomaly. *The Journal of Finance 56*(1), 279–304.

Backus, D., S. Foresi, and L. Wu (2004). Accounting for biases in Black-Scholes. *Available at SSRN No.585623*.

Baek, I., A. Bandopadhyaya, and C. Du (2005). Determinants of market-assessed sovereign risk: Economic fundamentals or market risk appetite? *Journal of International Money and Finance 24*(4), 533–548.

Bandi, F., C. Moise, and J. Russell (2008). The joint pricing of volatility and liquidity. *Manuscript, University of Chicago*.

Bansal, R. and M. Dahlquist (2000). The forward premium puzzle: Different tales from developed and emerging economies. *Journal of International Economics 51*(1), 115–144.

Battiston, S., D. Delli Gatti, M. Gallegati, B. Greenwald, and J. Stiglitz (2012). Liaisons dangereuses: Increasing connectivity, risk sharing, and systemic risk. *Journal of Economic Dynamics and Control 36*(8), 1121–1141.

Bekaert, G., M. Wei, and Y. Xing (2007). Uncovered interest rate parity and the term structure. *Journal of International Money and Finance 26*(6), 1038–1069.

Billio, M., M. Getmansky, A. Lo, and L. Pelizzon (2012). Econometric measures of systemic risk in the finance and insurance sectors. *Journal of Financial Economics 104*(3), 535–559.

Black, F. and M. Scholes (1973). The pricing of options and corporate liabilities. *The Journal of Political Economy 81*(3), 637–654.

Borri, N. and A. Verdelhan (2011). Sovereign risk premia. In *AFA 2010 Atlanta Meetings Paper*.

Breeden, D., M. Gibbons, and R. Litzenberger (1989). Empirical tests of the consumption-oriented CAPM. *The Journal of Finance 44*(2), 231–262.

Breeden, D. and R. Litzenberger (1978). Prices of state-contingent claims implicit in option prices. *The Journal of Business 51*(4), 621–651.

Brunnermeier, M., S. Nagel, and L. Pedersen (2009). Carry trades and currency crashes. In *NBER Macroeconomics Annual*, Volume 23, pp. 313–347. University of Chicago Press.

Brunnermeier, M. and L. Pedersen (2009). Market liquidity and funding liquidity. *Review of Financial studies 22*(6), 2201–2238.

Burnside, C. (2011). The cross section of foreign currency risk premia and consumption growth risk: Comment. *The American Economic Review 101*(7), 3456–3476.

Burnside, C., M. Eichenbaum, I. Kleshchelski, and S. Rebelo (2011). Do peso problems explain the returns to the carry trade? *Review of Financial Studies 24*(3), 853–891.

Burnside, C., M. Eichenbaum, and S. Rebelo (2007). The returns to currency speculation in emerging markets. *The American Economic Review 97*(2), 333–338.

Burnside, C., M. Eichenbaum, and S. Rebelo (2009). Understanding the forward premium puzzle: A microstructure approach. *American Economic Journal: Macroeconomics 1*(2), 127–154.

Caballero, R., E. Farhi, and P.-O. Gourinchas (2008). An equilibrium model of global imbalances and low interest rates. *The American Economic Review 98*(1), 358–393.

Caceres, C., V. Guzzo, and M. Segoviano Basurto (2010). Sovereign spreads: Global risk aversion, contagion or fundamentals? *IMF Working Paper No.06/194*.

Calvo, G. (1998). Capital flows and capital-market crises: The simple economics of sudden stops. *Journal of Applied Economics 1*(1), 35–54.

Campbell, J. (1993). Intertemporal asset pricing without consumption data. *The American Economic Review 83*(3), 487–512.

Campbell, J. and J. Cochrane (1999). By force of habit: A consumption-based explanation of aggregate stock market behavior. *The Journal of Political Economy 107*(2), 205–251.

Campbell, J., K. Serfaty-de Medeiros, and L. Viceira (2010). Global currency hedging. *The Journal of Finance 65*(1), 87–121.

Carr, P. and L. Wu (2007). Theory and evidence on the dynamic interactions between sovereign credit default swaps and currency options. *Journal of Banking and Finance 31*(8), 2383–2403.

Carr, P. and L. Wu (2009). Variance risk premiums. *Review of Financial Studies 22*(3), 1311–1341.

Carr, P. and L. Wu (2010). Stock options and credit default swaps: A joint framework for valuation and estimation. *Journal of Financial Econometrics 8*(4), 409–449.

Chang, B., P. Christoffersen, and K. Jacobs (2013). Market skewness risk and the cross section of stock returns. *Journal of Financial Economics 107*(1), 46–68.

Chernov, M., J. Graveline, and I. Zviadadze (2012). Sources of risk in currency returns. *CEPR Discussion Papers No.DP8745*.

Christiansen, C., A. Ranaldo, and P. Söderlind (2011). The time-varying systematic risk of carry trade strategies. *Journal of Financial and Quantitative Analysis 46*(4), 1107–1125.

Clarida, R., J. Davis, and N. Pedersen (2009). Currency carry trade regimes: Beyond the Fama regression. *Journal of International Money and Finance 28*(8), 1375–1389.

Clarida, R., L. Sarno, M. Taylor, and G. Valente (2003). The out-of-sample success of term structure models as exchange rate predictors: A step beyond. *Journal of International Economics 60*(1), 61–83.

Cochrane, J. (2005). *Asset Pricing (Revised Edition)*. Princeton, NJ: Princeton University Press.

Cox, J., J. Ingersoll, and S. Ross (1985). A theory of the term structure of interest rates. *Econometrica 53*(2), 385–408.

Daníelsson, J., H. Shin, and J.-P. Zigrand (2009). Risk appetite and endogenous risk. *Available at SSRN No.1360866*.

Diebold, F., C. Li, and V. Yue (2008). Global yield curve dynamics and interactions: A dynamic nelson–siegel approach. *Journal of Econometrics 146*(2), 351–363.

Diks, C. and V. Panchenko (2006). A new statistic and practical guidelines for nonparametric Granger causality testing. *Journal of Economic Dynamics and Control 30*(9), 1647–1669.

Dittmar, R. (2002). Nonlinear pricing kernels, kurtosis preference, and evidence from the cross section of equity returns. *The Journal of Finance 57*(1), 369–403.

Durdu, C., E. Mendoza, and M. Terrones (2013). On the solvency of nations: Cross-country evidence on the dynamics of external adjustment. *Journal of International Money and Finance 32*(1), 762–780.

Eichengreen, B., A. Rose, and C. Wyplosz (1996). Contagious currency crises. *NBER Working Paper No.5681*.

Eitrheim, O. and T. Teräsvirta (1996). Testing the adequacy of smooth transition autoregressive models. *Journal of Econometrics 74*(1), 59–75.

Engel, C. (1996). The forward discount anomaly and the risk premium: A survey of recent evidence. *Journal of Empirical Finance 3*(2), 123–192.

Fama, E. (1984). Forward and spot exchange rates. *Journal of Monetary Economics 14*(3), 319–338.

Fama, E. and K. French (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics 33*(1), 3–56.

Fama, E. and J. MacBeth (1973). Risk, return, and equilibrium: Empirical tests. *The Journal of Political Economy 81*(3), 607–636.

Farhi, E., S. Fraiberger, X. Gabaix, R. Ranciere, and A. Verdelhan (2009). Crash risk in currency markets. *NBER Working Paper No.15062*.

Farhi, E. and X. Gabaix (2008). Rare disasters and exchange rates. *NBER Working Paper No.13805*.

Forbes, K. and F. Warnock (2012). Capital flow waves: Surges, stops, flight, and retrenchment. *Journal of International Economics 88*(2), 235–251.

Garman, M. and S. Kohlhagen (1983). Foreign currency option values. *Journal of International Money and Finance 2*(3), 231–237.

Glosten, L. and P. Milgrom (1985). Bid, ask and transaction prices in a specialist market with heterogeneously informed traders. *Journal of Financial Economics 14*(1), 71–100.

Gourinchas, P.-O. and H. Rey (2007). International financial adjustment. *The Journal of Political Economy 115*(4), 665–703.

Hamilton, J. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica 57*(2), 357–384.

Hamilton, J. (1990). Analysis of time series subject to changes in regime. *Journal of Econometrics 45*(1), 39–70.

Hamilton, J. (2008). Regime-switching models. In *The New Palgrave Dictionary of Economics (Second Edition)*, Volume 2. Eds. Durlauf, S. and L. Blume, Basingstoke: Palgrave Macmillan.

Hansen, L. (1982). Large sample properties of generalized method of moments estimators. *Econometrica 50*(4), 1029–1054.

Hansen, L. and R. Hodrick (1980). Forward exchange rates as optimal predictors of future spot rates: An econometric analysis. *The Journal of Political Economy 88*(5), 829–853.

Hansen, L. and R. Jagannathan (1997). Assessing specification errors in stochastic discount factor models. *The Journal of Finance 52*(2), 557–590.

Harvey, C. and A. Siddique (2000). Conditional skewness in asset pricing tests. *The Journal of Finance 55*(3), 1263–1295.

He, Z. and W. Xiong (2012). Rollover risk and credit risk. *The Journal of Finance 67*(2), 391–430.

Hiemstra, C. and J. Jones (1994). Testing for linear and nonlinear Granger causality in the stock price-volume relation. *The Journal of Finance 49*(5), 1639–1664.

Hilscher, J. and Y. Nosbusch (2010). Determinants of sovereign risk: Macroeconomic fundamentals and the pricing of sovereign debt. *Review of Finance 14*(2), 235–262.

Jagannathan, R. and Z. Wang (1996). The conditional CAPM and the cross-section of expected returns. *The Journal of Finance 51*(1), 3–53.

Jarrow, R. and A. Rudd (1982). Approximate option valuation for arbitrary stochastic processes. *Journal of Financial Economics 10*(3), 347–369.

Jegadeesh, N. and S. Titman (1993). Returns to buying winners and selling losers: Implications for stock market efficiency. *The Journal of Finance 48*(1), 65–91.

Jegadeesh, N. and S. Titman (2001). Profitability of momentum strategies: An evaluation of alternative explanations. *The Journal of Finance 56*(2), 699–720.

Jurek, J. (2007). Crash-neutral currency carry trades. In *AFA 2010 Atlanta Meetings Paper*.

Kaminsky, G. and C. Reinhart (1999). The twin crises: The causes of banking and balance-of-payments problems. *The American Economic Review 89*(3), 473–500.

Kaminsky, G. and C. Reinhart (2000). On crises, contagion, and confusion. *Journal of International Economics 51*(1), 145–168.

Kim, C.-J. and C. Nelson (1999). Has the u.s. economy become more stable? a bayesian approach based on a markov-switching model of the business cycle. *Review of Economics and Statistics 81*(4), 606–616.

Kim, C.-J. and C. Nelson (2003). *State-space models with regime switching: Classical and Gibbs-sampling approaches with applications*. The MIT Press.

Kodres, L. and M. Pritsker (2002). A rational expectations model of financial contagion. *The Journal of Finance 57*(2), 769–799.

Kozhan, R., A. Neuberger, and P. Schneider (2012). The skew risk premium in the equity index market. In *AFA 2011 Denver Meetings Paper*.

Kraus, A. and R. Litzenberger (1976). Skewness preference and the valuation of risk assets. *The Journal of Finance 31*(4), 1085–1100.

Krugman, P. (1979). A model of balance-of-payments crises. *Journal of Money, Credit and Banking 11*(3), 311–325.

Lane, P. and G. Milesi-Ferretti (2007). The external wealth of nations Mark II: Revised and extended estimates of foreign assets and liabilities, 1970–2004. *Journal of International Economics 73*(2), 223–250.

Londono, J. and H. Zhou (2012). Variance risk premia and the forward premium puzzle. *Board of Governors of the Federal Reserve System, International Finance Discussion Papers No.1068*.

Longstaff, F., J. Pan, L. Pedersen, and K. Singleton (2011). How sovereign is sovereign credit risk? *American Economic Journal: Macroeconomics 3*(2), 75–103.

Lustig, H., N. Roussanov, and A. Verdelhan (2011). Common risk factors in currency markets. *Review of Financial Studies 24*(11), 3731–3777.

Lustig, H. and A. Verdelhan (2007). The cross section of foreign currency risk premia and consumption growth risk. *The American Economic Review 97*(1), 89–117.

Mendoza, E. and V. Yue (2008). A solution to the default risk-business cycle disconnect. *NBER Working Paper No.13861*.

Mendoza, E. and V. Yue (2012). A general equilibrium model of sovereign default and business cycles. *The Quarterly Journal of Economics 127*(2), 889–946.

Menkhoff, L., L. Sarno, M. Schmeling, and A. Schrimpf (2012). Carry trades and global foreign exchange volatility. *The Journal of Finance 67*(2), 681–718.

Merton, R. (1973). An intertemporal capital asset pricing model. *Econometrica 41*(5), 867–887.

Merton, R. (1974). On the pricing of corporate debt: The risk structure of interest rates. *The Journal of Finance 29*(2), 449–470.

Nelson, C. and A. Siegel (1987). Parsimonious modeling of yield curves. *The Journal of Business 60*(4), 473–489.

Neuberger, A. (2012). Realized skewness. *Review of Financial Studies 25*(11), 3423–3455.

Newey, W. and K. West (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica 55*(3), 703–708.

Obstfeld, M. (1996). Models of currency crises with self-fulfilling features. *European Economic Review 40*(3), 1037–1047.

Obstfeld, M. and K. Rogoff (1995). Exchange rate dynamics redux. *The Journal of Political Economy 103*(3), 624–660.

Pan, J. and K. Singleton (2008). Default and recovery implicit in the term structure of sovereign CDS spreads. *The Journal of Finance 63*(5), 2345–2384.

Parker, J. and C. Julliard (2005). Consumption risk and the cross section of expected returns. *The Journal of Political Economy 113*(1), 185–222.

Pastor, L. and R. Stambaugh (2003). Liquidity risk and expected stock returns. *The Journal of Political Economy 111*(3), 642–685.

Pericoli, M. and M. Sbracia (2003). A primer on financial contagion. *Journal of Economic Surveys 17*(4), 571–608.

Plantin, G. and H. Shin (2011). Carry trades, monetary policy and speculative dynamics. *CEPR Discussion Paper No.DP8224*.

Ranaldo, A. and P. Söderlind (2010). Safe haven currencies. *Review of Finance 14*(3), 385–407.

Ross, S. (1976). The arbitrage theory of capital asset pricing. *Journal of Economic Theory 13*(3), 341–360.

Shanken, J. (1992). On the estimation of beta-pricing models. *Review of Financial Studies 5*(1), 1–55.

Stuart, A. and K. Ord (2009). *Kendall's advanced theory of statistics (Volume I): Distribution Theory.* A. Arnold.

Teräsvirta, T. (1994). Specification, estimation, and evaluation of smooth transition autoregressive models. *Journal of the American Statistical Association 89*(425), 208–218.

Teräsvirta, T. (1998). Modelling economic relationships with smooth transition regressions. In *Handbook of Applied Economic Statistics*. Eds. Ullah, A. and Giles, D., New York: Dekker.

Teräsvirta, T. (2006). Forecasting economic variables with nonlinear models. *Handbook of Economic Forecasting 1*, 413–457.

Teräsvirta, T. and H. Anderson (1992). Characterizing nonlinearities in business cycles using smooth transition autoregressive models. *Journal of Applied Econometrics 7*(1), 119–136.

Tjøstheim, D. and B. Auestad (1994). Nonparametric identification of nonlinear time series: Selecting significant lags. *Journal of the American Statistical Association 89*(428), 1410–1419.

Tong, H. (1990). *Nonlinear time series: A dynamical system approach.* Oxford University Press.

van Rijckeghem, C. and B. Weder (2001). Sources of contagion: Is it finance or trade? *Journal of International Economics 54*(2), 293–308.

Vassalou, M. and Y. Xing (2004). Default risk in equity returns. *The Journal of Finance 59*(2), 831–868.

Verdelhan, A. (2010). A habit-based explanation of the exchange rate risk premium. *The Journal of Finance 65*(1), 123–146.

Wu, L. and F. Zhang (2008). A no-arbitrage analysis of macroeconomic determinants of the credit spread term structure. *Management Science 54*(6), 1160–1175.

Yogo, M. (2006). A consumption-based explanation of expected stock returns. *The Journal of Finance 61*(2), 539–580.

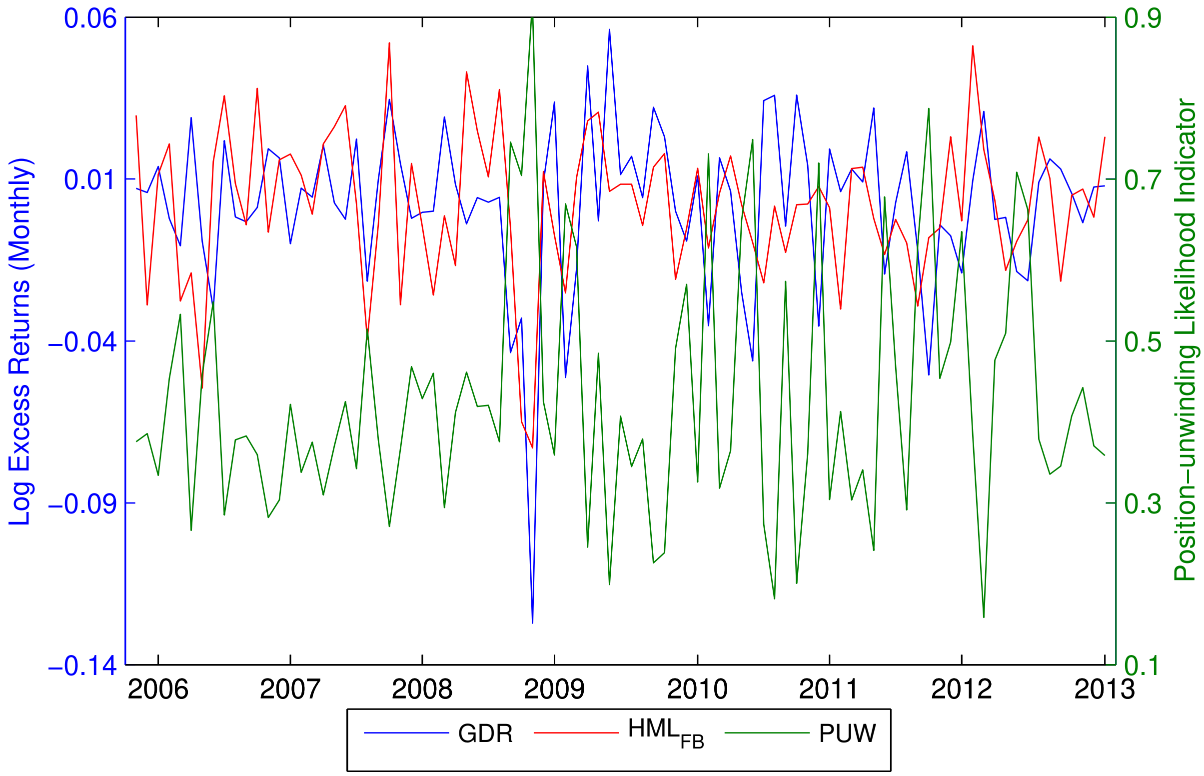
Appendix A.

Table A.1. Descriptive Statistics of Currency Carry Portfolios

All Countries with Bid-Ask Spreads								
Portfolios	C_0	C_1	C_2	C_3	C_4	C_5	Avg.	H/L
Mean (%)	-2.58	0.80	1.09	2.31	2.70	4.75	2.33	7.33
Median (%)	-3.93	2.32	3.83	5.40	5.57	8.05	5.03	10.60
Std.Dev. (%)	7.20	7.20	8.43	8.95	10.13	10.26	8.99	15.94
Skewness	0.14	-0.17	-0.70	-1.13	-1.26	-1.17	-0.89	-0.79
Kurtosis	0.25	0.27	2.42	5.05	3.95	4.11	3.16	2.49
Sharpe Ratio	-0.36	0.11	0.13	0.30	0.23	0.46	0.25	0.46
AC(1)	0.00	0.00	-0.09	0.05	0.15	0.14	0.07	0.14

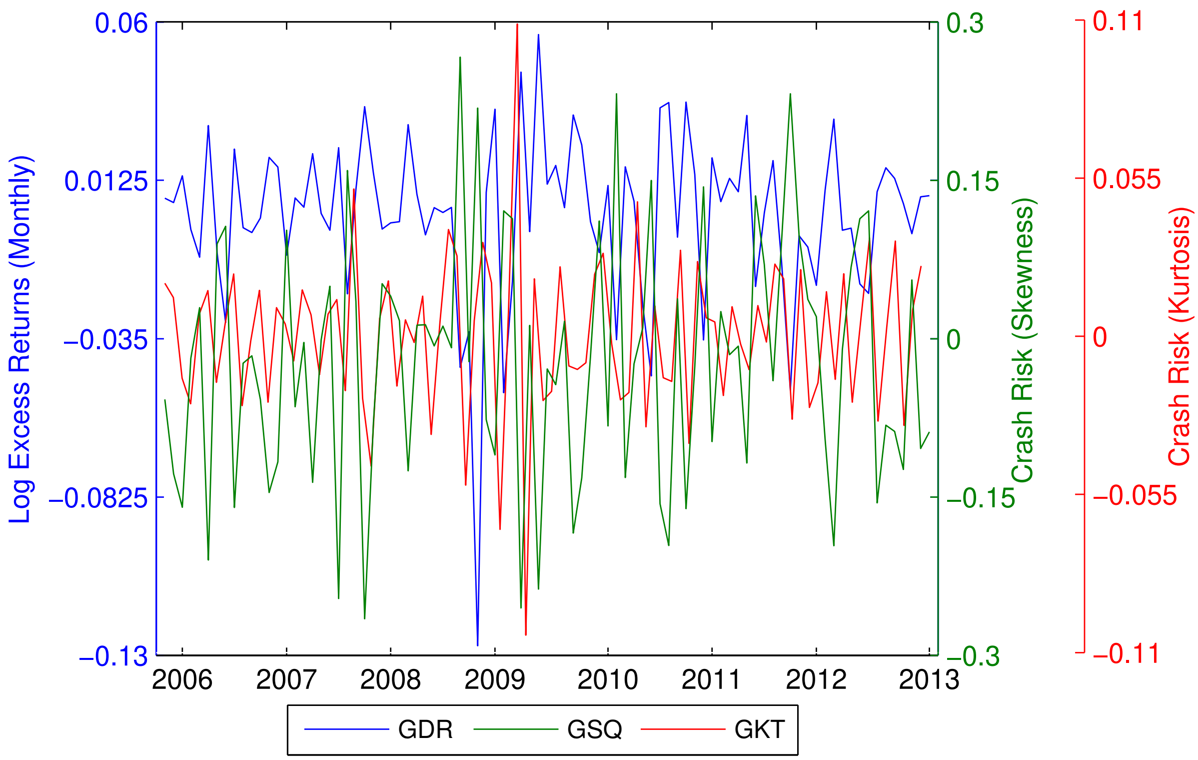
This table reports descriptive statistics of the excess returns in USD of currency carry portfolios sorted on 1-month forward discounts in local currencies. The 20% currencies with the lowest forward discounts are allocated to Portfolio C_1, and the next 20% to Portfolio C_2, and so on to Portfolio C_5 which contains the highest 20% forward discounts. Portfolio C_0 is Portfolio C_1 in short position and others are in long positions. The portfolios are rebalanced at the end of each former forward-rate agreement according to the updated contract. 'Avg.', and 'H/L' denotes the average excess returns of five portfolios in long positions, and difference in the excess returns between Portfolio C_5 and Portfolio C_0 respectively. All excess returns are monthly in USD and adjusted for transaction costs (bid-ask spreads) with the sample period from September 2005 to January 2013 with daily availability. The mean, median and standard deviation are annualized and in percentage. Skewness and kurtosis are in excess terms. AC(1) are the first order autocorrelation coefficients of the monthly excess returns in monthly frequency.

Figure A.1. Position-Unwinding Risk (Skewness-&-Kurtosis Adjusted)



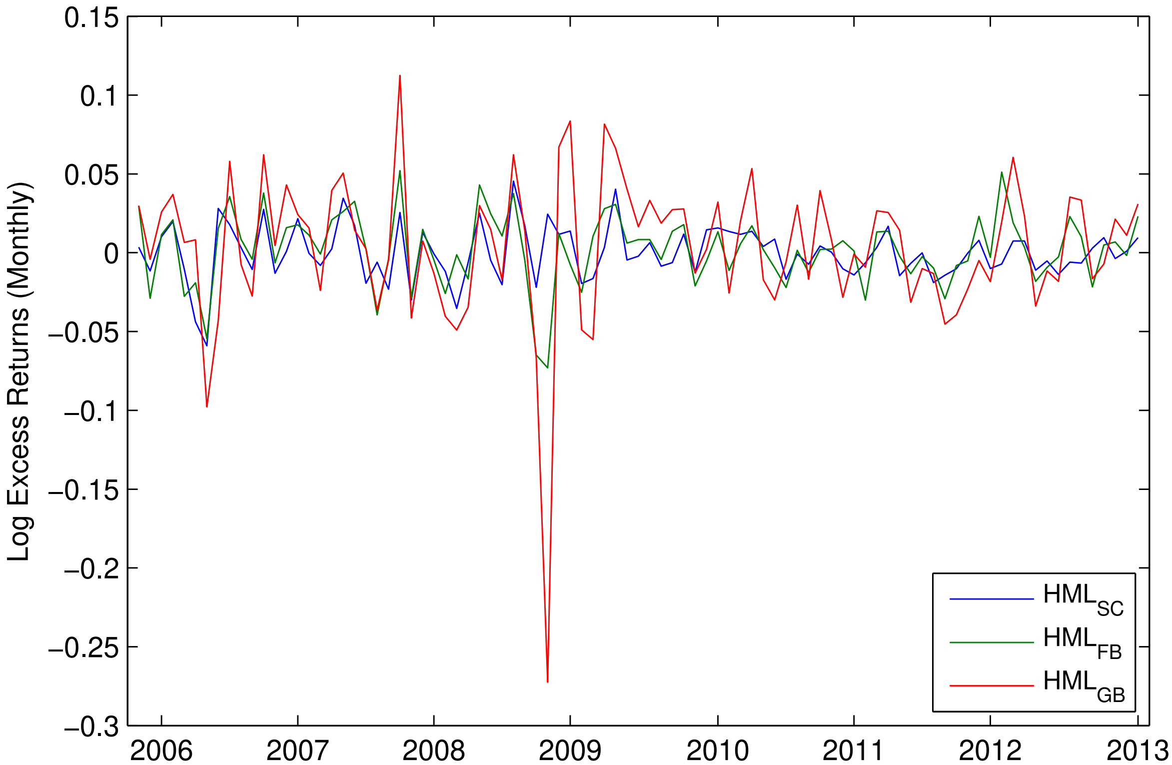
This figure shows skewness-and-kurtosis adjusted position-unwinding likelihood indicator (PUW) of the currency carry trades in comparison with Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) and forward bias risk (HML_{FB}) from September 2005 to January 2013.

Figure A.2. Dollar Risk VS. Crash Risk



This figure shows global skewness risk (GSQ) and global kurtosis risk (GKT) both as the proxy for currency crash risk in the graph for easier comparison with Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) from September 2005 to January 2013.

Figure A.3. Forward Bias Risk VS. Sovereign Credit Risk



This figure shows sovereign credit risk (HML_{SC} implied by currencies, and HML_{GB} implied by government bonds) in comparison with Lustig, Roussanov, and Verdelhan's (2011) forward bias risk (HML_{FB}) from September 2005 to January 2013.

Table A.2. Asset Pricing of Currency Carry Portfolios: HML_{SC} VS. HML_{GB}

All Countries with Transaction Costs										
Factor Exposures			Factor Prices							
	β_{GDR}	β_{SC}		b_{GDR}	b_{SC}	λ_{GDR}	λ_{SC}	R^2	$p-value$	MAE
C_1	0.726	-0.324							χ^2	
	(0.050)	(0.051)	FMB			2.395	3.287	0.933		0.302
C_2	0.900	-0.187				(3.194)	(3.143)		(0.893)	
	(0.073)	(0.063)				[3.174]	[3.072]		[0.901]	
C_3	1.022	-0.153								
	(0.039)	(0.031)							$HJ-dist$	
C_4	1.192	0.189	GMM_1	0.327	0.833	2.395	3.287	0.933	0.819	0.302
	(0.041)	(0.053)		(0.409)	(0.774)	(3.153)	(3.119)			
C_5	1.160	0.474	GMM_2	0.311	0.695	2.340	2.717	0.915	0.802	0.359
	(0.076)	(0.054)		(0.407)	(0.733)	(3.163)	(2.968)			
	β_{GDR}	β_{GB}		b_{GDR}	b_{GB}	λ_{GDR}	λ_{GB}	R^2	$p-value$	MAE
C_1	0.997	-0.186							χ^2	
	(0.059)	(0.030)	FMB			2.386	9.544	0.952		0.268
C_2	1.110	-0.147				(3.196)	(6.928)		(0.940)	
	(0.054)	(0.026)				[3.174]	[7.005]		[0.940]	
C_3	1.057	-0.019								
	(0.048)	(0.028)							$HJ-dist$	
C_4	1.047	0.098	GMM_1	-0.279	0.408	2.386	9.544	0.952	0.849	0.268
	(0.047)	(0.023)		(0.634)	(0.375)	(3.199)	(6.829)			
C_5	0.788	0.253	GMM_2	-0.224	0.388	2.633	9.563	0.920	0.848	0.288
	(0.038)	(0.024)		(0.623)	(0.373)	(3.253)	(6.976)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for comparison between two linear factor models (LFM) both based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor but differ in slope (country-specific) factor. The LFM in the top panel employs sovereign credit risk (HML_{SC}) implied in currencies and the LFM in the bottom panel adopts alternative measure of sovereign credit risk via government bonds total return indices (HML_{GB}). The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.3. Asset Pricing of Currency Carry Portfolios: $GDR + HML_{PC}$

All Countries with Transaction Costs										
Factor Exposures			Factor Prices							
	β_{GDR}	β_{PC}		b_{GDR}	b_{PC}	λ_{GDR}	λ_{PC}	R^2	$p-value$	MAE
C_1	0.872	-0.283							χ^2	
	(0.038)	(0.024)	FMB			2.388	5.695	0.968		0.193
C_2	0.942	-0.122				(3.191)	(4.545)		(0.960)	
	(0.065)	(0.029)				[3.174]	[4.476]		[0.963]	
C_3	1.048	-0.069								
	(0.045)	(0.019)							$HJ-dist$	
C_4	1.154	0.104	GMM_1	0.182	0.364	2.388	5.695	0.968	0.895	0.193
	(0.038)	(0.024)		(0.420)	(0.329)	(3.209)	(4.516)			
C_5	1.049	0.335	GMM_2	0.181	0.355	2.351	5.549	0.967	0.875	0.210
	(0.039)	(0.022)		(0.418)	(0.322)	(3.210)	(4.409)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for a linear factor model (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor, the first principal component (HML_{PC}) of sovereign credit risk (HML_{SC}) and Lustig, Roussanov, and Verdelhan's (2011) forward bias risk (HML_{FB}) as the slope (country-specific) factor. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.4. Asset Pricing of Currency Carry Portfolios: $GDR + HML_{PC} + HML_{SC_{\perp}}$

All Countries with Transaction Costs													
	Factor Exposures			Factor Prices									
	β_{GDR}	β_{PC}	$\beta_{SC_{\perp}}$		b_{GDR}	b_{PC}	$b_{SC_{\perp}}$	λ_{GDR}	λ_{PC}	$\lambda_{SC_{\perp}}$	R^2	$p-value$	MAE
C_1	0.93	-0.27	0.64									χ^2	
	(0.03)	(0.02)	(0.08)	FMB				2.39	3.96	-1.25	1.00		0.08
C_2	0.97	-0.13	0.17					(3.19)	(5.43)	(2.00)		(0.99)	
	(0.06)	(0.03)	(0.17)					[3.17]	[5.46]	[2.03]		[0.99]	
C_3	1.00	-0.06	-0.26										
	(0.04)	(0.02)	(0.11)									$HJ - dist$	
C_4	1.18	0.10	0.13	GMM_1	-0.04	0.29	-1.36	2.39	3.96	-1.25	1.00	0.84	0.08
	(0.05)	(0.02)	(0.12)		(0.59)	(0.35)	(2.58)	(3.21)	(5.45)	(1.99)			
C_5	0.93	0.36	-0.67	GMM_2	-0.04	0.29	-1.34	2.40	3.93	-1.24	1.00	0.84	0.08
	(0.03)	(0.02)	(0.08)		(0.59)	(0.34)	(2.57)	(3.24)	(5.38)	(2.00)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for the linear factor model (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor, the first principal component (HML_{PC}) of sovereign credit risk (HML_{SC}) and Lustig, Roussanov, and Verdelhan's (2011) forward bias risk (HML_{FB}), and the orthogonal component ($HML_{SC_{\perp}}$) of HML_{SC} to HML_{PC}, both as the slope (country-specific) factors. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ - dist$), and Mean Absolute Error (MAE) are also reported.

Table A.5. Asset Pricing of Currency Carry Portfolios: $PUW + HML_{SC}$

All Countries with Transaction Costs										
Factor Exposures			Factor Prices							
	β_{PUW}	β_{SC}		b_{PUW}	b_{SC}	λ_{PUW}	λ_{SC}	R^2	$p-value$	MAE
C_1	-0.108	-0.424							χ^2	
	(0.009)	(0.069)	FMB			-19.019	3.338	0.924		0.319
C_2	-0.139	-0.311				(21.518)	(3.132)		(0.879)	
	(0.009)	(0.074)				[21.238]	[3.077]		[0.887]	
C_3	-0.152	-0.294								
	(0.017)	(0.081)							$HJ-dist$	
C_4	-0.181	0.024	GMM_1	-0.058	0.801	-19.019	3.338	0.924	0.765	0.319
	(0.019)	(0.108)		(0.069)	(0.766)	(21.343)	(3.129)			
C_5	-0.171	0.313	GMM_2	-0.053	0.653	-17.509	2.720	0.892	0.583	0.377
	(0.022)	(0.088)		(0.068)	(0.725)	(21.282)	(2.979)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for my (benchmark) two linear factor models (LFM) based on skewness-and-kurtosis adjusted position-unwinding risk (PUW) as the intercept (global) factor, and sovereign credit risk (HML_{SC}) as the slope (country-specific) factor. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.6. Asset Pricing of Currency Carry Portfolios: PUW_{CR} & PUW_{FMP}

All Countries with Transaction Costs										
Factor Exposures			Factor Prices							
	β_{CR}	β_{SC}		b_{CR}	b_{SC}	λ_{CR}	λ_{SC}	R^2	$p-value$	MAE
C_1	-0.107	-0.426							χ^2	
	(0.009)	(0.069)	FMB			-19.156	3.335	0.924		0.319
C_2	-0.138	-0.313				(21.630)	(3.132)		(0.879)	
	(0.009)	(0.074)				[21.347]	[3.077]		[0.887]	
C_3	-0.151	-0.296								
	(0.017)	(0.081)							$HJ-dist$	
C_4	-0.180	0.022	GMM_1	-0.057	0.800	-19.156	3.335	0.924	0.733	0.319
	(0.018)	(0.108)		(0.069)	(0.766)	(21.451)	(3.128)			
C_5	-0.170	0.311	GMM_2	-0.053	0.652	-17.619	2.719	0.892	0.625	0.377
	(0.022)	(0.088)		(0.068)	(0.725)	(21.387)	(2.978)			
	β_{FMP}	β_{SC}		b_{FMP}	b_{SC}	λ_{FMP}	λ_{SC}	R^2	$p-value$	MAE
C_1	-0.124	-0.376							χ^2	
	(0.008)	(0.060)	FMB			-14.992	3.248	0.924		0.319
C_2	-0.160	-0.249				(18.243)	(3.138)		(0.880)	
	(0.012)	(0.057)				[18.082]	[3.067]		[0.887]	
C_3	-0.176	-0.226								
	(0.009)	(0.040)							$HJ-dist$	
C_4	-0.212	0.106	GMM_1	-0.058	0.801	-14.992	3.248	0.924	0.787	0.319
	(0.006)	(0.044)		(0.072)	(0.768)	(18.014)	(3.112)			
C_5	-0.202	0.391	GMM_2	-0.052	0.653	-13.548	2.640	0.877	0.618	0.388
	(0.015)	(0.062)		(0.070)	(0.725)	(17.958)	(2.957)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for comparison between two linear factor models (LFM) both based on sovereign credit risk (HML_{SC}) as the slope (country-specific) factor but differ in intercept (global) factor. The LFM in the top panel employs unadjusted position-unwinding risk (PUW_{CR}) and the LFM in the bottom panel adopts the excess returns of the factor-mimicking portfolio of position-unwinding risk (PUW_{FMP}). The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.7. Asset Pricing of Currency Carry Portfolios: $PUW + HML_{SC} + HML_{EP}$

All Countries with Transaction Costs													
	Factor Exposures				Factor Prices								
	β_{PUW}	β_{SC}	β_{EP}		b_{PUW}	b_{SC}	b_{EP}	λ_{PUW}	λ_{SC}	λ_{EP}	R^2	$p-value$	MAE
C_1	-0.11	-0.42	0.03									χ^2	
	(0.01)	(0.07)	(0.15)	FMB				-16.85	2.99	1.12	0.93		0.31
C_2	0.97	-0.31	0.04					(23.44)	(3.16)	(6.71)		(0.73)	
	(0.01)	(0.07)	(0.12)					[23.03]	[3.21]	[6.62]		[0.74]	
C_3	-0.15	-0.26	0.28										
	(0.01)	(0.05)	(0.22)									$HJ-dist$	
C_4	-0.18	0.06	0.33	GMM_1	-0.05	0.77	0.52	-16.85	2.99	1.12	0.93	0.56	0.31
	(0.01)	(0.08)	(0.23)		(0.08)	(0.75)	(2.68)	(23.83)	(3.21)	(6.90)			
C_5	-0.17	0.35	0.31	GMM_2	-0.04	0.65	0.48	-15.26	2.50	1.05	0.89	0.52	0.39
	(0.02)	(0.06)	(0.27)		(0.08)	(0.73)	(2.64)	(23.63)	(3.13)	(6.82)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for the linear factor model (LFM) based on position-unwinding risk (PUW) as the intercept (global) factor, sovereign credit risk (HML_{SC}) and equity premium risk (HML_{EP}) both as the slope (country-specific) factors (by double sorting the currencies into portfolios on both sovereign CDS spreads and equity premia (in local currencies) over U.S. market). The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.8. Asset Pricing of Currency Carry Portfolios: GSQ VS. GVI

All Countries with Transaction Costs										
Factor Exposures			Factor Prices							
	β_{GSQ}	β_{SC}		b_{GSQ}	b_{SC}	λ_{GSQ}	λ_{SC}	R^2	$p-value$	MAE
C_1	-0.132	-0.384							χ^2	
	(0.015)	(0.077)	FMB			-14.968	3.417	0.934		0.303
C_2	-0.169	-0.259				(18.230)	(3.135)		(0.897)	
	(0.016)	(0.091)				[17.844]	[3.089]		[0.906]	
C_3	-0.181	-0.239								
	(0.022)	(0.111)							$HJ-dist$	
C_4	-0.210	0.087	GMM_1	-0.084	0.847	-14.968	3.417	0.934	0.751	0.303
	(0.025)	(0.135)		(0.0097)	(0.771)	(18.133)	(3.104)			
C_5	-0.207	0.376	GMM_2	-0.084	0.711	-15.180	2.845	0.918	0.649	0.387
	(0.026)	(0.099)		(0.097)	(0.736)	(18.143)	(2.976)			
	β_{GSQ}	β_{GVI}		b_{GSQ}	b_{GVI}	λ_{GSQ}	λ_{GVI}	R^2	$p-value$	MAE
C_1	-0.124	-3.024							χ^2	
	(0.014)	(2.881)	FMB			2.731	-0.331	0.961		0.239
C_2	-0.153	-8.568				(25.034)	(0.285)		(0.961)	
	(0.014)	(2.162)				[22.502]	[0.259]		[0.960]	
C_3	-0.151	-11.429								
	(0.013)	(4.281)							$HJ-dist$	
C_4	-0.165	0.009	GMM_1	0.116	-27.217	2.731	-0.331	0.961	0.872	0.239
	(0.015)	(3.698)		(0.190)	(28.313)	(26.229)	(0.245)			
C_5	-0.149	-14.380	GMM_2	0.105	-29.215	-0.812	-0.369	0.561	0.045	0.850
	(0.016)	(3.789)		(0.178)	(28.565)	(23.121)	(0.250)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for comparison between two linear factor models (LFM) both based on global skewness risk (GSQ) as the intercept (global) factor but differ in slope (country-specific) factor. The LFM in the top panel employs sovereign credit risk (HML_{SC}) and the LFM in the bottom panel adopts Menkhoff, Sarno, Schmeling, and Schrimpf's (2012) global FX volatility (innovation) risk (GVI) with the pricing kernel $m_t = 1 - b_{GSQ} \cdot (GSQ_t - \mu_{GSQ}) - b_{GVI} \cdot GVI_t$. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.9. Asset Pricing of Currency Carry Portfolios: $GDR + HML_{SC} + \Delta VIX$

All Countries with Transaction Costs													
	Factor Exposures				Factor Prices								
	β_{GDR}	β_{SC}	$\beta_{\Delta VIX}$		b_{GDR}	b_{SC}	$b_{\Delta VIX}$	λ_{GDR}	λ_{SC}	$\lambda_{\Delta VIX}$	R^2	$p-value$	MAE
C_1	0.77	-0.29	0.03									χ^2	
	(0.05)	(0.05)	(0.02)	FMB				2.39	2.46	-11.88	0.95		0.30
C_2	1.00	-0.11	0.07					(3.20)	(3.52)	(16.71)		(0.78)	
	(0.07)	(0.07)	(0.02)					[3.17]	[3.50]	[16.42]		[0.80]	
C_3	1.00	-0.17	-0.02										
	(0.04)	(0.05)	(0.02)									$HJ-dist$	
C_4	1.18	0.18	-0.01	GMM_1	0.03	0.41	-0.20	2.39	2.46	-11.88	0.95	0.593	0.30
	(0.05)	(0.05)	(0.01)		(0.93)	(1.34)	(0.62)	(5.84)	(3.52)	(16.74)			
C_5	1.06	0.39	-0.08	GMM_2	-0.01	0.28	-0.23	2.44	2.03	-12.29	0.94	0.516	0.30
	(0.06)	(0.06)	(0.03)		(0.92)	(1.31)	(0.62)	(3.65)	(3.45)	(16.64)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for the linear factor model (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor, sovereign credit risk (HML_{SC}) and s simple changes in Chicago Board Options Exchanges (CBOE) VIX index (ΔVIX) both as slope (country-specific) factors. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.10. Asset Pricing of Currency Carry Portfolios: $GDR + HML_{SC} + GVI$

All Countries with Transaction Costs													
	Factor Exposures			Factor Prices									
	β_{GDR}	β_{SC}	β_{GVI}		b_{GDR}	b_{SC}	b_{GVI}	λ_{GDR}	λ_{SC}	λ_{GVI}	R^2	$p-value$	MAE
C_1	0.82	-0.29	3.29									χ^2	
	(0.04)	(0.05)	(0.91)	FMB				2.39	0.36	-0.38	0.98		0.16
C_2	0.97	-0.16	2.65					(3.20)	(5.35)	(0.54)		(0.94)	
	(0.06)	(0.07)	(1.57)					[3.17]	[5.16]	[0.50]		[0.93]	
C_3	1.02	-0.15	-0.23										
	(0.04)	(0.03)	(1.13)									$HJ-dist$	
C_4	1.17	0.18	-0.87	GMM_1	-0.71	-0.23	-36.34	2.39	0.36	-0.38	0.98	0.46	0.16
	(0.05)	(0.05)	(1.08)		(1.73)	(1.94)	(69.45)	(3.23)	(5.50)	(0.54)			
C_5	1.03	0.43	-4.84	GMM_2	-0.87	-0.44	-45.88	3.34	-0.17	-0.48	0.47	0.09	0.95
	(0.05)	(0.05)	(1.11)		(1.71)	(1.96)	(69.34)	(3.88)	(5.57)	(0.54)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for the linear factor model (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor, sovereign credit risk (HML_{SC}) and global FX volatility (innovation) risk (GVI) both as slope (country-specific) factors. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.11. Asset Pricing of Currency Carry Portfolios: $GDR + GKT + GVI$

All Countries with Transaction Costs													
	Factor Exposures				Factor Prices								
	β_{GDR}	β_{GKT}	β_{GVI}		b_{GDR}	b_{GKT}	b_{GVI}	λ_{GDR}	λ_{GKT}	λ_{GVI}	R^2	$p - value$	MAE
C_1	0.88	-0.04	4.58									χ^2	
	(0.04)	(0.03)	(1.02)	FMB				2.39	4.43	-0.33	1.00		0.02
C_2	0.99	0.06	3.45					(3.20)	(8.75)	(0.26)		(1.00)	
	(0.05)	(0.05)	(1.19)					[3.17]	[8.79]	[0.24]		[1.00]	
C_3	1.04	0.04	0.52										
	(0.04)	(0.04)	(1.36)									$HJ - dist$	
C_4	1.15	-0.09	-1.79	GMM_1	-0.55	0.35	-28.71	2.39	4.43	-0.33	1.00	1.00	0.02
	(0.05)	(0.03)	(0.90)		(0.80)	(0.86)	(29.82)	(3.21)	(8.85)	(0.68)			
C_5	0.94	0.02	-6.76	GMM_2	-0.54	0.354	-28.75	2.47	4.36	-0.33	1.00	0.99	0.07
	(0.06)	(0.06)	(1.26)		(0.77)	(0.84)	(29.78)	(3.76)	(8.73)	(0.24)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for Menkhoff, Sarno, Schmeling, and Schrimpf's (2012) linear factor model (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor and global FX volatility risk (GVI) both as slope (country-specific) factors, plus global kurtosis risk (GKT). The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ - dist$), and Mean Absolute Error (MAE) are also reported.

Table A.12. Asset Pricing of Currency Carry Portfolios: $GDR + HML_{SC} + GLR$

All Countries with Transaction Costs													
	Factor Exposures			Factor Prices									
	β_{GDR}	β_{SC}	β_{GLR}		b_{GDR}	b_{SC}	b_{GLR}	λ_{GDR}	λ_{SC}	λ_{GLR}	R^2	$p-value$	MAE
C_1	0.74	-0.33	10.14									χ^2	
	(0.05)	(0.05)	(7.08)	FMB				2.41	3.47	0.02	0.94		0.26
C_2	0.90	-0.19	1.89					(3.20)	(3.27)	(0.07)		(0.80)	
	(0.07)	(0.06)	(10.48)					[3.17]	[3.18]	[0.07]		[0.78]	
C_3	1.02	-0.15	-1.83										
	(0.04)	(0.03)	(11.25)									$HJ-dist$	
C_4	1.18	0.19	-13.79	GMM_1	0.41	0.87	87.39	2.41	3.47	0.02	0.94	0.69	0.26
	(0.04)	(0.05)	(7.25)		(0.48)	(0.76)	(329.33)	(3.17)	(3.28)	(0.08)			
C_5	1.16	0.47	3.59	GMM_2	0.41	0.73	88.82	2.51	2.89	0.02	0.93	0.24	0.34
	(0.08)	(0.05)	(8.30)		(0.48)	(0.72)	(325.03)	(2.74)	(3.24)	(0.07)			

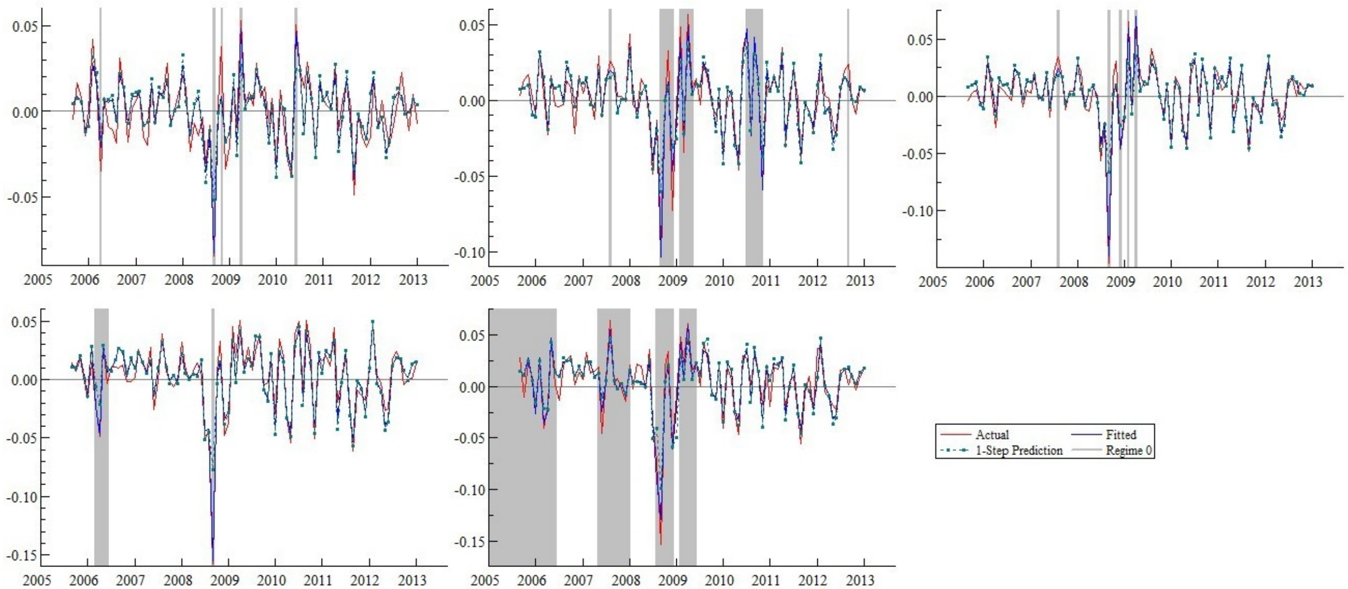
This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for the linear factor model (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor, sovereign credit risk (HML_{SC}) and global FX liquidity risk (GLR) measured by the aggregate level of relative bid-ask spreads, both as slope (country-specific) factors. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.13. Asset Pricing of Currency Carry Portfolios: $GDR + HML_{SC} + \Delta TED$

All Countries with Transaction Costs													
	Factor Exposures			Factor Prices									
	β_{GDR}	β_{SC}	$\beta_{\Delta TED}$		b_{GDR}	b_{SC}	$b_{\Delta TED}$	λ_{GDR}	λ_{SC}	$\lambda_{\Delta TED}$	R^2	$p-value$	MAE
C_1	0.73	-0.33	-0.03									χ^2	
	(0.05)	(0.05)	(0.23)	FMB				2.40	3.23	-0.33	0.93		0.30
C_2	0.90	-0.18	0.13					(3.19)	(3.65)	(3.34)		(0.74)	
	(0.08)	(0.07)	(0.14)					[3.17]	[3.54]	[3.30]		[0.75]	
C_3	1.03	-0.14	0.21										
	(0.04)	(0.02)	(0.18)									$HJ-dist$	
C_4	1.19	0.19	0.08	GMM_1	0.32	0.80	-0.46	2.40	3.23	-0.33	0.93	0.38	0.30
	(0.04)	(0.05)	(0.17)		(0.50)	(1.35)	(13.04)	(3.35)	(3.66)	(3.36)			
C_5	1.15	0.46	-0.38	GMM_2	0.32	0.73	0.40	2.34	2.78	-0.08	0.92	0.27	0.36
	(0.07)	(0.05)	(0.30)		(0.51)	(1.34)	(12.88)	(3.47)	(3.56)	(3.32)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for the linear factor model (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor, sovereign credit risk (HML_{SC}) and changes in T-Bill Eurodollar (TED) Spreads Index (ΔTED) both as slope (country-specific) factors. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Figure A.4. Markov Regime-switching Models of Currency Carry Portfolios: PUW + HML_{SC}



This figure shows a two-state Markov regime-switching models (Hamilton, 2008) with smoothed transition probabilities (Kim and Nelson, 2003) of currency carry portfolios regressed on position-unwinding likelihood indicator (PUW) and sovereign credit risk factor (HML_{SC}) from September 2005 to January 2013. The tested assets from the left to the right in graphs are PFL_1, PFL_2, and PFL_3 in first row; PFL_4, and PFL_5 in the second row. The grey areas (Regime 0) represents financial turbulence state.

Table A.14. Markov Regime-switching Models of Currency Carry Portfolios: Estimates & Tests

	C_1	C_2	C_3	C_4	C_5
$\alpha(0)$	0.078***	0.089***	0.125***	0.111**	0.118***
$\alpha(1)$	0.039***	0.047***	0.054***	0.073***	0.061***
$\alpha(0) = \alpha(1)$	10.419***	17.907***	41.706***	0.413	14.659***
$\beta_{PUW}(0)$	-0.171***	-0.208***	-0.285***	-0.290***	-0.272***
$\beta_{PUW}(1)$	-0.091***	-0.108***	-0.123***	-0.159***	-0.129***
$\beta_{PUW}(0) = \beta_{PUW}(1)$	31.929***	25.418***	93.339***	2.258	27.942***
$\beta_{SC}(0)$	-1.068***	-0.297*	-0.954***	0.087	0.580***
$\beta_{SC}(1)$	-0.382***	-0.380***	-0.270***	0.094	0.187*
$\beta_{SC}(0) = \beta_{SC}(1)$	10.799***	0.093	5.311**	0.000	2.065
$p_{00} = 1 - p_{11}$	0.297	4.27243**	0.319	2.51	35.580***
Average Duration (Month):					
Regime 0	1.00	3.00	1.00	2.50	7.25
Regime 1	14.00	12.33	14.00	28.00	15.00
Linearity LR-test	7.391	21.325***	58.721***	46.856***	35.979***

This table reports the parameter estimates of five currency carry portfolios (monthly excess returns) with Newey and West (1987) HAC standard errors. Asterisks refer to the level of statistical significance of the estimated coefficients, '*' 10%, '**' 5%, and '***' 1%. Regime 0 is high volatility state and Regime 1 is low volatility state. The Wald statistics computed by asymptotic covariance matrix for testing identical parameters and systematically alternating regimes (opposite to arbitrarily switching between two regimes) in terms of smoothed transition probabilities, average duration of each regime (month), and the linearity LR-tests are also reported. However, owing to the issue of non-standard asymptotic χ^2 distribution, the validity of the LR-statistic for linearity test is questioned (Teräsvirta, 2006). The sample period is from September 2005 to January 2013.

Table A.15. Asset Pricing of Currency Carry Portfolios: Peso Problem

All Countries with Transaction Costs										
Factor Exposures			Factor Prices							
	β_{PUW}	$\beta_{SC_{W95}}$		b_{PUW}	$b_{SC_{W95}}$	λ_{PUW}	$\lambda_{SC_{W95}}$	R^2	$p-value$	MAE
C_1	-0.108	-0.426							χ^2	
	(0.009)	(0.069)	FMB			-19.038	3.328	0.924		0.319
C_2	-0.139	-0.313				(21.518)	(3.127)		(0.879)	
	(0.009)	(0.074)				[21.240]	[3.069]		[0.887]	
C_3	-0.152	-0.296								
	(0.017)	(0.081)							$HJ-dist$	
C_4	-0.181	0.023	GMM_1	-0.058	0.804	-19.038	3.328	0.924	0.687	0.319
	(0.019)	(0.108)		(0.069)	(0.768)	(21.342)	(3.126)			
C_5	-0.171	0.313	GMM_2	-0.53	0.656	-17.525	2.712	0.892	0.527	0.377
	(0.022)	(0.088)		(0.068)	(0.727)	(21.281)	(2.975)			
	β_{PUW}	$\beta_{SC_{W90}}$		b_{PUW}	$b_{SC_{W90}}$	λ_{PUW}	$\lambda_{SC_{W90}}$	R^2	$p-value$	MAE
C_1	-0.108	-0.480							χ^2	
	(0.009)	(0.075)	FMB			-19.512	3.109	0.924		0.321
C_2	-0.139	-0.345				(21.385)	(2.938)		(0.882)	
	(0.009)	(0.082)				[21.284]	[2.859]		[0.890]	
C_3	-0.152	-0.344								
	(0.017)	(0.090)							$HJ-dist$	
C_4	-0.181	-0.006	GMM_1	-0.059	0.907	-19.512	3.109	0.924	0.486	0.321
	(0.018)	(0.119)		(0.069)	(0.850)	(21.268)	(2.932)			
C_5	-0.171	0.310	GMM_2	-0.054	0.738	-17.984	2.531	0.894	0.418	0.382
	(0.022)	(0.130)		(0.068)	(0.804)	(21.232)	(2.778)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for comparison between two linear factor models (LFM) both based on position-unwinding risk (PUW) as the intercept (global) factor but differ in slope (country-specific) factor. The LFM in the top panel employs sovereign credit risk winsorized at 95% level ($HML_{SC_{W95}}$) and the LFM in the bottom panel adopts sovereign credit risk winsorized at 90% level ($HML_{SC_{W90}}$). The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.16. Currency Portfolios Sorted on Betas with HML_{SC}

All Countries without Transaction Costs							
Portfolios	L	LM	M	UM	H	Avg.	H/L
Mean (%)	-1.71	2.15	2.26	3.24	4.07	2.69	5.78
Median (%)	-2.91	4.73	4.53	4.91	7.48	5.38	11.91
Std.Dev. (%)	9.33	10.57	7.27	5.20	10.64	8.60	17.65
Skewness	0.24	-0.90	-1.19	-0.85	-1.42	-0.92	-0.97
Kurtosis	0.40	3.14	4.19	1.79	5.86	3.07	2.99
Sharpe Ratio	-0.18	0.20	0.31	0.62	0.38	0.34	0.33
$f - s$ (%)	-0.77	0.69	1.49	4.30	5.05	2.15	5.82

This table reports descriptive statistics of the excess returns of currency portfolios sorted on individual currencies' average β_{SC}, which are the risk exposures to HML_{SC} (sovereign credit factor), from September 2005 to January 2013. The rolling window of 60 months is chosen to obtain stable estimations of β_{SC} with very low volatility. The rank of individual currencies' risk exposures is relatively persistent to the sorting over the sample period, hence the portfolios do not need to be rebalanced during the whole sample period. The 20% currencies with the lowest β_{SC} are allocated to Portfolio 'L' (Low), and the next 20% to Portfolio 'LM' (Lower Medium), Portfolio 'M' (Medium), Portfolio 'UM' (Upper Medium) and so on to Portfolio 'H' (High) which contains the highest 20% β_{SC}. 'Avg.', and 'H/L' denotes the average excess returns of five portfolios, and difference in the excess returns between Portfolio 'H' and the Portfolio 'L' respectively. All excess returns are monthly in USD with daily availability and adjusted for transaction costs (bid-ask spreads). The mean, median and standard deviation are annualized and in percentage. Skewness and kurtosis are in excess terms. The last row ($f - s$) shows the average annualized forward discounts of five portfolios in percentage.

Table A.17. Currency Portfolios Doubly Sorted on Betas with HML_{SC} & Betas with PUW

All Countries without Transaction Costs											
β_{SC}	Bottom			Mezzanine			Top				
β_{PUW}	Low	Medium	High	Low	Medium	High	Low	Medium	High	Avg.	H/L
Mean (%)	-0.99	1.42	2.18	1.81	2.57	3.68	2.91	2.79	5.13	2.61	6.12
Median (%)	-2.69	3.31	6.74	2.21	4.76	6.97	4.90	7.17	8.18	5.21	10.18
Std.Dev. (%)	6.53	10.85	13.05	3.17	9.09	13.86	5.49	11.35	11.85	9.47	15.78
Skewness	0.12	-0.19	-0.80	-0.44	-1.41	-0.94	-0.69	-1.12	-1.51	-0.80	-1.16
Kurtosis	0.89	1.25	2.12	1.39	5.96	2.95	1.08	3.51	6.81	2.88	4.85
Sharpe Ratio	-0.15	0.13	0.17	0.57	0.28	0.27	0.53	0.25	0.43	0.31	0.39
$f - s$ (%)	-0.61	-0.22	0.46	2.32	2.39	3.96	2.06	3.95	5.95	2.24	6.57

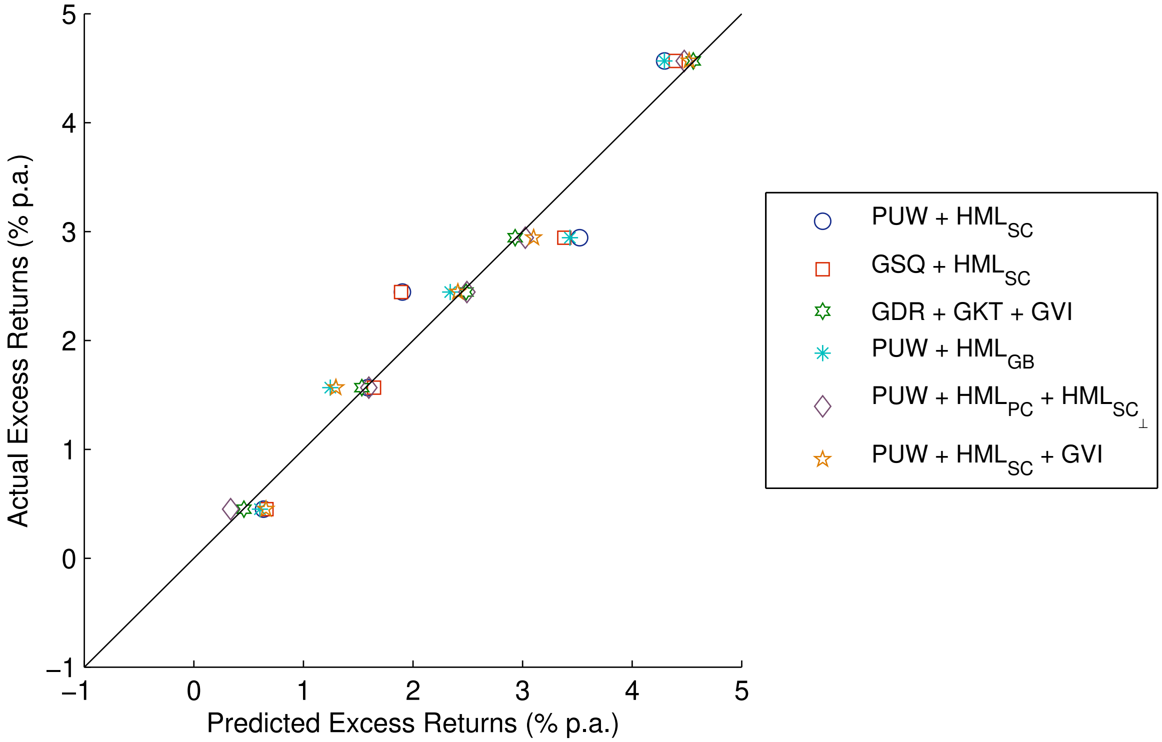
This table reports descriptive statistics of the excess returns of currency portfolios sorted on both individual currencies' average β_{SC} and average β_{PUW}, which are the risk exposures to HML_{SC} (sovereign credit factor) and to PUW (position-unwinding likelihood indicator) respectively, from September 2005 to January 2013. The rolling window of 60 months is chosen to obtain stable estimations of β_{SC} and β_{PUW} with very low volatility. The rank of individual currencies' risk exposures is relatively persistent to the sorting over the sample period, hence the portfolios do not need to be rebalanced during the whole sample period. The portfolios are doubly sorted on bottom 30%, mezzanine 40%, and top 30% basis. 'Avg.' denotes the average excess returns of nine portfolios, and 'H/L' is difference in the excess returns between the portfolio that consists of the top 30% currencies in both β_{SC} and β_{PUW} and the portfolio that consists of the bottom 30% currencies in both β_{SC} and β_{PUW}. All excess returns are monthly in USD with daily availability and adjusted for transaction costs (bid-ask spreads). The mean, median and standard deviation are annualized and in percentage. Skewness and kurtosis are in excess terms. The last row $(f - s)$ shows the average annualized forward discounts of five portfolios in percentage.

Table A.18. Asset Pricing of Currency Carry Portfolios: Quadratic Effect of PUW

All Countries with Transaction Costs													
	Factor Exposures				Factor Prices								
	β_{PUW}	β_{PUW^2}	β_{SC}		b_{PUW}	b_{PUW^2}	b_{SC}	λ_{PUW}	λ_{PUW^2}	λ_{SC}	R^2	$p-value$	MAE
C_1	-0.09	-0.02	-0.42									χ^2	
	(0.05)	(0.05)	(0.07)	FMB				-15.09	-20.52	2.69	0.95		0.28
C_2	-0.13	-0.01	-0.31					(27.41)	(24.37)	(3.09)		(0.87)	
	(0.22)	(0.22)	(0.08)					[22.38]	[21.85]	[3.10]		[0.81]	
C_3	-0.02	-0.14	-0.29										
	(0.09)	(0.09)	(0.07)									$HJ-dist$	
C_4	-0.06	-0.12	0.03	GMM_1	0.39	-0.44	0.67	-15.09	-20.52	2.69	0.95	0.65	0.28
	(0.20)	(0.20)	(0.10)		(1.20)	(1.20)	(0.72)	(23.43)	(24.11)	(3.01)			
C_5	-0.02	-0.15	0.32	GMM_2	0.42	-0.47	0.63	-14.91	-20.69	2.54	0.95	0.65	0.28
	(0.10)	(0.12)	(0.08)		(1.19)	(1.19)	(0.71)	(23.48)	(24.22)	(2.99)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for investigating the nonlinear relationship between position-unwinding risk (PUW) and transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The factor model is tested with sovereign credit risk (HML_{SC}). The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Figure A.5. Cross Sectional Goodness of Fit: Currency Carry Portfolios



This figure shows the cross-sectional predictive power of position-unwinding risk and sovereign credit risk on five currency carry portfolios. The excess returns are in percentage per annum.

Table A.19. Descriptive Statistics of Government Bond Portfolios

All Countries without Transaction Costs							
Portfolios	B_1	B_2	B_3	B_4	B_5	Avg.	H/L
Mean (%)	3.87	3.93	5.50	5.75	7.62	5.34	3.76
Median (%)	3.55	7.53	8.82	10.14	10.54	8.12	7.05
Std.Dev. (%)	6.30	8.45	8.28	12.57	16.72	10.46	15.54
Skewness	0.25	-0.68	-0.46	-1.28	-0.95	-0.62	-1.26
Kurtosis	0.23	2.23	1.64	4.58	6.40	3.02	7.24
Sharpe Ratio	0.61	0.47	0.70	0.44	0.46	0.53	0.24
AC(1)	-0.09	-0.18	-0.09	-0.01	0.04	-0.06	0.08

This table reports descriptive statistics of the excess returns in USD of government bond (total return) indices portfolios with 5-year maturity sorted on 1-month lagged redemption yields in local currencies. The 20% equity indices with the lowest lagged redemption yields are allocated to Portfolio B_1, and the next 20% to Portfolio B_2, and so on to Portfolio B_5 which contains the highest 20% lagged redemption yields. The portfolios are rebalanced simultaneously with the the currency portfolios, hence the excess returns have the same duration. 'Avg.', and 'H/L' denotes the average excess returns of five portfolios, and difference in the excess returns between Portfolio B_5 and Portfolio B_1 respectively. All excess returns are monthly in USD and unadjusted for transaction costs with the sample period from September 2005 to January 2013 with daily availability. The mean, median and standard deviation are annualized and in percentage. Skewness and kurtosis are in excess terms. AC(1) are the first order autocorrelation coefficients of the monthly excess returns in monthly frequency.

Table A.20. Asset Pricing of Government Bond Portfolios: Crash Risk & Sovereign Default Risk

All Countries without Transaction Costs										
Factor Exposures			Factor Prices							
	β_{PUW}	β_{GB}		b_{PUW}	b_{GB}	λ_{PUW}	λ_{GB}	R^2	$p-value$	MAE
B_1	-0.088	-0.214							χ^2	
	(0.012)	(0.059)	FMB			-41.035	3.755	0.837		0.465
B_2	-0.114	-0.053				(23.397)	(5.461)		(0.898)	
	(0.013)	(0.062)				[23.334]	[5.435]		[0.902]	
B_3	-0.117	0.063								
	(0.016)	(0.088)							$HJ-dist$	
B_4	-0.153	0.067	GMM_1	-0.170	-0.215	-41.035	3.755	0.837	0.791	0.465
	(0.014)	(0.044)		(0.112)	(0.310)	(23.546)	(5.488)			
B_5	-0.223	0.786	GMM_2	-0.171	-0.248	-39.411	2.936	0.727	0.568	0.558
	(0.012)	(0.059)		(0.111)	(0.304)	(23.136)	(5.425)			
	β_{GSQ}	β_{GB}		b_{GSQ}	b_{GB}	λ_{GSQ}	λ_{GB}	R^2	$p-value$	MAE
B_1	-0.125	-0.213							χ^2	
	(0.017)	(0.061)	FMB			-32.406	3.523	0.922		0.294
B_2	-0.148	-0.032				(18.435)	(5.457)		(0.905)	
	(0.020)	(0.111)				[18.395]	[5.419]		[0.928]	
B_3	-0.127	0.101								
	(0.027)	(0.119)							$HJ-dist$	
B_4	-0.174	0.234	GMM_1	-0.244	-0.228	-32.406	3.523	0.922	0.924	0.294
	(0.018)	(0.067)		(0.165)	(0.333)	(18.702)	(5.474)			
B_5	-0.125	0.787	GMM_2	-0.252	-0.265	-32.307	2.871	0.880	0.632	0.364
	(0.017)	(0.061)		(0.162)	(0.322)	(18.606)	(5.437)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for comparison between two linear factor models (LFM) both based on sovereign credit risk (HML_{GB}) as the slope (country-specific) factor but differ in intercept (global) factor. The LFM in the top panel employs position-unwinding risk (PUW) of currency carry trade portfolios and the LFM in the bottom panel adopts global skewness risk (GSQ). The test assets are the excess returns (unadjusted for transaction-cost) of five government bond portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.21. Descriptive Statistics of Equity Momentum Portfolios

All Countries without Transaction Costs							
Portfolios	E_1	E_2	E_3	E_4	E_5	Avg.	H/L
Mean (%)	1.33	1.59	2.98	4.44	4.74	3.01	3.41
Median (%)	9.80	14.85	15.68	15.60	16.99	14.58	5.03
Std.Dev. (%)	25.62	25.60	26.06	26.52	30.88	26.94	15.27
Skewness	-0.98	-1.39	-1.61	-1.62	-1.60	-1.44	-0.58
Kurtosis	2.98	5.44	7.54	8.07	8.02	6.41	3.98
Sharpe Ratio	0.05	0.06	0.11	0.17	0.15	0.11	0.22
AC(1)	0.10	0.22	0.20	0.20	0.19	0.20	-0.18

This table reports descriptive statistics of the excess returns in USD of equity momentum portfolios sorted on 1-month lagged equity-index excess returns in local currencies. The 20% equity indices with the lowest lagged excess returns are allocated to Portfolio E_1, and the next 20% to Portfolio E_2, and so on to Portfolio E_5 which contains the highest 20% lagged excess returns. The portfolios are rebalanced simultaneously with the the currency portfolios, hence the excess returns have the same duration. 'Avg.', and 'H/L' denotes the average excess returns of five portfolios, and difference in the excess returns between Portfolio E_5 and Portfolio E_1 respectively. All excess returns are monthly in USD and unadjusted for transaction costs with the sample period from September 2005 to January 2013 with daily availability. The mean, median and standard deviation are annualized and in percentage. Skewness and kurtosis are in excess terms. AC(1) are the first order autocorrelation coefficients of the monthly excess returns in monthly frequency.

Table A.22. Asset Pricing of Equity Momentum Portfolios: Crash Risk

All Countries without Transaction Costs										
Factor Exposures			Factor Prices							
	β_{PUW}	β_{EM}		b_{PUW}	b_{EM}	λ_{PUW}	λ_{EM}	R^2	$p-value$	MAE
E_1	-0.363	-0.139							χ^2	
	(0.065)	(0.125)	FMB			-4.934	7.496	0.976		0.351
E_2	-0.352	0.113				(25.631)	(8.428)		(0.993)	
	(0.035)	(0.126)				[24.200]	[5.098]		[0.988]	
E_3	-0.321	0.196								
	(0.037)	(0.128)							$HJ-dist$	
E_4	-0.360	0.266	GMM_1	0.010	0.346	-4.934	7.496	0.976	0.689	0.351
	(0.045)	(0.134)		(0.016)	(0.231)	(25.074)	(4.998)			
E_5	-0.363	0.861	GMM_2	0.015	0.350	-3.360	7.460	0.926	0.503	0.573
	(0.065)	(0.125)		(0.013)	(0.230)	(24.428)	(4.971)			
	β_{GSQ}	$\beta_{\Delta VIX}$		b_{GSQ}	$b_{\Delta VIX}$	λ_{GSQ}	$\lambda_{\Delta VIX}$	R^2	$p-value$	MAE
E_1	-0.447	-0.083							χ^2	
	(0.052)	(0.160)	FMB			-2.933	7.564	0.979		0.333
E_2	-0.409	0.184				(21.507)	(8.338)		(0.994)	
	(0.049)	(0.168)				[20.277]	[5.072]		[0.990]	
E_3	-0.374	0.260								
	(0.048)	(0.165)							$HJ-dist$	
E_4	-0.419	0.338	GMM_1	0.016	0.350	-2.933	7.564	0.979	0.429	0.333
	(0.055)	(0.179)		(0.134)	(0.235)	(21.347)	(4.980)			
E_5	-0.447	0.917	GMM_2	0.029	0.356	-0.751	7.482	0.837	0.212	0.958
	(0.052)	(0.160)		(0.127)	(0.234)	(20.414)	(4.965)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for comparison between two linear factor models (LFM) both based on equity momentum risk (HML_{EM}) as the slope (country-specific) factor but differ in intercept (global) factor. The LFM in the top panel employs position-unwinding risk (PUW) of currency carry trade portfolios and the LFM in the bottom panel adopts global skewness risk (GSQ). The test assets are the excess returns (unadjusted for transaction-cost) of five equity momentum portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.23. Asset Pricing of Equity Momentum Portfolios: Sovereign Default Risk

All Countries without Transaction Costs										
Factor Exposures			Factor Prices							
	β_{SC}	β_{EM}		b_{SC}	b_{EM}	λ_{SC}	λ_{EM}	R^2	$p-value$	MAE
E_1	0.969	0.180							χ^2	
	(0.500)	(0.240)	FMB			-0.974	7.739	0.991		0.215
E_2	0.826	0.429				(9.925)	(8.146)		(0.999)	
	(0.432)	(0.239)				[9.693]	[5.102]		[0.999]	
E_3	0.677	0.488								
	(0.405)	(0.241)							$HJ-dist$	
E_4	0.667	0.599	GMM_1	-0.387	0.368	-0.974	7.739	0.991	0.725	0.215
	(0.444)	(0.262)		(2.776)	(0.248)	(10.251)	(5.131)			
E_5	0.969	1.180	GMM_2	-0.662	0.374	-1.989	7.530	0.842	0.158	0.992
	(0.500)	(0.240)		(1.801)	(0.243)	(6.692)	(4.958)			
	β_{GB}	β_{EM}		b_{GB}	b_{EM}	λ_{GB}	λ_{EM}	R^2	$p-value$	MAE
E_1	1.379	-0.177							χ^2	
	(0.105)	(0.119)	FMB			1.484	7.520	0.977		0.570
E_2	1.223	0.110				(6.901)	(8.255)		(0.992)	
	(0.111)	(0.138)				[6.561]	[5.079]		[0.987]	
E_3	1.257	0.151								
	(0.106)	(0.123)							$HJ-dist$	
E_4	1.295	0.250	GMM_1	-0.032	0.346	1.484	7.520	0.977	0.888	0.358
	(0.151)	(0.128)		(0.282)	(0.233)	(6.640)	(4.993)			
E_5	1.379	0.823	GMM_2	-0.045	0.350	1.183	7.514	0.952	0.326	0.419
	(0.105)	(0.119)		(0.273)	(0.232)	(6.501)	(4.963)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for comparison between two linear factor models (LFM) both based on simple changes in equity momentum risk (HML_{EM}) as the slope (country-specific) factor but differ in intercept (global) factor. The LFM in the top panel employs sovereign credit risk (HML_{SC}) implied by currencies and the LFM in the bottom panel adopts sovereign credit risk (HML_{GB}) implied by government bonds. The test assets are the excess returns (unadjusted for transaction-cost) of five equity momentum portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.24. Asset Pricing of Currency Carry Portfolios: $GDR + HML_{EM}$

All Countries with Transaction Costs										
Factor Exposures			Factor Prices							
	β_{GDR}	β_{EM}		b_{GDR}	b_{EM}	λ_{GDR}	λ_{EM}	R^2	$p-value$	MAE
C_1	0.753	-0.005							χ^2	
	(0.044)	(0.022)	FMB			2.461	15.899	0.702		0.630
C_2	0.974	-0.092				(3.198)	(15.397)		(0.716)	
	(0.044)	(0.019)				[3.174]	[15.189]		[0.733]	
C_3	1.026	0.010								
	(0.038)	(0.017)							$HJ-dist$	
C_4	1.168	0.016	GMM_1	-0.036	0.475	2.461	15.899	0.702	0.522	0.630
	(0.038)	(0.019)		(0.541)	(0.524)	(3.216)	(15.311)			
C_5	1.080	0.071	GMM_2	0.125	0.202	2.300	7.576	0.584	0.114	0.590
	(0.047)	(0.030)		(0.485)	(0.440)	(3.229)	(13.120)			

This table reports time-series factor exposures (β), and cross-sectional factor loadings (b) and factor prices (λ) for my (benchmark) two linear factor models (LFM) based on Lustig, Roussanov, and Verdelhan's (2011) dollar risk (GDR) as the intercept (global) factor, and equity momentum risk (HML_{EM}) as the slope (country-specific) factor. The test assets are the transaction-cost adjusted excess returns of five currency carry portfolios from September 2005 to January 2013. The coefficient estimates of Stochastic Discount Factor (SDF) parameters b and λ are obtained by Fama-MacBeth (FMB) without a constant in the second-stage regressions (Fama and MacBeth, 1973), and by fist-stage (GMM_1) and iterated (GMM_2) Generalized Method of Moments procedures. Newey-West VARHAC standard errors (Newey and West, 1987) with optimal lag selection (Andrews, 1991) and corresponding p-value of χ^2 statistic (for testing the null hypothesis that the cross-sectional pricing errors are jointly equal to zero) are in the parentheses. The Shanken-adjusted standard errors (Shanken, 1992) and corresponding p-value of χ^2 statistic are in the brackets. The cross-sectional R^2, the simulation-based p-value of Hansen-Jagannathan distance (Hansen and Jagannathan, 1997) for testing whether it is equal to zero ($HJ-dist$), and Mean Absolute Error (MAE) are also reported.

Table A.25. Linear & Nonlinear Granger Causality Tests for Impulsive Country-specific Risk

	Linear	Nonlinear
HML_{SC} does not Granger cause HML_{FB}	0.01	0.02
HML_{FB} does not Granger cause HML_{SC}	0.37	0.03
HML_{SC} does not Granger cause GVI	0.03	0.04
GVI does not Granger cause HML_{SC}	0.63	0.73
HML_{SC} does not Granger cause ΔVIX	0.04	0.07
ΔVIX does not Granger cause HML_{SC}	0.92	0.41
HML_{SC} does not Granger cause ΔTED	0.00	0.03
ΔTED does not Granger cause HML_{SC}	0.29	0.05
HML_{SC} does not Granger cause GLR	0.25	0.07
GLR does not Granger cause HML_{SC}	0.44	0.10
HML_{SC} does not Granger cause HML_{GB}	0.03	0.05
HML_{GB} does not Granger cause HML_{SC}	0.65	0.12
HML_{SC} does not Granger cause HML_{EM}	0.05	0.22
HML_{EM} does not Granger cause HML_{SC}	0.70	0.19

This table reports the $p - values$ of linear and nonlinear Granger causality tests (see Hiemstra and Jones, 1994; Diks and Panchenko, 2006 for details) for the impulsive country-specific risk. The first column lists the null hypotheses to be tested. Due to the limited sample size, Akaike's Final Prediction Error (also as known as AIC) is chosen as the lag-length selection procedure rather than Schwarz (Bayesian) Information Criterion (SIC) or Hannan-Quinn Information Criterion (see Anderson, 2004 for details). The bandwidth of 1.50 is chosen according to the sample size. The sample period is from September 2005 to January 2013.

Table A.26. Linear & Nonlinear Granger Causality Tests for Global Contagion

	Linear	Nonlinear		Linear	Nonlinear
HML_{SC} does not Granger cause GDR	0.08	0.06	HML_{FB} does not Granger cause GDR	0.02	0.13
GDR does not Granger cause HML_{SC}	0.43	0.41	GDR does not Granger cause HML_{FB}	0.54	0.27
GVI does not Granger cause GDR	0.36	0.05	ΔVIX does not Granger cause GDR	0.00	0.04
GDR does not Granger cause GVI	0.64	0.10	GDR does not Granger cause ΔVIX	0.35	0.11
GLR does not Granger cause GDR	0.85	0.69	ΔTED does not Granger cause GDR	0.00	0.54
GDR does not Granger cause GLR	0.05	0.38	GDR does not Granger cause ΔTED	0.03	0.75
HML_{SC} does not Granger cause PUW	0.27	0.30	HML_{FB} does not Granger cause PUW	0.09	0.51
PUW does not Granger cause HML_{SC}	0.40	0.65	PUW does not Granger cause HML_{FB}	0.99	0.51
GVI does not Granger cause PUW	0.23	0.78	ΔVIX does not Granger cause PUW	0.04	0.53
PUW does not Granger cause GVI	0.29	0.06	PUW does not Granger cause ΔVIX	0.69	0.07
GLR does not Granger cause PUW	0.65	0.12	ΔTED does not Granger cause PUW	0.18	0.56
PUW does not Granger cause GLR	0.07	0.23	PUW does not Granger cause ΔTED	0.05	0.24
HML_{SC} does not Granger cause GSQ	0.24	0.06	HML_{FB} does not Granger cause GSQ	0.04	0.06
GSQ does not Granger cause HML_{SC}	0.22	0.14	GSQ does not Granger cause HML_{FB}	0.27	0.16
GVI does not Granger cause GSQ	0.46	0.68	ΔVIX does not Granger cause GSQ	0.03	0.02
GSQ does not Granger cause GVI	0.06	0.07	GSQ does not Granger cause ΔVIX	0.13	0.08
GLR does not Granger cause GSQ	0.86	0.22	ΔTED does not Granger cause GSQ	0.17	0.43
GSQ does not Granger cause GLR	0.34	0.28	GSQ does not Granger cause ΔTED	0.22	0.50

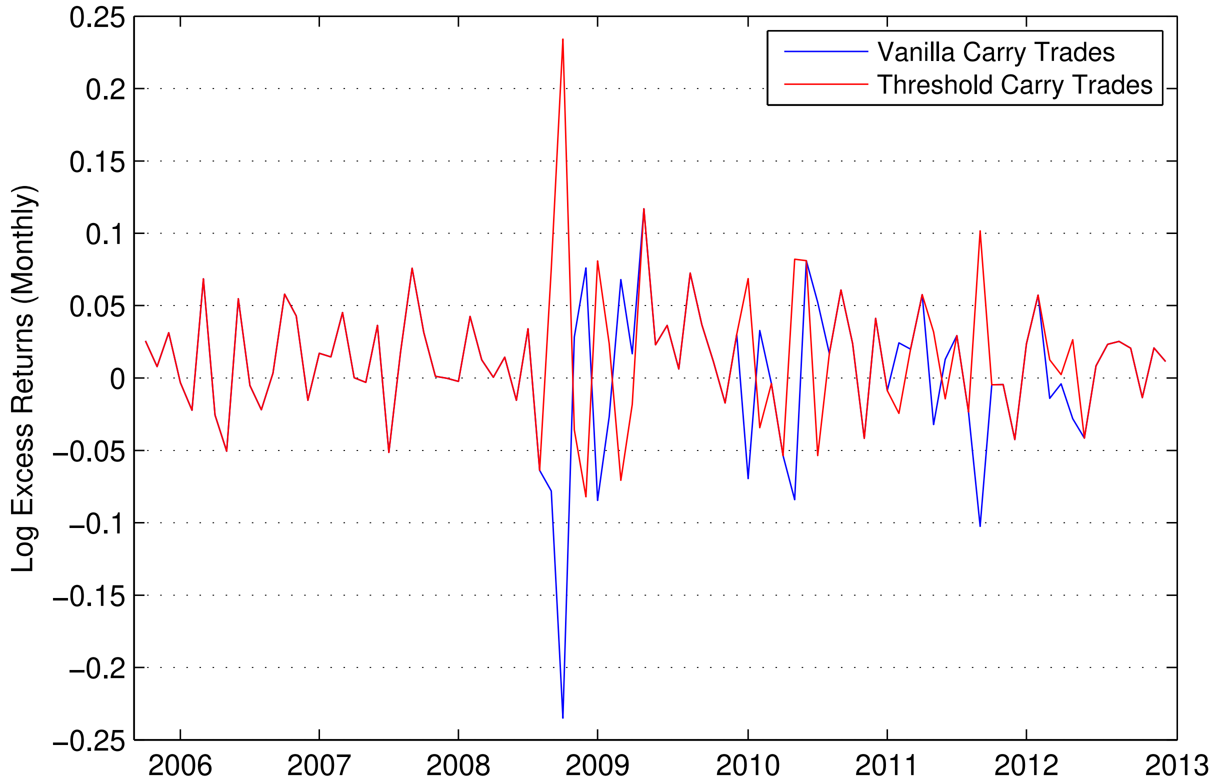
This table reports the $p-values$ of linear and nonlinear Granger causality tests (see Hiemstra and Jones, 1994; Diks and Panchenko, 2006 for details) for global contagion. The first column lists the null hypotheses to be tested. Due to the limited sample size, Akaike's Final Prediction Error (also as known as AIC) is chosen as the lag-length selection procedure rather than Schwarz (Bayesian) Information Criterion (SIC) or Hannan-Quinn Information Criterion (see Anderson, 2004 for details). The bandwidth of 1.50 is chosen according to the sample size. The sample period is from September 2005 to January 2013.

Table A.27. Smooth Transition Models of Currency Carry Portfolios: Estimates & Tests

	C_1	C_2	C_3	C_4	C_5
β_{FB}	-0.426***	-0.177***	-0.065***	0.120***	0.572***
$\alpha(0)$	-0.002***	-0.001	0.001	0.044***	-0.001
$\beta_{GDR}(0)$	0.984***	1.066***	0.967***	0.118	0.989***
$\alpha(1)$	0.003***	0.005	0.003	-0.044***	0.003*
$\beta_{GDR}(1)$	-0.050	-0.196	0.243***	1.011***	-0.070
γ	27.0	138.0	99.0	149.0	26.0
c	0.462	0.751	0.721	0.719	0.462
Nonlinearity LM-test	1.75	0.424	2.21*	0.433	1.780

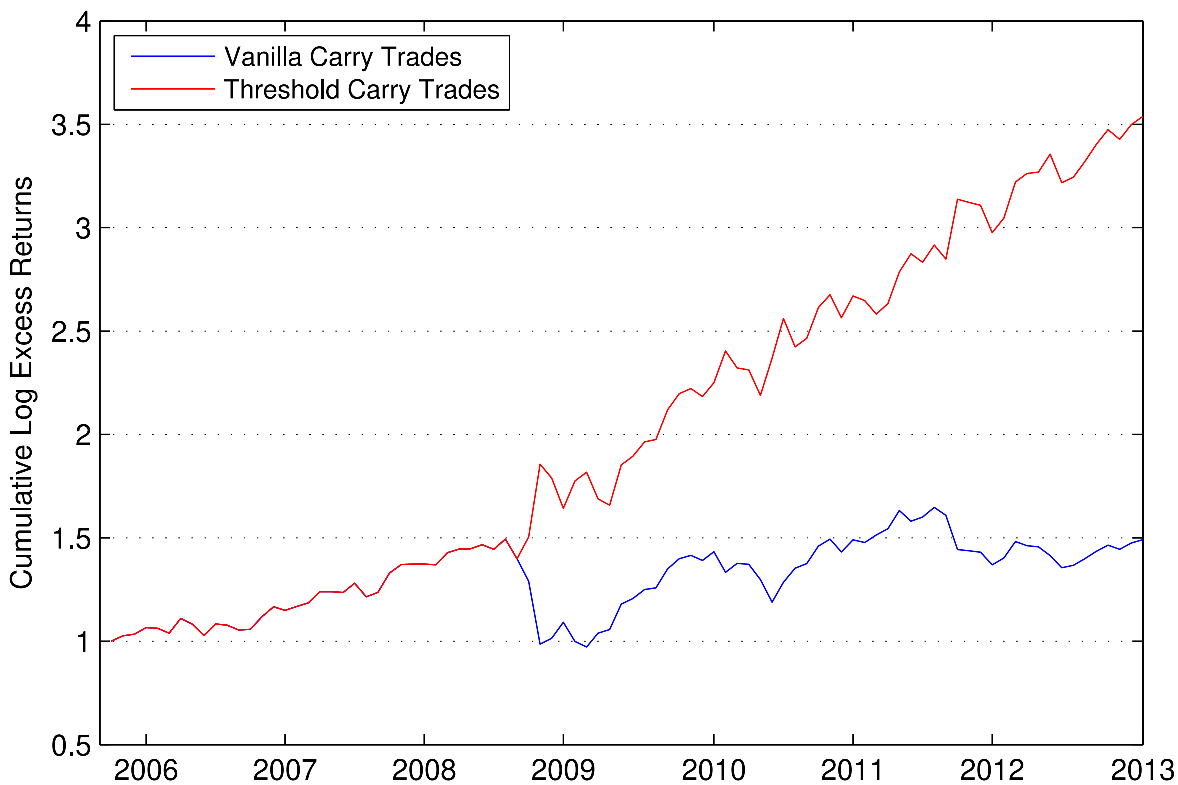
This table reports the parameter estimates of five currency carry portfolios (monthly excess returns) with Teräsvirta (1998) standard errors scaling procedure. Regime 0 denotes linear regime and Regime 1 the nonlinear regime. Both the constant term (α) and dollar risk (GDR) enter the model nonlinearly, forward bias risk (HML_{FB}) enters the linear part of the STR model only. Position-unwinding likelihood indicator (PUW) is the transition variable (ν_t). γ_j, and c_j denotes the slope parameter that determines the smoothness of the transition function $\omega(\cdot)$, and the threshold level, respectively. Asterisks refer to the level of statistical significance of the estimated coefficients (not for γ and c), '*' 10%, '**' 5%, and '***' 1%. $LM - test$ for examining the null hypothesis of no remaining nonlinearity (Eitrheim and Teräsvirta, 1996) is employed. The sample period is from September 2005 to January 2013.

Figure A.6. Monthly Excess Returns of the Alternative Currency Carry Portfolio: Threshold Trading on PUW



This figure shows the monthly excess returns of an alternative carry trade strategy that is immunized from currency crashes, in comparison of the traditional long-short strategy. It trades on the threshold level of position-unwinding risk that investing in the highest interest-rate currencies funded by the lowest interest-rate currencies during the tranquil period and reverse the positions once the threshold level of position-unwinding likelihood indicator is reached. The sample period is from September 2005 to January 2013.

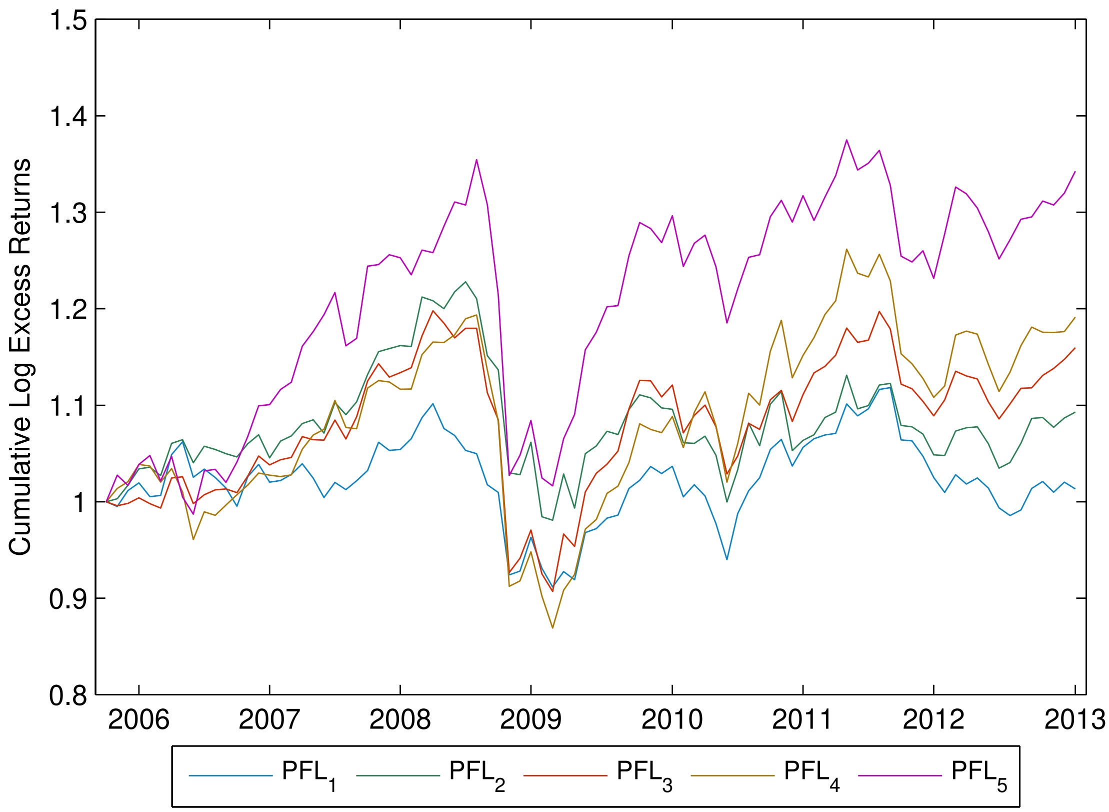
Figure A.7. Cumulative Excess Returns of the Alternative Currency Carry Portfolio: Threshold Trading on PUW



This figure shows the cumulative excess returns of an alternative carry trade strategy that is immunized from currency crashes, in comparison of the traditional long-short strategy. It trades on the threshold level of position-unwinding risk that investing in the highest interest-rate currencies funded by the lowest interest-rate currencies during the tranquil period and reverse the positions once the threshold level of position-unwinding likelihood indicator is reached. The sample period is from September 2005 to January 2013.

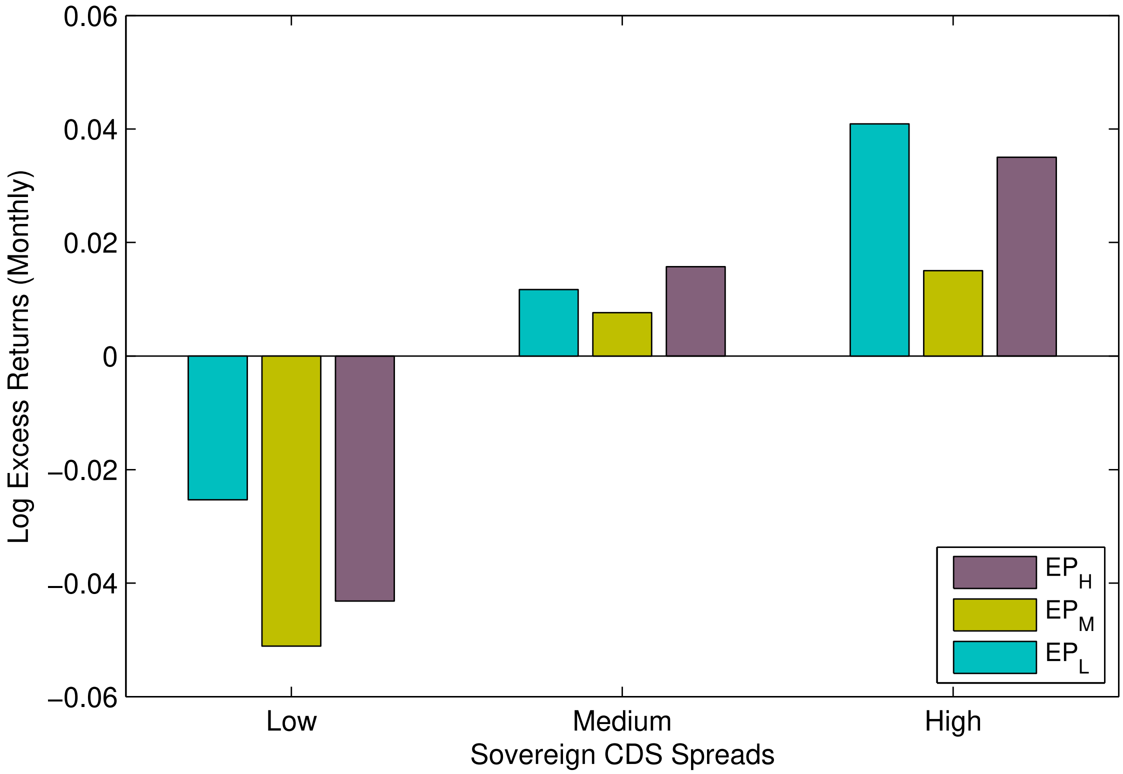
Appendix B.

Figure B.1. Cumulative Excess Returns of Currency Carry Portfolios Sorted on Forward Discounts



This figure shows the cumulative excess returns of currency carry portfolios sorted on forward discounts and in long positions from September 2005 to January 2013. PFL_1, PFL_2, and PFL_3, PFL_4, and PFL_5 denotes the currency carry portfolios with lowest, lower medium, medium, higher medium, and highest forward discounts, respectively.

Figure B.2. Currency Portfolios Doubly Sorted on Sovereign CDS Spreads and Equity Premia



This figure shows the average monthly excess returns of nine currency portfolios (the vertical axis) that are sorted on both sovereign CDS spreads and equity premia over U.S. market from September 2005 to January 2013. EP_L, EP_M, and EP_H denotes the low, medium, and high equity-premium currency portfolios, respectively. The horizontal axis represents the level of sovereign CDS spreads of currency portfolios in ascending order.

Table B.1. Principle Component Analysis of Asset Excess Returns

	Currency Carry Portfolios					
	C_1	C_2	C_3	C_4	C_5	Variance (%)
PC_1	0.876	0.946	0.959	0.952	0.904	86.120
PC_2	0.442	0.143	-0.043	-0.157	-0.368	7.552
Total						93.672
	Government Bond Portfolios					
	B_1	B_2	B_3	B_4	B_5	Variance (%)
PC_1	0.741	0.932	0.951	0.919	0.831	77.120
PC_2	0.635	0.111	0.049	-0.252	-0.469	14.035
Total						91.155
	Equity Momentum Portfolios					
	E_1	E_2	E_3	E_4	E_5	Variance (%)
PC_1	0.956	0.976	0.977	0.974	0.958	93.730
PC_2	0.259	0.066	-0.015	-0.067	0-.242	2.699
Total						96.429

This table reports the principal component coefficients of currency carry, government bonds, equity momentum portfolios. PC_1, PC_2 denotes the first principal component, and the second principal component, respectively. The last column shows the share of the total variance (in %) explained by each common factor. The last row provides the cumulative share of the total variance (in %) explained by the first two common factors. The sample period is from September 2005 to January 2013.

Table B.2. Correlations between Risk Factors and Principle Components

	Currency		Bond		Equity	
	PC_1	PC_2	PC_1	PC_2	PC_1	PC_2
GDR	0.999	0.047	0.915	0.205	0.837	0.047
PUW	-0.918	-0.090	-0.807	-0.210	-0.781	-0.001
GSQ	-0.837	-0.019	-0.785	-0.146	-0.697	-0.003
GKT	0.158	0.041	0.127	0.080	0.123	-0.118
HML_{FB}	0.390	0.904	0.156	0.820	0.566	-0.088
HML_{SC}	-0.082	0.712	-0.106	0.697	0.287	0.038
HML_{GB}	0.693	0.551	0.561	0.752	0.829	0.005
HML_{EM}	0.329	0.203	0.307	0.128	0.340	0.925
GVI	-0.629	-0.369	-0.443	-0.369	-0.582	0.065
ΔVIX	-0.541	-0.431	-0.374	-0.475	-0.703	-0.122
GLR	-0.268	-0.178	-0.205	-0.218	-0.299	0.048
ΔTED	-0.084	-0.176	-0.092	-0.115	-0.201	-0.087

This table reports the correlations between risk factors and the principal components of currency carry, government bonds, equity momentum portfolios. PC_1, PC_2 denotes the first principal component, and the second principal component, respectively. The sample period is from September 2005 to January 2013.