Solvency Risk Premia and the Carry Trades[*]

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Draft, 04.2016

Comments are appreciated!

Abstract

This paper shows that currency carry trades can be rationalized by the time-varying risk premia originating from the sovereign solvency risk. We find that solvency risk is a key determinant of risk premia in the cross section of carry trade returns, as its covariance with returns captures a substantial part of the cross-sectional variation of carry trade returns. Importantly, low interest rate currencies serve as insurance against solvency risk, while high interest rate currencies expose investors to more risk. The results are not attenuated by existing risks and pass a broad range of various robustness checks.

JEL classifications: F31, G15

Keywords: Solvency Risk; Carry Trades; Risk Premia

1. Introduction

This paper studies risk-return characteristics of the currency carry trade strategy that is implemented by borrowing in a low interest rate currency and subsequent investing in a high interest rate currency. Provided that uncovered interest parity holds, investment currency depreciation offsets the interest rate differential (forward premium) and returns to carry are zero. In fact, the opposite holds true and the long-standing phenomena of currency carry trade has its roots in persistent deviations from uncovered interest parity and empirical rejection of the forward rate unbiasedness hypothesis; that is, the forward premium is an apparent biased predictor of a future spot exchange rate change (Fama, 1984). These feasible discrepancies in macroeconomic parity conditions give rise to positive average historical returns of the carry trade strategy and the forward premium puzzle.

Seeking an explanation of the forward premium puzzle and carry trade returns has been a prime topic in international finance for over three decades, the debate being initiated by Hansen and Hodrick (1980, 1983) and Fama (1984). The main avenue for research perceives the carry trade returns as a compensation for a common risk. Therein currencies are prone to deliver low/high carry trade returns in bad/good times due to persistent heterogeneity in risk exposures between investment and funding currencies. Several recent studies suggest a number of possible explanations for observed patterns of heterogeneous risk exposures (see, e.g., Lustig, Roussanov, and Verdelhan, 2011; Menkhoff, Sarno, Schmeling, and Schrimpf, 2012; Lettau, Maggiori, and Weber, 2013; and others cited below). Overall, the cumulative evidence points to time-varying risk premia as the pervasive source of the carry trade returns and to the forward premium puzzle not being without costs. Nonetheless, the identification of an appropriate risk premia that explains the carry trade profitability remains an ongoing debate.

This paper contributes to current debate by revealing a new economic-based time-varying risk premia in the currency market– the sovereign solvency risk premium– that depends upon a country's ability to payout an outstanding external debt. We argue that the financial capacity of the economy, captured by the solvency measure, lies at heart of persistent heterogeneity across currencies' exposures to a common risk, and incites the differences in average excess returns. In other words, the profitability of currency carry trades can be rationalized by the time-varying risk premia that originate from the sovereign solvency risk. Consistently, we find that high interest rate currencies demand a higher risk premium, as they deliver low carry trade returns at times of high solvency risk, therefore exposing investors to more risk, whereas low interest currencies are a hedge against the solvency risk.

Importantly, this paper proposes a new risk-adjusted version of uncovered interest parity (UIP). Bridging the macroeconomic concepts of debt elastic interest rate and risk premium associated with lending to the economy, we lay out a UIP that is disturbed by country-specific risk premia given by the increasing convex function of the debt service capacity of the economy. Therein, time-varying solvency risk premia offset the disparity between actual and expected exchange rate, establishing equilibrium. This provides a simple and intuitive risk-based view on exchange rate determination by a risk premium varying in the solvency of the economy.

The empirical findings of the paper indicate that solvency risk preserves the substantial power to explain the cross-section of carry trade returns. This paper introduces a new, solvency-based, risk factor and show that its covariance with returns accounts for almost all of the variation in the cross-section of carry trade returns. Our empirical approach relies on much of the recent literature (Lustig, Roussanov, and Verdelhan, 2011; and Ready, Roussanov, and Ward, 2015). We perform portfolio sorts on forward discounts and the solvency measure, identify risk factor as the returns on zero-cost long-short strategy between

the last and first solvency-sorted portfolios and label it IMS, for indebted-minus-solvent economies. The IMS factor explains the substantial part of the cross-sectional variation in carry trade portfolios, exhibiting monotonically increasing factor loadings and significant prices of risk, consistent with risk premia explanation. Moreover, the factor is empirically powerful in various model specifications and sample splits, prices different test assets, stands out horse races with other currency-specific risk factors, robust against an alternative funding currency (the Japanese Yen) and alternative solvency measure specifications, and passes several other robustness checks, pointing to the solvency risk factor being a persuasive tool for pricing the cross-section of carry returns.

This study contributes to the literature in several important ways. First, the empirical findings of this paper lend additional support to the risk-based view of the forward premium puzzle. In line with findings of studies, such as those of Hansen and Hodrick (1980), Fama (1984) and Engel (1996), this paper shows that the apparent slump of UIP can be interpreted as a compensation for risk. Second, this paper extends the findings of prior research searching for an appropriate time-varying currency risk premium that rationalizes returns to the carry trade strategy (see, e.g., Lustig and Verdelhan, 2007; Lustig, Roussanov, and Verdelhan, 2011; Menkhoff, Sarno, Schmeling, and Schrimpf, 2012; Lettau, Maggiori, and Weber, 2013; and Ready, Roussanov, and Ward, 2015). This paper identifies a new source of risk premia and shows that currency carry trades can be comprehended as a compensation for sovereign solvency risk. Third, relying on fundamental measures of the financial competence of the economy, this study adds to the prior literature on a country's creditworthiness as an explanation of currency carry trades (see, e.g., Hui and Chung, 2011; Coudert and Mignon, 2013; and Huang and MacDonald, 2014), while addressing the critique of Longstaff, Pan, Pedersen, and Singleton (2011) of applying market measures to assess sovereign financial solvency.

The remainder of the paper is organized as follows. In Section 2 we provide an overview of the essential theories behind carry trade, initiate the discussion of our main solvency measure, and derive risk-adjusted UIP. Section 3 is dedicated to descriptions of the data, portfolios, and risk factors, and supplying descriptive statistics. The empirical approach and asset pricing tests are discussed in Section 4, followed by a review of the main empirical evidence on solvency risk in Section 5. The results of the robustness checks are presented in Section 6. Section 7 concludes the paper. This paper also incorporates an Appendix that provides supplementary derivations and results. Moreover, the results of additional robustness checks are presented in the Internet Appendix.

2. Background Ideas

In this section we present the theoretical background and the analytical framework underpinning this paper. We start with an overview of the existing literature and focus on rational risk premia interpretations. Next, we specify our measure of creditworthiness of the economy, and the rationale behind it. Finally, we consider the highly indebted economy and introduce the sovereign risk premium through the specification of an upward sloping foreign debt supply function and present risk-adjusted version of UIP.

2.1 Essential theory

The exercise of the carry trade strategy is firmly related to the forecasting shortcomings of forward rates, which is commonly referred to as the forward premium anomaly. Specifically, forward premia, contrary to the unbiasedness hypothesis, fall short in predicting future spot exchange rate appreciation. If forward rates were unbiased, the carry trade returns would be indistinguishable from zero. The explanation of positive historical carry trade payoffs has become a cornerstone of understanding the forward premium puzzle. Historically, foreign

exchange market arbitrage is a long standing issue of international finance stretching back as far as the pre-gold standard study of Keynes (1923). Nevertheless, literature on the forward premium puzzle emerged in the early 1980's and has often identified four major ways to interpret the existence of carry trade returns and the empirical rejection of the forward unbiasedness hypothesis.

The first stream of literature strives to provide a risk-based explanation for the puzzle through defining carry trade returns as a compensation for an appropriate risk. Building on the classic contribution of Hansen and Hodrick (1980), Fama (1984) brings the discussion to the efficient markets framework and shows the apparent failure of UIP across various currencies and time periods, which manifests in negative estimates of the slope parameter of the so-called Fama-regression. Importantly, the residual component of that regression is interpreted as the time-varying currency risk premium that rationalizes returns to the carry trade strategy.

Alternatively, the existence of that residual component is taken as evidence of market inefficiency, constituting the second interpretation. Pioneered by Bilson (1981), one can show that the nature of forward premium bias is broadly coherent with the behavioral finance perspectives found in Froot and Thaler (1990). Burnside, Han, Hirshleifer, and Wang (2011) argue that the forward premium puzzle can be interpreted by investor overconfidence causing overreaction to macro information and discrepancies in forward and spot rate responses.

The third class of explanations focuses on errors in market expectations due to the potential for "peso problems", and was first introduced by Krasker (1980). That is, uncertainty about a future shifts in regimes results in biased measures of market expectations and, hence, a skewed distribution of forecast errors. In addition, Kaminsky (1993), Evans (1996), and Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) examine peso problems, measurement errors and rare disasters, and infer that forward rates are biased. Furthermore, Lewis (2011) shows that

potentially rare disasters may bias slope estimates of the Fama-regression. Building on evidence of peso problems, Lewis (1989) demonstrates that learning effects can account for as much as half of the magnitude of forward premium bias.

Finally, several studies focus on the interpretation of the puzzle from the microstructure point of view. Evans and Lyons (2002) adopting the microstructure approach find evidence of order flow related determinants of exchange rates. Lyons (2001) proposes limits to the speculation hypothesis and demonstrates that order flow information may reveal additional insights into the forward premium puzzle.

Perhaps the major avenue for research to comprehend the forward premium puzzle is the identification of a convenient time-varying risk premia. The inability of conventional risk factors to indisputably reconcile the puzzle, manifested in Burnside, Eichenbaum, and Rebelo (2011), has spurred a number of original currency-specific interpretations. Lustig, Roussanov, and Verdelhan (2011) adopt a Fama and French (1993) style approach to forward-sorted currencies and find heterogeneity in exposures to common risks across portfolios, related to rational risk premia. In a similar vein, Menkhoff, Sarno, Schmeling, and Schrimpf (2012) demonstrate that global currency market volatility shocks exert a compelling pricing power in the cross-section of carry trade returns. Rafferty (2012) indicate that global foreign exchange market skewness is also a valid risk factor. Mancini, Ranaldo, and Wrampelmeyer (2013) and Karnaukh, Ranaldo, and Söderlind (2015) reveal the substantial role of currency market liquidity in explaining the carry trade strategy payoffs. Orlov (2015) points out the significant role of temporal variations in equity market illiquidity. Hassan (2013) and Martin (2013) adopt theoretical models to argue that the spread between two countries' currency returns is related to the size of the countries. Jylhä and Souminen (2011) show that hedge fund capital flows affect interest rates and exchange rates, in turn affecting carry trade profitability, in a manner consistent with the risk-based explanation. Ready, Roussanov, and Ward (2015) in

the model of equilibrium show that heterogeneity in excess returns between high and low interest rate currencies arises from the differences in composition of the trade balance. Bakshi and Ponayotov (2013) document the predictive role of commodities in explaining the time-series of carry trade returns. Lettau, Maggiori, and Weber (2013) argue that 'investment' currencies exhibit large beta loadings conditional on the state of the market, particularly in times of market downturn. Correspondingly, Jurek (2014) shows that returns on short put position in such currencies explain carry trades. Daniel, Hodrick and Lu (2015), however, find no evidence of downside risk in dollar-neutral carry trades. Ranaldo and Soderlind (2010) find that low interest rate currencies serve as a hedge against market turmoil, appreciating when the aggregate risk is high. Mueller, Stathopoulos, and Vedolin (2015) find a counter cyclicality in cross-sectional correlation dispersion between high and low carry trade currencies which is consistent with the rational risk premia interpretation. Finally, Koijen, Pedersen, Moskowitz, and Vrugt (2012) provide a comprehensive overview of carry trade strategy in different markets and reviews of research within the area.

2.2 Solvency measure

The macroeconomics literature has a long history of investigating optimal borrowing. The first study to assume imperfect capital markets for debt is that of Bardhan (1967) who suggested that cost of debt increases at the aggregate level of foreign debt. Diamond (1965) investigates the effects of the stock of external debt on the economy dynamics with a neoclassical growth model. More recent studies also investigate equilibrium dynamics with debt level elastic interest rates (see, e.g., Obstfeld, 1982; Eaton and Turnovsky, 1983; Bhandari, Haque, and Turnovsky, 1990; and Schmitt-Grohe and Uribe, 2003). Another way to incorporate the idea of imperfect markets is to consider the measure of a country's ability to service the outstanding debt, as creditworthiness of the economy can be a function of more

than just a level of foreign debt. Otani and Villanueva (1988) model the risk premium charged on foreign debt as a function of the debt-to-export ratio. Cohen and Sachs (1986) and Escudé (2013) assume that risk premia depend on a country's ability to cover the debt as represented by debt-to-output or capital ratio. In this paper we assume risk premium is a function of external debt service capacity measured by a ratio of foreign debt to economy's earning ability (henceforth, the *solvency measure*). Risk premium is then represented by an increasing convex function of that measure. In the most of our analysis, we consider foreign debt-to-output ratio as a measure of solvency of the country, expressed as:

$$\gamma_t^i = \frac{Gross\ Foreign\ Debt_t^{USD}}{GDP_t^{USD}} \tag{1}$$

where we quantify the ability of the economy *i* to pay external debt by expressing gross foreign debt as the percentage of gross domestic product in period *t*. To ensure comparability between countries we convert both quantities into U.S. dollars at an average exchange rate for that period. The change in this measure can be altered by variations in the level of foreign debt and/or a shift in the output measure. This measure is empirically quantifiable and within our framework indicates the level of solvency of the economy, reflecting the degree to which the country bears the risk. Later in the paper we describe the data collection process and consider alternative ways to quantify the financial competence of the economy.

Importantly, we abstract from the market measures of country's creditworthiness and rely on fundamentals. Several recent studies identify the marginal value of sovereign CDS spreads in interpreting the forward premium puzzle around the financial crisis as being broadly consistent with the crash risk explanations. Hui and Chung (2011) show that CDS implied information is transmitted to the currency options and, consequently, to the Euro crash risk probability. Similarly, Coudert and Mignon (2013) find the crash-consistent behavior of

emerging currencies, such that default risk contributes to higher returns during expansion and massive losses during market turmoil. Nevertheless, no evidence on reconciliation of the forward premium puzzle using CDS spreads emerges from the most common carry trade currencies. Huang and MacDonald (2014) consider the cross-sectional pricing ability of CDS spreads and its link to currency market volatility around the financial crisis. Along with that, there is also evidence that market-based measures (CDS spreads) do not offer a true prediction of financial distress, if they contain country-specific information at all. Longstaff, Pan, Pedersen, and Singleton (2011) demonstrate that sovereign CDS spreads are plagued by time-varying systemic risk, global risk premia and other global and regional economic forces, while exhibiting almost no evidence of sovereign-specific credit risk premia. Among others, Mauro, Sussman, and Yafeh, (2002), Pan and Singleton (2008), and Ang and Longstaff (2013) also show that sovereign CDS spreads do not in fact capture country-specific information, but are rather related to market-wide factors. Capitalizing on that evidence, this study considers the fundamental measures of the financial competence of the economy.

2.3 UIP with the Solvency Risk disturbance term

As noted earlier, the key assumption of the paper is that the domestic economy does not face a perfectly elastic supply of debt, but rather an upward sloping supply curve for debt. Kharas (1983) and Kharas and Shishido (1986) show that this supposition appears to be realistic as repayment commitments for various reasons are not always made on time. Thus, foreign lenders are likely to form expectations about the ability of an economy to repay debt, requiring a risk premium over the international interest rate for lending to each economy. Merging the concepts of debt elastic interest rate and risk premium associated with lending to the economy, the interest rate charged on foreign debt is:

$$i(y)_t = i_t^* + v(y)_t, \qquad v' > 0, \quad v'' > 0, \tag{2}$$

where the interest rate $i(y)$ faced by domestic agents in time t depends on the level of world interest rate (i^*) and the country-specific risk premium $(v(y))$, which varies with the debt service capacity of the economy as measured by solvency measure (y_t). Sovereign risk premium is assumed to be an increasing and convex function $(v \equiv 1 + \bar{v} > 1, v'' > 0)$, so that the interest rate grows at an increasing rate with the level of indebtedness of the economy until a predetermined borrowing constraint is reached. Thus, the risk premium inversely related to the debt service capacity of the economy. Next, we assume risk-adjusted interest rate parity, so that domestic agents can borrow from and lend to the government at rate $i(y)$. Thus, rewriting equation (2) in a form that represents domestic rate provides the following expression for foreign currency gross interest rate that households must deal with:

$$(1 + i_t) = (1 + i_t^*) \, v(y)_t \tag{3}$$

In this setup, we devote our attention to shocks associated with the imperfect debt supply confronting an indebted domestic economy. There are two sources of shocks: exogenously derived world interest rate; and, specifically, an endogenous risk premium associated with the financial capacity of the domestic economy. The change in the former reflects the general tightening/relaxing of global credit conditions, while a change to the latter reflects country-specific borrowing constraints. Importantly, we derive the risk-adjusted UIP of the following form:[1]

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[1] To save space, we provide the description of the setup, the detailed derivation of UIP disturbed by the solvency risk premia in the Appendix A.

$$(1 + i_t) = (1 + i_t^*)v(\gamma_t)E_t(\delta_{t+1}) \tag{3}$$

The result is a UIP that is disturbed by the endogenous risk premium given by the increasing convex function of the debt service capacity of the economy as measured by the foreign debt-to-output ratio. Independent of the presence of the risk premium and under the rational expectation assumption, UIP stipulates the exchange rate (δ_{t+1}) depreciation (appreciation) equivalent to the interest rate differential. Conversely, equation (3) suggests the risk-adjusted version of UIP such as the time-varying risk premium $(v(\gamma_t))$ balances the difference between the actual and expected exchange rate. Importantly, since the risk premium is plausibly assumed to be an increasing and convex function such a parity condition predicts that interest rate differentials should increase in the solvency measure, followed by higher excess returns. In addition, a positive change in the interest rate differential can produce an even larger change in the risk premium, as it results in an upward shift in the increasing convex risk premium function.

Summing up, the resulting risk-adjusted equilibrium parity condition of currency pricing implies: First, highly indebted countries have higher interest rates and forward discounts on average than solvent countries; second, an indebted currency earns positive expected return, that increases in the solvency measure; third, the interest rate differential and the solvency currency risk premium both increase in measures of an economy's financial capacity; and, finally, indebted currency is risky, as it appreciates in good times and depreciates in bad times. Overall, this section provides an intuitive risk-based view of exchange rate determination with risk premium varying with the debt service capacity of the economy. Notably, we propose a new version of risk-adjusted UIP, and outline the abovementioned qualitative predictions, which we also evaluate empirically.

3. Data, Currency Portfolios and Risk factor building

3.1 Currency data

The full sample of this study consists of 48 currencies. For each currency we collect end-of-month data of spot exchange rates and of one-month forward exchange rates from Barclays and Reuters via Datastream. The countries in the sample are those of: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Euro area, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Iceland, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Ukraine, United Kingdom. The sample coverage for spot and forward rates spans January 1985- December 2014.[2] All of the rates are expressed as units of foreign currency per one U.S. dollar. Our analysis is executed on a monthly frequency.

Also, we consider a subsample of spot and forward rates of the ten most actively traded currencies, henceforth referred to as *developed countries*. These ten counties are: Australia, Canada, Denmark, Germany/Euro area, Japan, New Zealand, Norway, Sweden, Switzerland, United Kingdom. We merge the time series on forward discount and excess returns of the German Deutschemark prior to 1999 and those for the Euro. To further assess robustness, we

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[2] Burnside, Eichenbaum, and Rebelo (2011) and Menkhoff, Sarno, Schmeling, and Schrimpf (2012) extend their datasets back to 1976 by complementing BBI and Reuters data (available from October 1983) with historical Reuters data quoted against the British Pound, resulting in the longest possible time series of currency data. Lustig, Roussanov, and Verdelhan (2011) operate with the sample that starts in 1983. However, data on only nine currencies is available prior to 1985 and, as noted in Ready, Roussanov and Ward (2015), major carry trade currencies were undergoing transition to a floating exchange rate regime before 1985. Motivated by this and due to the availability of data on solvency measure our sample period begins in 1985.

repeat the empirical analysis with data samples identical to Lustig, Roussanov, and Verdelhan (2011) (37 currencies) and Burnside, Eichenbaum, and Rebelo (2011) (20 currencies).[3]

In this study we estimate currency excess returns from the U.S. investor point of view, so that the U.S. dollar is considered to be a domestic currency. In the empirical analysis we operate with logarithms, denoting s and f as log spot and log forward rate, respectively. We rely on the relation implied by covered interest parity, where the interest rate differential is approximately equal to the log forward discount ($i_t^* - i_t \approx f_t - s_t$), spot exchange rate appreciation/depreciation is defined by $s_{t+1} - s_t$ and the currency excess return is then defined such that $r_{t+1} = i_t^* - i_t - s_{t+1} + s_t \approx f_t - s_{t+1}$.

3.2 Solvency data

In our empirical analysis we consider the ratio of foreign debt to GDP as a measure of the indebtedness of the economy. Specifically, we collect the estimated foreign debt and estimated GDP at the end of each year for each country in our sample from International Financial Statistics, subsequently putting quantities at an equal footing by converting estimates into U.S. dollars at an average exchange rate for the year in question. The data period is matched with the one for currency data and spans the period December 1984-December 2014.

Table 1 presents unconditional average monthly estimates for forward discounts, excess returns and average values of solvency measure for the most actively traded currencies (sample of developed countries) over the sample period. Notably, countries with high average excess returns are associated with high values of forward discount (high interest rate differentials), which is consistent with the evidence from the previous studies (see, e.g., Brunnermeier, Nagel and Pedersen, 2009; Lustig, Roussanov, and Verdelhan, 2011).

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[3] Results are unreported, but available upon request.

Importantly, we observe a remarkable heterogeneity in the average solvency measures across countries aligning with the unconditional carry trade returns and forward discounts. Countries with a high foreign debt to GDP ratio also have high interest rate differentials and exhibit high carry trade returns; examples include Australia and New Zealand. Conversely, low interest rate currencies (like Japan and Switzerland) have relatively low solvency ratio values as well as low carry trade returns. To further assess the observed pattern, we plot the average monthly interest rate differential and average excess returns of developed countries against the average foreign debt to GDP ratio over the full sample period (Figure 1). Both graphs expose clear cross-sectional differences between low and high interest rate currencies, commonly referred to as funding and investment currencies.

Insert Table 1 here

Insert Figure 1 here

In addition, to test the robustness of the findings, we consider another measure of the economy's ability to finance its official, commercial, and trade debt obligations. Specifically, we rely on the current account-to-exports of goods and services measure (CAXGS) obtained from the International Country Risk Guide published by the PRS Group. This measure is calculated by dividing the current account of the balance of payments for the year in question by the estimated aggregate of total exports of goods and services for that year. Both quantities are converted into a U.S. dollar amount beforehand. Results for our alternative measure are reported in the robustness section. Finally, we also consider a composite financial risk

measure of the PRS Group, as an alternative solvency measure.[4] The main results of the paper remain unchanged.

3.3 Carry trade portfolios and portfolios sorted on solvency ratio

In order to empirically test the prediction of the model of heterogeneity in carry trade returns exposure to a common risk factor we construct currency portfolios. In particular, to form carry trade portfolios, following Ready, Roussanov and Ward (2015), we sort all of the currencies in our sample into six portfolios (four portfolios for the subsample of developed countries) on the lagged forward discount. Similarly, in order to construct portfolios sorted on a solvency measure we use the foreign debt–to–GDP ratio as in (1).

To ascertain that the portfolio construction process results in empirically implementable trading strategies we operate only with solvency measure data that is available at the time of portfolio construction. Thus, our approach differs from the conventional sorting on one-month lagged forward discount as in Lustig, Roussanov, and Verdelhan (2011) and Menkhoff, Sarno, Schmeling, and Schrimpf (2012). Specifically, due to the availability of macroeconomic data, we adopt an annual portfolio formation period, that is, we rebalance currency portfolios at the end of January of year t based on solvency ratios available for year t-1. Similarly, to put carry trade sorts on a par with solvency ratio portfolios, we sort currencies on a one-month forward discount at an annual frequency, rebalancing portfolios at the end of January of each year based on a one-month forward discount at the end of December in year t-1. Thus, in both cases, portfolios are rebalanced annually, but average returns are calculated on a monthly basis. Table 1 presents summary statistics for average excess returns of portfolios sorted on forward discounts (Panel A) and solvency measures

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[4] See the supplementary Internet Appendix for the detailed description of PRS group composite financial risk measure and estimation results.

(Panel B) as well as for components of excess returns, namely, average forward discounts and average change in spot exchange rate.

Insert Table 2 here

Performing sorts on the forward discount results in six equally weighted portfolios where the top (low) sextile comprises currencies with the highest (lowest) forward discounts (interest rate differential) relative to the U.S. dollar. The spread in average excess returns between extreme portfolios in the full sample is similar to that obtained using a traditional sorting procedure with monthly rebalancing as in Menkhoff, Sarno, Schmeling, and Schrimpf (2012). The sample results arising exhibit a monotonic increase in average excess returns across portfolios, a smaller spread in developed sample relative to the full sample results and magnitudes that are similar to the conventional monthly sorts in Lustig, Roussanov, and Verdelhan (2011). In both subsamples the average profitability of the carry trade strategy originates mainly from the average forward discounts across portfolios.

The results of sorting on the solvency measure are reported in Panel B of Table 2. The high portfolio (portfolio 6) captures currencies with the largest values for the economy's solvency measure, while the low portfolio consists of currencies with the smallest values for the foreign debt-to-GDP ratio. The results indicate that the average excess return of portfolios monotonically increases when moving from a low to a high portfolio, in other words, from solvent to insolvent countries. The spread in average excess returns between extreme portfolios is around 2% per annum in the full sample, which is smaller than the one for carry

trade portfolios.[5] However, the magnitudes of spread in average excess returns between the two sorts are largely identical (around 4% per annum) in the sample of developed counties.

Importantly, and consistent with the outcome predicted, the average forward discount of portfolios also monotonically increases in the values of solvency measure. Specifically, the most solvent countries report low average forward discounts, indicating that those are the countries with the lowest interest rate differentials from the perspective of the U.S. investor. Conversely, the most indebted countries are associated with the highest forward discounts. Similar patterns are evident in the sample of developed countries. The spreads in the average forward discounts between extreme portfolios are close in magnitudes to those from the sort based on forward discount, regardless of the subsample.

3.4 IMS risk factor and other currency-based risk factors

Arbitrage pricing theory (APT) (see Ross, 1976) implies that the expected return of assets is approximately linearly related to the factor loadings, in that risk factors capture the common variation in asset returns. The general version of APT, however, is silent on the factors to be used. Lustig, Roussanov, and Verdelhan (2011) show that forward discount sorted portfolios exhibit a strong factor structure, specifically, the large proportion of the average carry trade returns in the cross-section can be explained by two risk factors.

Relying on a similar empirically motivated approach, we strive to pin down heterogeneity in pricing kernels' exposure to a common source of risk, which we previously referred to as a solvency risk. In order to form a candidate risk factor we estimate the difference between the

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[5] Note that we operate with a large dataset in order to maintain the most complete currency universe possible. Sorting in a smaller set of currencies (e.g., as in Ready, Roussanov and Ward, 2015) results in a larger high-minus-low spread, thus a smaller gap between spreads in forward discount and solvency sorted portfolios. See the separate Internet Appendix for a detailed description.

return on the sixth (fourth for developed countries) and the first portfolios sorted on the solvency measure. This factor can be thought of as the U.S. investor's return on a zero-cost strategy that takes long position in the currencies of the countries that are the most indebted and goes short in the currencies of the most solvent countries. We refer to such a strategy as IMS (Indebted-Minus-Solvent). The IMS factor is essentially the implementable trading strategy. In a further estimation, the no arbitrage condition is satisfied, so the price of risk of the IMS factor is equivalent to its average excess return.

The results of principal component analysis indicate that the cross-section of carry trade returns can be explained by two principal component factors: the first is the *level* factor with similar loadings across portfolios, and the second is the *slope* factor with a monotonic increase in factor loadings. IMS risk factor is most closely related to the latter principal component (the *slope* factor) with a correlation coefficient of .71. This is important because the second principal component captures most of the cross-sectional information in the space of portfolio returns.[6] A further analysis considers both a single IMS factor model and a two factor model with IMS and the *level* factor depicted by average currency excess returns against the U.S. dollar (DOL_{FX}).

Additionally, we compare the performance of the IMS factor in explaining cross sectional heterogeneity in the average excess returns of portfolios sorted on the forward discount against other currency-specific risk factors. Specifically, along with the DOL_{FX} risk factor we consider the HML_{FX} risk factor of Lustig, Roussanov, and Verdelhan (2011) constructed directly from the sorted portfolios as high-minus-low carry trade portfolio returns. Moreover, we construct a global volatility risk factor VOL_{FX} as introduced by Menkhoff, Sarno,

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[6] See Lustig, Roussanov, and Verdelhan (2011) for principal component analysis on currency portfolios and the importance of the second principal component.

Schmeling, and Schrimpf (2012) as an intra-month realized standard deviation of the daily log changes of the spot exchange rates.

4. Empirical Strategy

In this section we specify our empirical approach and asset pricing tests used to identify if the carry trade returns can be understood as a compensation for solvency risk. First, since the risk factor in this paper is a portfolio of traded assets, we apply the standard time-series tests. To be precise, we run time-series regressions (4) of each carry trade portfolio's excess return as well as high-minus-low portfolio on a candidate risk factor(s). Further, we check if beta loadings are statistically significant and if alphas both individually and jointly are equal to zero.

$$r_{it} = \alpha_i + \beta_i f_t' + \varepsilon_t \tag{4}$$

where r_{it} excess return on portfolio i at time t, α is an intercept, f' is the vector of candidate risk factors, and ε is the residual. To assess significance we rely on Newey and West (1987) HAC standard errors with optimal lags based on Andrews (1991). A J-test ($\alpha' V_\alpha^{-1} \alpha$) is used to test if intercepts are jointly equal to zero.

Next, we turn to the cross-sectional asset pricing, where the empirical approach is based on the argument that there is a stochastic discount factor (henceforth, SDF) that prices all the assets, as in Cochrane (2005). To estimate the market price of risk and the portfolio's betas we rely on two widely used procedures: first, the Generalized Method of Moments (henceforth, GMM) as in Hansen (1982) with linear SDF and, second, Fama and MacBeth (1973) procedure (henceforth, FMB).

In order to rationalize returns to the carry trade strategy one can assume that a currency risk premium defined by a residual (ε_t) exists:

$$i_t^* - i_t = s_{t+1} - s_t + \varepsilon_t \tag{5}$$

Backing out the risk premium from equation (5), one can show that the risk premium should offset the difference between the actual and expected exchange rate. Revolving around the classic pricing kernel equation, the risk-based explanation implies the absence of arbitrage opportunities and a zero price for such a risk-adjusted excess return. In particular, an excess return to a carry trade strategy must satisfy the Euler equation ($E_t(M_{t+1}r_{t+1}^i) = 0$). Applying the law of iterated expectations, we derive the unconditional version of it with a suppressed expectation time subscript:

$$E(M_t r_t^i) = 0 \tag{6}$$

where E is an unconditional the mathematical expectation; $\alpha = 1 + b'E(f)$, so M_t is a linear SDF that takes the form of $M_t = 1 - b'(f_t - \mu)$ with b is a vector of factor loading, f_t is a vector of factors and $\mu = E(f)$ stands for factor means. In this manner, we force the mean of the SDF to be equal to 1 and the GMM-estimation then performs a cross-sectional regression of mean excess returns on their covariances with the factors. Thus, GMM tests the theoretical prediction that excess returns should be proportional to the covariances between returns and factors, so that:

$$E(r_{t+1}^i) = cov\left(r_t^i, \tilde{f}_t'\right)\Sigma_f^{-1}\Sigma_f b \tag{7}$$

where $\tilde{f}_t \equiv f_t - E(f)$. Alternatively, in a traditional beta pricing model form with factor risk

prices λ and factor loadings β of portfolio i, equation (7) takes the form of $E(r_t^i) = \lambda'\beta_i$ with

$\lambda = \Sigma_f b$ representing the prices of risk, where $\Sigma_f = E(f_t - E(f))(f_t - E(f))'$ is the

covariance matrix of the risk factor and b is the coefficient estimates of returns regressed on a

factor. We use the GMM procedure (Hansen, 1982) with the following moment conditions as

in (8) from (6) for $n \times 1$ vector of excess returns along with $\mu = E(f_t)$ restrictions to

empirically estimate the prices of risk and the factor loadings.

$$E([1 - b'(f_t - \mu)r_t^i) = 0 \tag{8}$$

The GMM estimator of b then takes the following form:

$$\hat{b} = (d_T'W_T d_T)^{-1}d_T'W_T\bar{r} \tag{9}$$

where d_T is a covariance matrix of z with f, W_T is the weighting matrix.

Throughout the estimations we operate with overidentified GMM systems with a larger

number of assets (moment conditions) than number of parameters. In such overidentified

systems, it is generally impossible to set all the moments to zero simultaneously, thus we try

to set a linear combination of these moments to be as close to zero as possible. In the first

step of the procedure to minimize the objective function we use a pre-defined weighting

matrix set to be identical matrix ($W_T = I_n$) as a covariance of the moment conditions. This

works alongside the starting values, the prices of risk, and the pricing errors computed using

an FMB regression. In the second step, we iterate values obtained from the first stage to

obtain the optimal weighting matrix and an asymptotically efficient estimate of $\hat{b}$. The price

of risk is calculated as $\hat{\lambda} = \hat{\Sigma}_f\hat{b}$. We also report Newey-West based standard errors, cross-

sectional R^2, and a J-test of pricing errors ($\alpha' V_\alpha^{-1} \alpha$). In the following table we report estimates of the iterated GMM procedure.

Furthermore, we report the results of the traditional FMB procedure, which is similar to the first stage of the GMM. In particular, to obtain estimates of interest we run a cross-sectional regression of average portfolio excess returns on the previously estimated first step time-series betas. Note, that we do not include the constant in the second stage in the following models with dollar risk factor as it captures a common variation in returns similar to the constant. For FMB we report both Shanken (1992) and Newey-West standard errors.

5. Empirical Evidence

This section presents our main empirical results regarding the predictions of heterogeneity in carry trade returns exposure to a common solvency risk factor. First we estimate exposure of the portfolios' covariances to common risk by estimating the model with only one linear risk factor (IMS). Subsequently, we assess the performance of the model enhanced with dollar risk factor (DOL_{FX}). Finally, the performance of the model is compared to alternative currency-specific risk factor models.

5.1 Explaining the carry trade with the solvency factor

Table 3 reports the results of benchmark asset pricing tests described in the previous section, as we test the ability of the candidate pricing kernel, linearly defined by the single IMS risk factor, to price the six (four for developed countries) carry trade portfolios sorted on forward discount.

Insert Table 3 here

Panel A of Table 3 presents results of time series regressions of each portfolio's log carry trade excess returns r^i on an intercept and solvency risk factor alone. We report estimates for the constant α^i and the slope coefficient β_{IMS} as well as adjusted R-squares and joint test for alphas. The alphas are annualized and presented in percentage points. The individual portfolio's alphas are statistically different from zero, albeit high carry trade portfolios in both samples (all and developed countries) record alphas that are significant at 1% and 5%, respectively. The joint test for alphas yields mixed results for the two subsamples, as the null that the alphas are jointly zero is rejected in the full sample, while confirmed in the sample of developed countries at 5% level (p-value of 0.07).

The IMS factor loadings of each individual portfolio are reported in the second column. Betas for the IMS risk factor increase monotonically from -0.16 for low portfolio (low interest rate currencies) to 0.34 for high portfolio ones, while being significantly different from zero for the extreme portfolios. Essentially, a similar monotonic pattern in solvency risk exposure occurs in the sample of developed countries (the right-hand side of the table). Additionally, the IMS risk factor is capable of pricing the high-minus-low carry trade strategy (last row of Panel A).

Panel B of Table 3 reports results of standard cross-sectional asset pricing tests. GMM refers to the iterated SDF-GMM estimation and FMB stands for the Fama-MacBeth approach. Importantly, the IMS risk factor exhibits a positive and significant price of risk (λ_{IMS}) in most of the tests. The risk price is 17.19 for the full sample and 6.19 for the developed country sample, while both values are more than two standard errors away from zero (with GMM errors equal to 353 and 284 b.p., respectively), and are thus statistically significant. Overall, the results broadly indicate that the IMS factor is priced in the data and,

alone can partially explain the cross-sectional variation in expected returns with the R^2 of 43% (in the full sample).[7]

Next, we consider the model with two risk factors, namely the dollar risk factor (DOL_{FX}) and the solvency risk factor (IMS). The dollar risk factor is highly correlated with the first principal component (0.98), captures common variation across portfolios and naturally can be interpreted as a currency-specific market level risk factor. Table 4 shows the estimates of factors loadings and cross sectional asset pricing results for the two factor model.

Insert Table 4 here

The upper panel of Table 4 presents time series regression statistics for the two factor model with carry trade portfolios as the test assets. The introduction of the dollar risk factor (DOL) results in smaller pricing errors, greater explanatory power, and an overall better fit for the model. Factor loadings on the DOL factor (the *level* factor) are all close to one in value, and statistically significant. Importantly, the IMS factor betas are essentially unchanged from those in a single factor model. Again, we observe a striking monotone increase in IMS factor betas when moving from portfolio 1 (low interest rate currencies) to portfolio 6 (high interest rate currencies), which precisely produces a large spread in portfolio's mean returns (see Table 2). The IMS betas for the first three portfolios are negative and uniformly statistically significant. The betas for the last two portfolios are positive. The individual pricing errors are low for all six regressions, while (mostly) being not statistically different from zero. Similar results are observed in the sample of developed

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[7] Additionally, since the factor is traded return, we check that the IMS risk factor is able to price itself and that the risk price of the IMS factor is roughly equal to the mean return of the IMS trading strategy. We find that this is indeed the case, thus no-arbitrage condition is satisfied. The relevant results are reported in Appendix B.

countries (the right-hand side of the table); furthermore, alphas are not statistically significant either individually or jointly.

Next, we suggest that observed unconditional betas are driven by covariances between the log spot exchange rate change and the solvency risk. Essentially, we run time series regression of logarithmic exchange rate change for each portfolio on the DOL and IMS factors and find beta coefficients on the IMS factor are identical in magnitude, but opposite in sign to those in Table 4. As expected, conditional covariance between carry returns and solvency risk factor ($cov_t(r^i_{t+1}, IMS_{t+1})$) equates to negative covariance between the spot rate change and solvency risk ($cov_t(\Delta s^i_{t+1}, IMS_{t+1})$).[8] These findings indicate that low carry trade currencies (often referred as funding currencies) provide a hedge against solvency risk (in that they commove negatively with the IMS risk factor) as they appreciate during episodes of low solvency risk. Conversely, high carry trade currencies (investment currencies) payoff badly (depreciate) when the IMS factor exhibits low returns, expose investors to more risk, and thus demand a higher risk premium.

The bottom panel of Table 4 shows the results of cross-sectional asset pricing tests for the two factor model. We perform tests on carry trade excess returns in levels, not on logarithmic returns, and do not include the constant in the second stage of FMB procedure ($\lambda_0 = 0$) to avoid redundancy with the dollar risk factor. The price of risk of the IMS factor is once again large and highly statistically significant in both samples, being more than two standard errors away from zero. The dollar risk factor is, however, on the borderline of statistical significance. Inclusion of the DOL factor results in low values for the square root of mean-squared errors (RMSE) for both iterated GMM and FMB procedures. At the same time, regardless of the subsample, the cross-sectional R^2 values are as high as 96%.

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[8] We report results of these regressions in the Appendix B.

Overall, the results indicate that the model with DOL and IMS factors provides a good cross-sectional fit. The solvency-sorted and forward-discount-sorted portfolios are exposed to a risk of a common origin that spurs the heterogeneity in average excess returns. The results suggest that the IMS factor is an empirically powerful risk factor and explains the cross sectional variation in carry trade returns.

The question, however, is whether the IMS risk factor conveys any additional pricing information that is not captured by the existing currency-specific risk factors. This is important because the previously proposed HML_{FX} and VOL_{FX} factors are found to have a large cross-sectional pricing capacity and both, as well as IMS, are closely related to the second principal component. Next we address this concern.

5.2 Horse races between currency-specific factors

Thus far results indicate that the IMS factor is a powerful pricing factor and, being closely related to the second principal component, provides a high cross-sectional fit. Next, we challenge the pricing competency of the proposed factor against well-established currency based risk factors, namely, the high-minus-low carry trade returns (HML_{FX}) and the global FX volatility innovations risk factor (VOL_{FX}). First, we test factors by concurrently including them in the SDF together with the dollar risk factor. The result is two models where the SDF is linearly defined as in Lustig et al. (2011) (Panel A of Table 5) or in Menkhoff et al. (2012) (Panel B of Table 5), but enhanced with the IMS factor. Second, we test two modifications of the model comprising the DOL, the HML_{FX} and the IMS risk factors in which we sequentially orthogonalize the latter two factors against each other.

Insert Table 5 here

Importantly, the results of the iterated GMM procedure in Panels A and B indicate that the solvency risk factor (IMS) does not become attenuated when included in the model with the HML_{FX} and VOL_{FX}, respectively. In both panels all of the factors, including the IMS factor, are significantly priced with lambdas that are more than two standard errors away from zero, albeit the HML_{FX} dominates the solvency factor in significance. Notably, jointly specified SDFs improve on the cross-sectional explanatory power (R^2 of 97% and 92%) and the mean-squared errors (RMSE of 0.84 and 1.49) relative to any of the individual specifications.

Panels C and D report iterated GMM estimates for the SDFs enhanced with either the IMS or the HML_{FX} orthogonal components. Specifically, the IMS factor is orthogonalized with respect to the HML_{FX} in Panel C and, conversely, the HML_{FX} is orthogonalized with respect to the IMS in Panel D. As a result, in that test design we are able deconfound the effects of the slope factors and avert the statistical inference problems. First, the orthogonalized component of the solvency risk factor is priced (the GMM *t-stat.* of 3.70) in the joint SDF specification (Panel C). This indicates that the IMS factor has a supplementary pricing capacity over the HML_{FX} factor. The results presented in Panel D confirm that the orthogonalized constituent of the HML_{FX} lacks pricing power when jointly estimated with the IMS factor, while the latter is still significantly priced with the GMM *t*-statistic being 2.23.

Armed with the aforementioned evidence, we suggest that the IMS factor is not only significantly priced, but also captures additional information in the cross-section of carry trade returns that is unexplained by other currency-specific risk factors, namely the carry risk factor and the FX volatility. It is notable that, the HML_{FX} risk is clearly pervasive in the cross-section of currency carry trade returns and dominates in significance. However, the HML_{FX} is extracted directly from the forward-discount-sorted returns; and thus reflects the monotonic patterns of carry returns and is strongly related to the second principal component. Diversely, the IMS has to be estimated and, potentially, embodies measurement error

problems, as solvency ratio is calculated using macroeconomic data. Nevertheless, the IMS factor is a competitive risk factor, seizes additional information ancillary to that commonly explained by prominent risk factors and, furthermore, improves on standard errors and explanatory power. Thus, it seems fair to conclude that the solvency risk is priced in the cross-section of currency carry trade returns.

6. Robustness

This section presents a battery of supplementary empirical findings on the robustness of the solvency risk-based explanation of carry trade returns under various modifications.

6.1 Asset pricing: Splitting Samples

First, we perform a conventional sample split test. Specifically, we split the full sample in halves so the left-hand panel of Table 6 covers the period from January 1985 to December 1999 and the right-hand panel presents results for the second half of the period (January 1999 to December 2014).

Insert Table 6 here

The outcomes of the half-splitting procedure applied to the sample validate a previous finding that solvency risk is priced in the cross-section, and the process also ensures that results are not unduly affected by outliers and are not prone to a mechanical returns-factor relationship. Regardless of the subsample, the beta loadings on the IMS risk factor increase when moving from a low to a high carry portfolio, albeit not as monotonically as corresponding estimates in Table 4. In addition, both individual and joint pricing errors are mainly low and not significant, while cross-sectional fit is high. Risk premia differ

considerably in magnitudes and significance between the two subsamples, perhaps due to small sample period. Nevertheless, at least for the latter sample we find that the implied price of solvency risk estimates remains significant. Overall, the results are reassuring.

6.2 Asset pricing: Alternative solvency measure

To further assess robustness, we consider an alternative solvency measure: current account-to-export of goods and services (CAXGS), which is the ratio of the balance of the current account of the balance of payments for the year in question to the estimated aggregate of total exports of goods and services for that year (both quantities are converted to USD at an average annual FX rate). The portfolios sorting and empirical estimation procedures are similar to that shown in Table 4, with only exception that SDF is now linearly defined by the dollar risk factor (DOL) and the alternatively specified indebted-minus-solvent risk factor (further IMS_{CAXGS}). Not surprisingly, the IMS_{CAXGS} is positively, but not perfectly correlated, with the IMS with a correlation coefficient of .58 for the full sample.

Insert Table 7 here

Essentially, the results of the analysis based on the alternatively specified solvency measure (Table 7) are very similar to those reported in Table 4. The dispersion in the intercepts is now a little larger compared to the IMS results, consistent with the larger dispersion in the IMS_{CAXGS} beta loadings. Importantly, we still observe an increasing monotonic pattern in factor loadings (β_{CAXGS}^{IMS}) from the first to the last portfolio. Moreover, the solvency price of risk estimates, obtained by the abovementioned cross-sectional asset pricing tests, is positive and significant, with the magnitudes of the premia, in either sample, being like its counterparts in Table 4. Moreover, we find a cross-sectional R^2 of 86% and a

square root of mean-squared errors of 1.92 for the full sample, indicating weaker explanatory capacity relative to IMS enhanced model, but still a high level of cross-sectional fit. Overall, the findings again suggest that investors require a risk premium on currencies that co-vary more with the solvency risk factor, as they are riskier and thus deliver higher excess returns. Hence, the solvency risk-based explanation of carry trade returns is robust against alternative measures of solvency.

6.3 Various portfolio formation dates

Thus far, in our empirical analysis we formed portfolios based on advance macroeconomic estimates available at the end of January. Although, such estimates are usually reliable and accurate projections of the actual values, they are often further revised and corrected. In order to ensure that constructed portfolios reflect an implementable trading strategy based on accurate macroeconomic estimates, we repeat the empirical analysis with portfolios sorted on the solvency measure data available on various dates. To do so, we run asset pricing tests with portfolios sorted on both the previous month's forward discount and previous year's macroeconomic data available to investors at the end of March (second estimates), June (third estimates) and December (final updates). The results of these estimations are reported in Table 8.

Insert Table 8 here

The results presented in Table 8 are analogous to those in Table 4, as we observe a similar monotonic increasing pattern in factor betas and significant risk prices for the information sets available on the aforementioned dates. Thus, it seems reasonable to conclude that the IMS risk factor is an empirically powerful risk factor and robust in the face of various

formation dates. In this regard, the finding of the time-varying solvency risk premia are the source of the carry trade returns is further reinforced by the evidence from the solvency trading strategies' temporal implementable efficacy.

6.4 Other robustness tests

We also perform a number of supplementary robustness checks of various types. First, we ensure that main results of the paper do not originate from a small number of funding/investment currencies and are not sample-specific, but rather comprehensively robust in the cross-section of carry trade returns. For this purpose, we exclude currencies with the most of extreme portfolio hits on both sides from the dataset and re-estimate the model from Section 5.1. Further, we repeat the empirical analysis using various data samples identical to several prominent carry trade literature studies.

Second, we examine if the results of the paper are robust internationally. Daniel, Hodrick, and Lu (2015) argue that carry trade performance and risk characteristics depend on the choice of funding (base) currency. In order to demonstrate that our findings are robust in the face of an alternative funding currency, we take the Japanese investor point of view and consider the Japanese Yen as a base currency, and repeat the empirical analysis.

Third, we consider another alternative proxy for solvency risk - the composite financial risk measure - that essentially is the aggregate estimate of country's financial competency indicators, such as, alternatively specified external debt service capacity, exchange rate stability, and the country's international liquidity, converted into scores.

Fourth, to guard against the known shortcomings of portfolio construction, such as the possibility of security-idiosyncratic information loss (Litzenberger and Ramaswamy, 1979), we follow the prescriptions of Lo and MacKinlay (1990) and perform currency-level asset

pricing tests.[9] Specifically, we test the pricing ability of the solvency risk factor using the sample of individual currencies as test assets.

In addition, we report additional descriptive statistics of constructed portfolios, introduce transaction costs to the data, perform additional sample partitioning and introduce alternative test assets from within and outside the currency universe space, such as currency momentum sorted returns and U.S. equity momentum portfolios.

Although ultimately the results of a few tests deviate from the central findings of the paper, principally, the robustness checks confirm that the solvency risk is priced in these cross sections of carry trade returns. In most of the tests the solvency risk factor posts a similar asset pricing estimates to the counterpart's values in the benchmark specifications of the previous sections. In the interest of conciseness, we provide the detailed discussion on the aforementioned robustness procedures and document the corresponding empirical results in the supplementary Internet Appendix.

7. Conclusions

Currency carry trade profitability emerges from exploitable failures of foreign exchange parity relations, that is, currencies traded on a forward premium are apt to appreciation, contrarily to the UIP predicted depreciation. There is abundant evidence suggesting the existence of common determinants of inter-temporal variations in carry trade returns, which lends support to a rationalization of strategy returns as a compensation for common risk. This implies that there are persistent differences in global risk exposures across countries and this heterogeneity is the source of carry trade profitability. This paper sheds light on a possible origin of such heterogeneity and offers a new risk-based explanation for currency risk premia.

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[9] For more evidence on importance of security-level tests see, e.g. Brennan, Chordia, and Subrahmanyam (1998), Avramov and Chordia (2006) and the references therein.

This study builds on the classic APT approach in explaining the cross-section of carry trade returns and identifies persistent heterogeneity in loadings on a common component across countries' pricing kernels. We argue that currency carry trade returns can be rationalized by the time-varying risk premia that originate from the sovereign solvency risk. Specifically, we suggest that solvency risk maintains the substantial power to explain the cross-section of carry trade returns. The solvency sorted and forward discount sorted portfolios exposed to a risk of a common origin that spur on the heterogeneity in average excess returns. In line with that, heterogeneous risk exposures of currencies reveal that low carry trade currencies serve as hedge against solvency risk, while high carry trade currencies depreciate, exposing investors to more risk and requiring a higher risk premium. Hinging on classic asset pricing procedures we introduce a new, solvency-based, risk factor and show that its covariance with returns accounts for almost all cross-sectional variation across portfolios. The factor is empirically powerful and withstands a battery of different robustness checks.

The cumulative evidence points to the solvency risk factor as a persuasive tool for pricing the cross-section of carry returns. Accordingly, the overall results offer a new interpretation of currency risk premia, and, *inter alia*, an unambiguous risk-based perspective on the forward premium puzzle.

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Table 1: Developed currencies and solvency measures

Currency	Forward discount	Excess Return	Solvency Measure
GBP	0.16	0.24	16.17
CHF	-0.13	0.14	7.44
JPY	-0.21	0.00	16.52
CAD	0.07	0.11	14.68
AUD	0.27	0.27	62.10
NZD	0.36	0.50	76.86
SEK	0.13	0.17	39.47
NOK	0.18	0.23	6.64
DKK	0.08	0.25	22.47
EUR/DEM	-0.02	0.35	16.39

Note: Table presents descriptive statistics for average monthly forward discounts, average monthly excess returns (without bid-ask spread) and average foreign debt to GDP ratio (solvency measure) for the ten most traded carry trade currencies. Time period spans from 01/1985 to 12/2014. Pre-1999 data on German Mark is merged with post-1999 data on Euro.

Table 2: Portfolios sorted on forward discount and solvency measure

Portfolio	1	2	3	4	5	6	1	2	3	4
	Panel A: Portfolios Sorted on Forward Discounts									
	All Countries						Developed countries			
	Spot change: Δs^i						Δs^i			
Mean	-2.34	-1.74	-2.05	-0.51	1.07	3.07	-2.37	-2.47	0.07	-1.28
SD	7.79	7.07	8.16	8.08	9.24	9.68	9.89	8.78	8.73	11.25
	Forward discount: $f^i - s^i$						$f^i - s^i$			
Mean	-2.07	-0.59	0.45	2.10	3.34	13.09	-1.96	0.18	1.89	4.23
SD	3.16	0.49	1.45	0.56	1.49	3.96	0.69	0.50	0.69	1.00
	Excess returns: r^i						r^i			
Mean	0.27	1.15	2.50	2.62	2.27	10.02	0.42	2.65	1.81	5.51
SD	8.26	6.95	8.21	7.94	9.08	10.59	9.94	8.81	8.79	11.35
SR	0.03	0.17	0.30	0.33	0.25	0.95	0.04	0.30	0.21	0.49
	Panel B: Portfolios Sorted on Solvency Measure									
	All Countries						Developed countries			
	Spot change: Δs^i						Δs^i			
Mean	-1.94	-0.85	-0.10	-0.31	-0.67	1.92	-2.36	-0.79	-0.93	-1.95
SD	9.44	7.92	6.38	6.66	8.44	10.75	10.50	8.47	8.87	10.56
	Forward discount: $f^i - s^i$						$f^i - s^i$			
Mean	0.25	1.82	2.89	3.23	3.64	6.23	-0.77	1.25	1.58	3.01
SD	0.80	0.73	0.84	1.63	3.05	4.07	0.68	0.69	0.95	0.70
	Excess returns: r^i						r^i			
Mean	2.18	2.66	2.99	3.54	4.30	4.31	1.59	2.04	2.51	4.96
SD	9.43	7.95	6.45	7.03	8.87	11.36	10.54	8.52	8.98	10.66
SR	0.23	0.34	0.46	0.50	0.49	0.38	0.15	0.24	0.28	0.47

Note: The table reports descriptive statistics (annualized) for portfolios sorted on forward discounts (carry trade) and on solvency measure (foreign debt to GDP) for the full sample (left side) and developed countries (right side). Mean and standard deviation are reported for spot exchange rate changes, forward discounts and excess returns for each portfolio. Returns are monthly and updated on the annual basis based on previous year values of solvency measure and current forward discounts. Returns do not take into account bid-ask spreads. The sample period is January 1985 - December 2014.

Table 3. Asset Pricing: IMS risk factor

	Panel A. Factor Betas							
	All Countries				Developed Countries			
Portfolio	α	β_{IMS}	adj.-R^2	J	α	β_{IMS}	adj.-R^2	J
1	1.05	-0.16	3.37		2.59	-0.44	16.70	
	(0.53)	(-2.20)			(1.35)	(-6.00)		
2	1.73	-0.12	2.71		3.68	-0.17	3.10	
	(1.20)	(-1.89)			(1.79)	(-2.41)		
3	3.09	-0.09	1.11		2.39	-0.05	0.22	
	(1.50)	(-1.16)			(1.22)	(-0.65)		
4	2.94	0.00	0.00		5.35	0.21	3.08	
	(1.54)	(0.03)			(2.27)	(1.87)		
5	2.63	0.03	0.11					
	(1.37)	(0.34)						
6	9.75	0.34	10.14					
	(3.81)	(2.67)						
J-test				32.82				8.71
(p-value)				0.00				0.07
High-Low	8.70	0.50	22.11		2.75	0.66	31.73	
	(3.82)	(5.61)			(1.59)	(7.36)		

	Panel B. Risk Prices					
	All Countries			Developed Countries		
GMM	IMS	R^2	RMSE	IMS	R^2	RMSE
λ	17.91	42.97	3.64	6.19	12.44	3.86
[s.e.]	[3.53]			[2.84]		
FMB	IMS	R^2	RMSE	IMS	R^2	RMSE
λ	19.17	43.16	3.64	1.13	0.66	3.62
[NW]	[3.63]			[3.29]		
[Sh.]	[3.64]			[3.31]		

Note: The table reports time-series regressions and cross-sectional asset pricing test results for the linear factor model based on a single IMS (indebted-minus-solvent) factor. The IMS factor is based on solvency measure (foreign debt-to-GDP) sorts. Returns are monthly and portfolios are rebalanced on an annual basis. Results for the sample of all countries are presented in the left-hand panel and for developed countries in the right-hand panel. Panel A reports estimates for monthly time series regressions of (log) carry trade excess returns on the intercept and the IMS risk factor for each forward discount sorted portfolio and the high-minus-low carry trade portfolio. These estimates are: the constant (α) (annualized and in percentage points); the IMS factor loading (β_{IMS}); and the adjusted-R^2 (in percentage points). T-statistics based on HAC Newey and West (1987) standard errors with Andrews (1991) lag selection are reported in parentheses. The J-test of pricing errors ($\alpha'V_\alpha^{-1}\alpha$) tests if intercepts are jointly equal to zero. Panel B reports cross-sectional asset pricing tests results, namely iterated GMM and FMB. Returns of test assets (carry trade portfolios) are in levels and annualized (multiplied by 12). We report the IMS factor price of risk (λ), the cross-sectional R^2 and the square root of mean-squared errors (RMSE) for each procedure. The standard errors [s.e.] are reported in brackets and based on the Newey-West [NW] approach with optimal lags and Shanken (1992) correction [Sh]. A constant is not included in the second stage of FMB regression. The sample period is January 1985 to December 2014.

Table 4. Asset Pricing: Two factor model

	Panel A. Factor Betas									
	All Countries					Developed Countries				
Portfolio	α	β_{DOL}	β_{IMS}	adj.-R^2	J	α	β_{DOL}	β_{IMS}	adj.-R^2	J
1	-2.18	0.91	-0.16	65.94		-0.65	0.92	-0.34	76.34	
	(-1.77)	(12.74)	(-4.16)			(-0.62)	(18.05)	(-8.09)		
2	-1.25	0.85	-0.12	78.52		0.40	0.94	-0.06	81.39	
	(-1.80)	(18.37)	(-5.84)			(0.66)	(29.09)	(-1.89)		
3	-0.49	1.01	-0.09	79.28		-0.95	0.95	0.06	82.49	
	(-0.67)	(23.29)	(-2.39)			(-1.22)	(31.44)	(1.63)		
4	-0.54	0.98	0.00	78.98		1.20	1.19	0.35	79.45	
	(-0.69)	(18.21)	(0.08)			(1.31)	(25.11)	(6.79)		
5	-1.34	1.12	0.03	78.79						
	(-1.33)	(26.26)	(0.63)							
6	5.80	1.12	0.34	66.79						
	(3.83)	(16.17)	(5.40)							
J-test					24.48					3.87
(p-value)					(0.00)					(0.42)

	Panel B. Risk Prices								
	All Countries					Developed Countries			
GMM	DOL	IMS	R^2	RMSE		DOL	IMS	R^2	RMSE
λ	3.49	16.94	96.29	0.93		3.10	6.03	96.88	0.64
[s.e.]	[1.26]	[3.38]				[1.48]	[2.82]		
FMB	DOL	IMS	R^2	RMSE		DOL	IMS	R^2	RMSE
λ	3.49	17.71	96.36	0.92		3.10	6.09	96.88	0.64
[NW]	[1.33]	[3.59]				[1.53]	[2.87]		
[Sh.]	[1.35]	[3.61]				[1.55]	[2.91]		

Note: The table set up is identical to that in Table 3 with the only exception being that the results are reported for time-series regressions and cross-sectional asset pricing tests based on the two factor model. These factors are: the dollar risk factor (DOL) from Lustig, Roussanov, and Verdelhan (2011) and the IMS (indebted-minus-solvent) factor. The IMS factor is based on a solvency measure (foreign debt-to-GDP) sorts. Returns are monthly and portfolios are rebalanced on an annual basis. Results for the sample of all countries are presented in the left panel and for developed countries in the right panel. Panel A reports estimates for monthly time series regressions of (log) carry trade excess returns on the intercept, the DOL factor and the IMS factor for each forward discount sorted portfolio. These estimates are: the constant (α) (annualized and in percentage points); the DOL factor loading (β_{DOL}); the IMS factor loading (β_{IMS}); and the adjusted-R^2 (in percentage points). T-statistics based on HAC Newey and West (1987) standard errors with Andrews (1991) lag selection are reported in parentheses. The J-test of pricing errors ($\alpha'V_\alpha^{-1}\alpha$) tests if intercepts are jointly equal to zero. Panel B reports cross-sectional asset pricing tests results, namely iterated GMM and FMB. Returns of test assets (carry trade portfolios) are in levels and annualized (multiplied by 12). We report the factor price of risk (λ) for the DOL and the IMS factors, the cross-sectional R^2 and the square root of mean-squared errors (RMSE) for each procedure. The standard errors [s.e] are reported in brackets and based on Newey-West [NW] approach with optimal lags and Shanken (1992) correction [Sh]. A constant is not included in the second stage of FMB regression. The sample period is January 1985 to December 2014.

Table 5. Asset pricing: IMS vs. HML_{FX} and VOL_{FX} risk factors

Panel A. Lustig et. al (2011) model and IMS					Panel B. Menkhoff et. al (2012) model and IMS				
Factor	λ	[s.e.]	R^2	RMSE	Factor	λ	[s.e.]	R^2	RMSE
DOL	3.49	[0.65]	96.96	0.84	DOL	3.88	[1.35]	91.97	1.49
HML_{FX}	10.18	[1.54]			VOL_{FX}	1.12	[0.40]		
IMS	9.95	[2.69]			IMS	11.72	[3.15]		
Panel C. IMS (orth.) and HML					Panel D. IMS and HML(orth.)				
Factor	λ	[s.e.]	R^2	RMSE	Factor	λ	[s.e.]	R^2	RMSE
DOL	3.50	[0.97]	96.96	0.84	DOL	3.49	[0.27]	96.96	0.84
HML_{FX}	10.18	[1.04]			$HML_{FX}^{Orth.}$	5.22	[3.39]		
$IMS^{Orth.}$	5.41	[0.28]			IMS	9.95	[4.49]		

Note: The table reports the results of the iterated GMM procedure where SDF is linearly defined as in Lustig, Roussanov, and Verdelhan (2011) (Panel A) or in Menkhoff, Sarno, Schmeling, and Schrimpf (2012) (Panel B), but enhanced with the various modifications of the IMS factor. Returns of test assets (six carry trade portfolios) are in levels and annualized (multiplied by 12). We report the factor price of risk (λ) for the DOL, the *IMS* factors and either HML_{FX} (Panels A, C and D) or VOL_{FX}(Panel B), the cross-sectional R^2 and the square root of mean-squared errors (RMSE). In Panels C the *IMS* factor is orthogonalized w.r.t. HML_{FX}, and in Panel D we orthogonalize HML_{FX} w.r.t. *IMS*. The GMM standard errors [s.e] are reported in brackets. The sample period is January 1985 to December 2014.

Table 6. Asset Pricing: Sample split

	Panel A. Factor Betas									
	First half					Second half				
Portfolio	α	β_{DOL}	β_{IMS}	adj.-R^2	J	α	β_{DOL}	β_{IMS}	adj.-R^2	J
1	-2.90	0.94	-0.17	63.72		-1.61	0.86	-0.10	70.50	
	(-1.45)	(8.64)	(-3.88)			(-1.19)	(12.13)	(-2.39)		
2	-0.60	0.87	-0.12	79.72		-1.97	0.81	-0.10	76.73	
	(-0.58)	(13.24)	(-5.60)			(-2.07)	(14.07)	(-3.73)		
3	0.59	0.94	-0.11	75.14		-1.73	1.08	-0.06	84.93	
	(0.50)	(17.06)	(-2.54)			(-2.06)	(19.52)	(-1.49)		
4	0.56	0.88	-0.01	71.49		-1.62	1.11	-0.03	87.57	
	(0.46)	(12.12)	(-0.37)			(-2.24)	(18.53)	(-1.07)		
5	0.25	1.17	0.07	79.22		-2.66	1.12	-0.05	79.36	
	(0.19)	(17.26)	(1.13)			(-2.05)	(20.08)	(-0.61)		
6	2.10	1.20	0.35	69.23		9.59	1.03	0.34	65.11	
	(1.32)	(14.22)	(5.13)			(3.98)	(9.56)	(3.47)		
J-test					4.41					26.01
(p-value)					(0.62)					(0.00)

	Panel B. Risk Prices							
	First half				Second half			
GMM	DOL	IMS	R^2	RMSE	DOL	IMS	R^2	RMSE
λ	3.08	6.88	92.91	0.95	3.87	27.12	96.75	1.17
[s.e.]	[1.86]	[4.86]			[1.61]	[3.82]		
FMB	DOL	IMS	R^2	RMSE	DOL	IMS	R^2	RMSE
λ	3.08	6.88	92.91	0.95	3.85	32.34	98.31	0.85
[NW]	[1.94]	[5.27]			[1.82]	[4.95]		
[Sh.]	[1.97]	[5.27]			[1.86]	[5.17]		

Note: The table set up is identical to the one in Table 4 with the only exception being that results of time-series regressions and cross-sectional asset pricing tests are reported for the 50/50 time split of the full sample. Results for the first half of the sample (January 1985 to December 1999) are presented in the left panel and for the second half (January 1999 to December 2014) in the right panel. Returns are monthly and portfolios are rebalanced on an annual basis. Panel A reports estimates for monthly time series regressions of (log) carry trade excess returns on the intercept, the DOL factor and the IMS factor for each carry trade portfolio. These estimates are: the constant (α) (annualized and in percentage points); the DOL factor loading (β_{DOL}); the IMS factor loading (β_{IMS}); and the adjusted-R^2 (in percentage points). T-statistics based on HAC Newey and West (1987) standard errors with Andrews (1991) lag selection are reported in parentheses. The J-test of pricing errors ($\alpha' V_\alpha^{-1} \alpha$) tests if intercepts are jointly equal to zero. Panel B reports cross-sectional asset pricing tests results, namely iterated GMM and FMB. Returns of test assets (carry trade portfolios) are in levels and annualized (multiplied by 12). We report the factor price of risk (λ) for the DOL and the IMS factors, the cross-sectional R^2 and the square root of mean-squared errors (RMSE) for each procedure. The standard errors [s.e] are reported in brackets and based on the Newey-West [NW] approach with optimal lags and Shanken (1992) correction [Sh]. A constant is not included in the second stage of FMB regression.

Table 7. Asset Pricing: Alternative measure of solvency

				Panel A. Factor Betas				
		All Countries				Developed Countries		
Portfolio	α	β_{DOL}	β_{CAXGS}^{IMS}	adj.-R^2	α	β_{DOL}	β_{CAXGS}^{IMS}	adj.-R^2
1	-2.27	0.90	-0.24	70.35	-0.68	0.94	-0.35	81.09
	(-1.94)	(13.37)	(-6.36)		(-0.71)	(19.93)	(-10.16)	
2	-1.63	0.85	-0.09	77.11	0.42	0.94	-0.07	81.81
	(-2.20)	(17.31)	(-3.78)		(0.68)	(27.30)	(-2.56)	
3	-0.86	1.02	-0.05	78.25	-0.94	0.95	0.06	82.82
	(-1.04)	(24.00)	(-1.66)		(-1.23)	(31.30)	(1.80)	
4	-0.74	0.99	0.01	78.68	1.20	1.17	0.37	84.03
	(-0.94)	(18.11)	(0.31)		(1.34)	(24.50)	(7.17)	
5	-1.75	1.19	0.10	77.92				
	(-1.49)	(23.77)	(2.26)					
6	7.25	1.05	0.28	58.33				
	(3.77)	(13.15)	(4.69)					
J-test				33.27				4.32
(p-value)				(0.00)				(0.36)

				Panel B. Risk Prices				
		All Countries				Developed Countries		
GMM	DOL	IMS_{CAXGS}	R^2	RMSE	DOL	IMS_{CAXGS}	R^2	RMSE
λ	3.64	17.81	86.46	1.92	3.10	5.89	96.89	0.64
[s.e.]	[1.18]	[3.43]			[1.47]	[2.65]		
FMB	DOL	IMS_{CAXGS}	R^2	RMSE	DOL	IMS_{CAXGS}	R^2	RMSE
λ	3.61	18.40	86.49	1.92	3.10	5.94	96.89	0.64
[NW]	[1.31]	[3.72]			[1.53]	[2.74]		
[Sh.]	[1.34]	[3.73]			[1.55]	[2.76]		

Note: The table reports time series regressions and cross-sectional asset pricing tests results with SDF linearly defined by the dollar risk factor (DOL) and the alternatively specified indebted-minus-solvent risk factor (CAXGS). The CAXGS factor is of a similar nature to the IMS factor, but is based on an alternative solvency measure, which is current account-to-export of goods and services. As before, returns are monthly and portfolios are rebalanced on an annual basis. Results for the sample of all countries are presented in the left panel and for developed countries in the right panel. Panel A reports estimates of monthly time series regressions of (log) carry trade excess returns on the intercept, the DOL factor and the CAXGS factor for each carry portfolio. These estimates are: the constant (α) (annualized and in percentage points); the DOL factor loading (β_{DOL}); the CAXGS factor loading (β_{CAXGS}); and the adjusted-R^2 (in percentage points). T-statistics based on HAC Newey and West (1987) standard errors with Andrews (1991) lag selection are reported in parentheses. A J-test of pricing errors ($\alpha' V_\alpha^{-1} \alpha$) tests if intercepts are jointly equal to zero. Panel B reports cross-sectional asset pricing tests results, namely iterated GMM and FMB. Returns of test assets (carry trade portfolios) are in levels and annualized (multiplied by 12). We report the factor price of risk (λ) for the DOL and the CAXGS factors, the cross-sectional R^2 and the square root of mean-squared errors (RMSE) for each procedure. The standard errors [s.e] are reported in brackets and based on the Newey-West [NW] approach with optimal lags and Shanken (1992) correction [Sh]. A constant is not included in the second stage of FMB regression. The sample period is January 1985 - December 2014.

Table 8. Asset Pricing: Various information sets

	Factor Betas						Risk Prices	
Set A (updated 03/31)								
Portfolio	1	2	3	4	5	6		GMM
α	-2,31	-1,72	-0,04	0,75	-1,82	5,15	λ_{DOL}	3,82
	(-1.83)	(-2.05)	(-0.07)	(1.02)	(-1.48)	(3.51)		[1.31]
β_{DOL}	0,80	0,94	0,99	1,02	1,19	1,07	λ_{IMS}	14,73
	(9.35)	(16.78)	(24.97)	(23.19)	(23.36)	(18.06)		[3.49]
β_{IMS}	-0,21	-0,08	-0,06	-0,05	0,03	0,36	J-test	52,15
	(-3.77)	(-2.28)	(-2.39)	(-0.86)	(0.85)	(6.15)		(0.00)
adj.-R^2	58,68	74,96	84,30	79,31	78,33	67,76	R^2	92,94
Set B (updated 06/30)								
Portfolio	1	2	3	4	5	6		GMM
α	-2,00	-1,23	-0,57	-0,63	0,16	4,27	λ_{DOL}	3,50
	(-1.90)	(-1.65)	(-0.89)	(-0.89)	(0.16)	(3.23)		[1.33]
β_{DOL}	0,89	0,84	1,04	1,02	1,06	1,16	λ_{IMS}	9,92
	(11.22)	(16.94)	(23.32)	(18.71)	18.27)	(23.01)		[2.65]
β_{IMS}	-0,24	-0,11	-0,05	-0,01	-0,05	0,47	J-test	40,45
	(-6.65)	(-3.60)	(-1.24)	(-0.38)	(-1.52)	(8.23)		(0.00)
adj.-R^2	69,05	74,82	82,77	81,57	78,01	74,20	R^2	98,98
Set C (updated 12/31)								
Portfolio	1	2	3	4	5	6		GMM
α	-2,09	-1,06	-0,30	-0,29	-1,42	5,12	λ_{DOL}	3,21
	(-1.73)	(-1.48)	(-0.39)	(-0.36)	(-1.37)	(3.29)		[1.32]
β_{DOL}	0,89	0,83	1,03	1,00	1,12	1,13	λ_{IMS}	13,94
	(11.32)	(17.51)	(23.19)	(17.33)	(24.75)	(14.32)		[2.96]
β_{IMS}	-0,20	-0,14	-0,11	-0,02	0,07	0,41	J-test	55,84
	(-4.22)	(-5.65)	(-3.06)	(-0.62)	(1.23)	(5.43)		(0.00)
adj.-R^2	64,50	77,46	79,13	78,80	78,77	67,73	R^2	94,57

Note: The table reports time series regressions and cross-sectional asset pricing tests results with SDF linearly defined by the dollar risk factor (DOL) and the indebted-minus-solvent risk factor (IMS). As before, returns are monthly and portfolios are rebalanced on an annual basis, but using the macro data for previous year that is available at the end of March (Set A), June (Set B) and December (Set C) of the current year. Carry trade portfolios are updated at the end of each of the above mentioned periods using the previous month's forward discounts. Results for monthly time series regressions of (log) carry trade excess returns on the intercept, the DOL factor and the IMS factor for each carry portfolio are presented in the left-hand panel. These estimates are: the constant (α) (annualized and in percentage points); the DOL factor loading (β_{DOL}); the IMS factor loading (β_{IMS}); and the adjusted-R^2 (in percentage points). T-statistics based on HAC Newey and West (1987) standard errors with Andrews (1991) lag selection are reported in parentheses. The right-hand panel reports results of the iterated GMM. Returns of test assets (carry trade portfolios) are in levels and annualized (multiplied by 12). J-test of pricing errors ($\alpha' V_\alpha^{-1} \alpha$) tests if intercepts are jointly equal to zero. We report the factor price of risk (λ) for the DOL and the IMS factors, the cross-sectional R^2. The standard errors [s.e] are reported in brackets and based on Newey-West [NW] approach with optimal lags and p-values for the J-test are in parentheses. A constant is not included in the second stage of FMB regression.
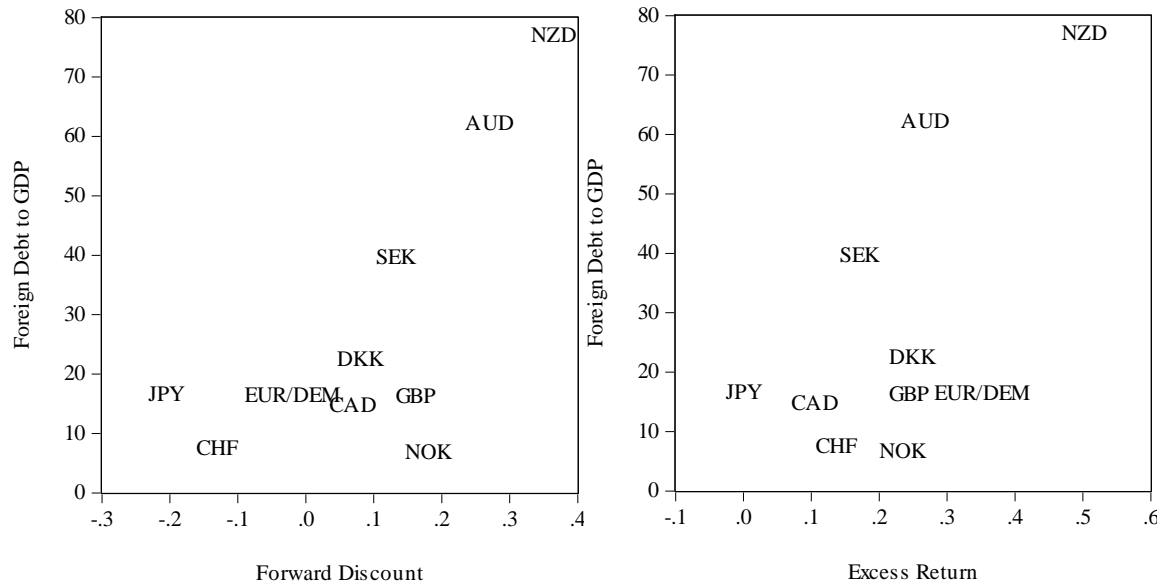
Figure 1. Developed countries and Solvency measure.

Note: The figure plots forward discount and excess return for each country in the developed sample against the corresponding solvency measure. The sample period is January 1985 to - December 2014. Pre-1999 data on the German Mark is merged with post-1999 data on the Euro. The solvency measure is defined by the foreign debt to GDP ratio.

Appendix

In the Appendix, we present the detailed derivation of UIP disturbed by the solvency risk premia (Appendix A) and additional results (Appendix B). In Appendix A, we describe the basic structure of the world economy and briefly remark on notation. Further, we outline the representative household preferences, followed by UIP derivations. Finally, in Appendix B we present the results of asset pricing tests from Section 4 using solvency-measure-sorted portfolios (Table B1), and DOL and IMS factor loadings on log currency returns (Table B2).

Appendix A

The Setup

Consider two economies populated with consumers and a government (central bank). Households are assumed to be identical in both economies and consume a CES bundle of domestic and imported products. Governments are allowed to borrow from the international capital market and consumers may borrow from and lend to the government. The only financial instrument in the world is a traded bond. Governments can issue both domestic and foreign currency denominated one-period bonds, paying an interest rate of i_t and i_t^*, respectively. In the following model, we mainly focus on one economy and its interaction with the second economy, and with the world as a whole. Thus, we specify variables for the economy of interest (domestic) without any subscripts, while using a superscript asterisk when referring to the foreign economy.

UIP with the disturbance term

The households in the domestic economy are maximizing the utility function, which is given by the following constant relative risk aversion function of consumption:

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ \frac{C_{t+k}^{1-\varepsilon}}{1-\varepsilon} \right\}, \tag{A-1}$$

where E_t stands for the mathematical expectation conditional upon complete information related to period t and earlier. The composite consumption index (C_t) is given by standard CES functions of domestic and imported goods. The subjective intertemporal discount factor is denoted by β ($0<\beta<1$), ε is the constant relative risk aversion coefficients for consumption.

A household possesses net stocks of one-period domestic (D) and foreign (F) currency bonds, receives interest (i), and spends on consumption and taxes (Tax). Its period t nominal budget constraint is:

$$P_t C_t + D_t + S_t F_t = (1 + i_{t-1})D_{t-1} + (1 + i^*_{t-1})S_t F_{t-1} - Tax_t \tag{A-2}$$

where P_t is price index of the consumption bundle, Tax_t are lump sum taxes net of transfers payable in period t, and S_t is the nominal exchange rate. Next we derive the real budget constraint by introducing equation (3) in equation (A-2) and dividing by the price index of domestic goods (P_t^d):

$$p_t C_t + d_t + e_t f_t = (1 + i_{t-1})\frac{d_{t-1}}{\pi_t} + (1 + i^*_{t-1})v(\gamma_{t-1})e_t \frac{f_{t-1}}{\pi^*_t} - tax_t \tag{A-3}$$

where

$$p_t \equiv \frac{P_t}{P_t^d}, \quad d_t \equiv \frac{D_t}{P_t^d}, \quad f_t \equiv \frac{F_t}{P_t^*}, \quad e_t \equiv \frac{S_t P_t^*}{P_t^d}, \quad \pi_t \equiv \frac{P_t^d}{P_{t-1}^d}, \quad \pi^*_t \equiv \frac{P_t^*}{P_{t-1}^*}, \quad \gamma_t \equiv \frac{e_t f_t}{Y_t}$$

are the relative price of consumption goods, the real stock of domestic and foreign bond, the real exchange rate, the gross rates of domestic and foreign inflation, and the foreign debt to economy's earning capacity ratio, respectively. Moreover, tax_t is the real lump sum tax, and

P_t^* is the price index of foreign goods. As noted earlier, each household seeks to maximize it lifetime expected utility (A-1). To do so it chooses the optimal strategy of $\{C_{t+k}, d_{t+k}, f_{t+k}\}_{k=0}^{\infty}$ subject to its real budget constraint (A-3) and initial values of d_0, and f_0. Lagrangian with a no-Ponzi game condition, where $\lim_{t \to \infty} \beta^t d_t = 0$, is presented by:

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ \frac{C_{t+k}^{1-\varepsilon}}{1-\varepsilon} + \lambda_{t+k} \left\{ (1+i_{t-1+k})\frac{d_{t-1+k}}{\pi_t+k} + (1+i_{t-1+k}^*)v(\gamma_{t-1+k})e_{t+k}\frac{f_{t-1+k}}{\pi_{t+k}^*} - \right. \right.$$

$$\left. \left. tax_{t+k} - p_{t+k}C_{t+k} - d_{t+k} - e_{t+k}f_{t+k} \right\} \right\}, \tag{A-4}$$

First order conditions for C_t, d_t, f_t are:

$$C_t : \qquad C_t^{-\varepsilon} = \lambda_t p_t \tag{A-5}$$

$$d_t : \qquad 1 = \beta(1+i_t)E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} \right) \tag{A-6}$$

$$f_t : \qquad 1 = \beta(1+i_t^*)v(\gamma_t)E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{e_{t+1}}{e_t} \frac{1}{\pi_{t+1}^*} \right) \tag{A-7}$$

where equations (A-6) and (A-7) are corresponding classic Euler conditions for d_t and f_t.

Next by definition the real exchange rate change is given by:

$$\frac{e_{t+1}}{e_t} = \frac{S_{t+1}}{S_t} \frac{\pi_{t+1}^*}{\pi_{t+1}}, \tag{A-8}$$

Henceforth, we define a nominal change in the domestic currency exchange rate as δ, where $\delta_{t+1} \equiv S_{t+1}/S_t$. Multiplying both sides of (A-6) by δ_{t+1} and substituting (A-8) in (A-7) we have:

$$E_t(\delta_{t+1}) = \beta(1 + i_t)E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\frac{\delta_{t+1}}{\pi_{t+1}}\right) \tag{A-9}$$

$$1 = \beta(1 + i_t^*)v(\gamma_t)E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\frac{\delta_{t+1}}{\pi_{t+1}}\right) \tag{A-10}$$

Combining equations (A-9) and (A-10) we have solvency risk-adjusted UIP:

$$(1 + i_t) = (1 + i_t^*)v(\gamma_t)E_t(\delta_{t+1}) \tag{A-11}$$

Appendix B

Table B1. Asset Pricing: Solvency sorted test assets

		All Countries					Developed Countries			
		Panel A. Factor Betas								
Portfolio	α	β_{DOL}	β_{IMS}	adj.-R^2	J	α	β_{DOL}	β_{IMS}	adj.-R^2	J
1	-0.68	1.17	-0.31	91.51		0.17	1.10	-0.37	93.71	
	(-1.11)	(42.17)	(-13.48)			(0.33)	(41.43)	(-18.03)		
2	-0.04	0.93	-0.10	75.28		-0.32	0.86	0.00	75.33	
	(-0.04)	(15.86)	(-4.00)			(-0.36)	(18.74)	(-0.09)		
3	-0.40	0.76	-0.03	73.81		0.62	0.88	-0.11	70.22	
	(-0.60)	(26.07)	(-1.43)			(0.72)	(19.81)	(-2.77)		
4	1.95	0.82	-0.02	71.68		-0.25	1.10	0.63	94.03	
	(2.47)	(19.40)	(-0.62)			(-0.48)	(45.88)	(31.29)		
5	1.06	1.08	-0.07	79.83						
	(0.94)	(22.15)	(-2.24)							
6	-0.97	1.16	0.70	94.11						
	(-1.59)	(42.56)	(30.69)							
J-test					30.97					34.55
(p-value)					(0.00)					(0.00)

		Panel B. Risk Prices							
		All Countries				Developed Countries			
GMM	DOL	IMS	R^2	RMSE		DOL	IMS	R^2	RMSE
λ	3.91	2.58	92.33	1.07		3.21	3.42	99.11	0.33
s.e.	[1.32]	[1.62]				[1.54]	[1.70]		
FMB	DOL	IMS	R^2	RMSE		DOL	IMS	R^2	RMSE
λ	3.65	1.64	93.51	0.99		3.15	3.26	99.17	0.32
[NW]	[1.33]	[1.88]				[1.54]	[1.73]		
(Sh)	[1.36]	[1.89]				[1.56]	[1.75]		
Mean	**3.53**	**2.64**				**3.08**	**3.81**		

Note: The table reports time series regressions and cross-sectional asset pricing tests results for the two factor model using a solvency measure (foreign debt to GDP) sorted portfolios as test assets. The risk factors are: the dollar risk factor (DOL) from Lustig, Roussanov, and Verdelhan (2011) and the IMS (indebted-minus-solvent) factor. The IMS factor is based on solvency measure sorts. Returns are monthly and portfolios are rebalanced on an annual basis. Results for the sample of all countries are presented in the left panel and for developed countries in the right panel. Panel A reports estimates for monthly time series regressions of (log) carry trade excess returns on the intercept and the IMS risk factor for each solvency sorted portfolio. These estimates are: the constant (α); the IMS factor loading (β_{IMS}); and the adjusted-R^2 (in percentage points). T-statistics based on HAC Newey and West (1987) standard errors with Andrews (1991) lag selection are reported in parentheses. A J-test of pricing errors ($\alpha' V_\alpha^{-1} \alpha$) tests if intercepts are jointly equal to zero. Panel B reports cross-sectional asset pricing tests results, namely iterated GMM and FMB. Returns of test assets (carry trade portfolios) are in levels and annualized (multiplied by 12). We report the IMS factor price of risk (λ), the cross-sectional R^2 and the square root of mean-squared errors (RMSE) for each procedure. The standard errors [s.e.] are reported in brackets and based on the Newey-West [NW] approach with optimal lags and Shanken (1992) correction [Sh]. A constant is not included in the second stage of FMB regression. The sample period is January 1985 - December 2014.

Table B2. The log currency returns and the risk factors

	Panel A. Factor Betas							
	All Countries				Developed Countries			
Portfolio	α	β_{DOL}	β_{IMS}	adj.-R^2	α	β_{DOL}	β_{IMS}	adj.-R^2
1	0.00	-0.85	0.16	67.67	-0.00	-0.91	0.34	76.06
	(0.01)	(-12.98)	(4.28)		(-1.14)	(-16.80)	(8.14)	
2	0.00	-0.84	0.13	78.31	-0.00	-0.93	0.07	81.06
	(0.91)	(-18.16)	(-5.89)		(-0.43)	(-29.04)	(2.00)	
3	0.00	-1.00	0.08	80.40	0.00	-0.95	-0.06	81.99
	(1.34)	(-21.80)	(2.43)		(-0.95)	(-30.25)	(-1.64)	
4	0.00	-0.98	0.00	78.29	0.00	-1.17	-0.35	78.33
	(3.10)	(-17.70)	(0.07)		(2.68)	(-22.30)	(-6.63)	
5	0.00	-1.12	-0.02	78.10				
	(4.48)	(-0.02)	(-0.43)					
6	0.01	-1.02	-0.24	65.12				
	(5.57)	(14.04)	(-3.11)					

Note: The table reports estimates for monthly time-series regressions of the logarithmic change in the spot exchange rate for each carry trade portfolio on the currency-specific risk factors, namely, the dollar risk factor (DOL) from Lustig, Roussanov, and Verdelhan (2011) and the IMS (indebted-minus-solvent) factor. The IMS factor is based on the solvency measure (foreign debt to GDP) sorts. Returns are monthly and portfolios are rebalanced on an annual basis. Results for the sample of all countries are presented in the left panel and for developed countries in the right panel. These estimates are: the constant (α); the IMS factor loading (β_{IMS}); and the adjusted-R^2 (in percentage points). T-statistics based on HAC Newey and West (1987) standard errors with Andrews (1991) lag selection are reported in parentheses. A J-test of pricing errors ($\alpha' V_\alpha^{-1} \alpha$) tests if intercepts are jointly equal to zero. The sample period is January 1985 - December 2014.