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Abstract

This paper tests a novel explanation for excess returns to the carry trade, namely, that investors are rewarded for exposure to equity risk of the target country. This risk factor is motivated via a hedging argument, whereby investors reallocate portfolio holdings to government debt in response to an increase in equity risk. Data from 1952 to 2007 on a broad sample of countries are used to test this hypothesis in an asset pricing framework which controls for global equity returns, exchange rate volatility, and global consumption factors. Target currency equity returns are found to be a priced risk factor after controlling for these factors. Implications for the diversification of international portfolio risk are discussed.

JEL: G12, G15, F31

Keywords: uncovered interest parity, exchange rates, carry trade.

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1 Introduction

Low interest rate currencies do not appreciate as much as the interest differential. This widely documented breach of the Uncovered Interest Parity condition leads to positive returns for investors who borrow money in a low interest rate currency and use their borrowings to purchase T-Bills or similar securities in a high interest rate currency, thus engaging in the so-called carry trade. A large literature debates the existence of risk factors which can explain these returns. The most recent contributions to this literature argue that currency crash risk provides a more plausible explanation for carry trade returns than correlation with traditional risk factors (Brunnermeier et al, 2008). The present paper identifies risk factors that are significantly priced when controlling for currency risk, one of which is new to the literature. The new factor is target currency equity risk. The primary motivation for this factor arises from a hedging argument. An increase in the risk of a country's stock market returns may lead to a reallocation into the bond market, thus giving rise to an association between stock market and t-bill returns. This argument is developed further in Section 3.2, along with competing explanations for the significance of target country equity returns.

Apart from controlling for commonly cited risk factors (global equity returns and currency risk), the target country equity return explanation is also tested against the Consumption Capital Asset Pricing Model (CCAPM) model examined by Lustig and Verdelhan (2007) (Jack Treynor (1961) and William Sharpe (1964)). The CCAPM assumes that all investors are intertemporal consumption maximisers with full knowledge of the correlation of consumption growth with asset returns, leading to a model where returns derive from an asset's correlation with consumption. This paper adopts a more general Arbitrage Pricing Theory (APT) framework, where returns are modeled as deriving from an asset's exposure to various macroeconomic risk factors (Ross, 1976). The APT framework is capable of incorporating consumption risk factors, facilitating a direct comparison of the two models, as well as other factors commonly used in the literature.

This paper studies real returns to a U.S. investor investing in portfolios of foreign T-Bills. The Fama-Macbeth asset pricing procedure is used to test which factors from competing risk-based explanations can explain the returns (Fama and Macbeth, 1973). Exposure to global and target country stock market risk and to currency risk provides the most robust explanation for excess returns to the carry trade. In finding exchange rate volatility to be a risk factor which generates carry trade returns, this paper also contributes to an emerging literature which stresses the potential importance of rare disasters as an explanation for currency risk premia (Brunnermeier et al, 2008 and Farhi and Gabaix, 2008).

2 Empirical Studies of Carry Trade Returns

The failure of the Uncovered Interest Parity (UIP) condition, which is necessary for the carry trade to be profitable, is of relevance to macroeconomists, since UIP is generally assumed in general equilibrium open economy models. Some models account for the observed failure of UIP by adding a shock to the UIP equation, a so-called Risk Premium shock (e.g. McCallum 1994). Such risk premium shocks affect domestic interest rates and hence real variables like consumption and output, as pointed out by Burnside et al (2006). Thus it is of interest to ask whether breaches of UIP are associated with risk factors, with investors who are exposed to such risk being compensated accordingly.

A large literature attempts to explain the failure of UIP. Proposed explanations include the importance of risk premia, the interaction of risk premia and monetary policy, and biases in expectations (Fama (1984), McCallum (1994), and Frankel and Rose (1994), respectively). Recent contributions include those of Alvarez, Atkeson, and Kehoe (2006), who investigate time-variation in risk premia resulting from endogenous market segmentation, and Bacchetta and Van Wincoop (2006), who suggest that the cost of actively managing foreign exchange portfolios may help to explain the failure of UIP.

In a paper which examines the choices facing a U.K. investor, Burnside et al (2006) confirmed the existence of high Sharpe ratios in returns to the carry trade, but concluded that these returns are not related to risk factors, and cannot be exploited due to a number of frictions. Among others, the authors tested U.K. consumption growth as a potential risk factor. In contrast, Lustig and Verdelhan (2007) find that aggregate consumption risk does explain returns to the carry trade on a large sample of countries over the period 1952-2002. According to the authors, the key innovation in their study is to form portfolios of currencies based on the interest rate. Burnside (2007) raises a number of objections to the findings of Lustig and Verdelhan (2007), primarily that the constant in the second stage regression in the Fama-MacBeth equations run by Lustig and Verdelhan (2007) is too large to be credible, and that the authors ignored sampling uncertainty in the first stage of the procedure. Lustig and Verdelhan (2008) counter that the constant was not significantly different from zero, and so was not too large, and that the market price of consumption risk remains significantly different from zero after accounting for sample uncertainty in the first stage estimation. Lustig et al (2008) confirm the finding of Lustig and Verdelhan (2007) that consumption risk can explain carry trade returns, and find evidence for time variation in the correlation of carry trade returns with the macroeconomic risk factors. The authors also find evidence supporting the presence of U.S. stock market excess returns as an explanatory factor for carry trade returns when allowance is made for time variation in this correlation, which may be caused by a flight-to-quality effect during periods of financial crisis.

Burnside et al (2008) use options data to calculate stochastic discount factors and payoffs in the peso currency crash state and the non-peso stable state, and find that realistic values for these discount factors can explain excess carry trade returns. The motivation for this approach is the failure to find significant covariance between carry trade returns and traditional risk factors. The present paper claims to have found such covariance. The new finding is that a carry trade portfolio may be exposed to equity risk of the target country. Many target countries are emerging markets with relatively high interest rates, whose stock market returns show greater volatility than those of the U.S. The factor price for target country equity returns is therefore also higher than that of the U.S. equity return factor. This innovation is motivated in an Arbitrage Pricing Theory framework, in which investors are rewarded for exposure to a number of risk factors. The finding that carry trade and foreign equity returns are related confirms and extends the insights of Campbell et al (2007), who, for example, show that the Australian and Canadian dollars comove positively with those countries' stock market returns, while the opposite is true for the Euro and Swiss Franc. As pointed out by the authors, if foreign equity returns denominated in their local currency covary negatively with the foreign currency, then a long position in foreign T-Bills provides a hedge against foreign equity risk. Investigating the relationship between carry trade and equity returns is therefore of interest to globally diversified equity investors. This paper concludes that engaging in the carry trade appears to expose investors to foreign and global stock market risk, and documents the cross sectional variation in the foreign equity market exposure.

In addition to allowing for target-country and global stock market risk, this paper also attempts to quantify the importance of exchange rate volatility in determining carry trade returns, thus combining insights from two separate strands of the carry trade literature. Recent papers that address the question of exchange rate volatility include those of Brunnermeier et al (2008), who suggest that the presence or threat of liquidity crises may lead to the sudden unwinding of carry trade positions and negatively skewed exchange rates, and

Koyama and Ichiue (2008), who link volatility with the unwinding of carry trade positions.

3 Explanations of Observed Returns

3.1 Return Calculations

Empirical asset pricing studies often seek to explain the returns to portfolios of assets, sorted on variables that predict returns (for the case of stocks, size and book-to-market ratio), thus eliminating the diversifiable, asset-specific component of returns that is not of interest. This produces more precise estimates of the risk/return trade-off in asset markets. Likewise, by sorting currencies into portfolios based on the nominal interest rate differential, it is possible to abstract from the country-specific component of exchange rate changes that is not related to the drivers of carry trade returns. This isolates the source of variation in excess returns that is of interest for the carry trade.

Following this approach, nominal returns are calculated as:

$$R^i_{t+1} = R^{for}_t (E^i_{t+1}/E^i_t). \tag{1}$$

where R^{for} stands for the foreign interest rate (T-Bill yield) and E is the nominal exchange rate, expressed as dollars per unit of foreign currency.

Real excess returns to a U.S. investor are then calculated as:

$$R^{i,e}_{t+1} = (R^i_{t+1} - R^{USD}_t)(P_t/P_{t+1}) \tag{2}$$

where P stands for the U.S. CPI index.

These calculations follow Lustig and Verdelhan (2007). Countries are ranked by interest rate. They are then grouped into eight portfolios with an equal number of countries in portfolios 1-7 and the remaining countries in portfolio 8 (the highest interest rate portfolio).

3.2 Explanatory Risk Factors

3.2.1 Hypothesis 1: Carry Trade Returns Provide Compensation for Exposure to U.S. and Target Country Stock Market Risk and Exchange Rate Volatility.

Target Country Stock Market Risk

T-Bill (and hence carry trade) and stock market returns (net of the three month t-bill yield) might show positive correlation due to variation in real interest rates, since the prices of both assets are negatively related to the discount rate. Common movements in future expected returns likewise promote a positive correlation. Alternatively, carry trade and equity returns could be linked via the exchange rate. A positive correlation could arise between the exchange rate and the inflation rate if the monetary policy authority follows a Taylor Rule. In this way "bad news about inflation may be good news about the exchange rate", and therefore also about carry trade returns (Clarida and Waldman, 2007).

Alternatively, a negative correlation could also arise between equity and carry trade returns. Foreign currency denominated excess returns on foreign equity would be negatively correlated with the return on foreign currency if stocks are real assets and the shocks to foreign currency are primarily related to foreign inflation (Campbell et al, 2007). This would lead to

$$Corr[dE_t, (R^s_{i,t} - R_{i,t})(P_{t-1}/P_t)] < 0 \tag{3}$$

where E is the nominal exchange rate (in dollars per unit of foreign currency, e.g. dollars per euro), R^s refers to the return to a broad index of shares, R refers to the T-Bill yield, P refers to the domestic CPI and the i subscript indicates country. A negative correlation between equity returns and exchange rates could also occur via the portfolio rebalancing effect documented in Hau and Rey (2007), whereby higher equity returns in the target currency lead to greater exposure to that currency and hence a reallocation out of the currency, causing its depreciation. If many investors are marking to market, aggregate effects are possible, as argued by Adrian and Shin (2009).

Carry trade returns could also be related to target country equity returns through the government debt market, instead of through the exchange rate. A negative correlation between equity and T-bill returns could arise in a joint stock-bond asset pricing model with an equity-specific source of risk. In such a model, a shock to equity returns could lead to a reallocation of capital out of equity and into government debt, lowering stock prices and returns and increasing bond prices and returns. This argues for negative correlation between carry trade returns and target currency denominated stock market returns:

$$Corr[R^e_{i,t}, R^s_{i,t} - R_{i,t}] < 0, \tag{4}$$

in other words negative equity betas for every country i, or negative β^j_s for every portfolio j. Thus the expectation is that carry trade returns are a function of exposure to stock market risk

$$E[R^{j,e}] = \alpha + \beta^j_s \lambda_s + \epsilon_j, \tag{5}$$

where $\lambda_s > 0$ is the associated risk premium and $\beta^j_s < 0$ is the factor loading. If this is the case, then an investor holding a long position in foreign equities can reduce portfolio risk by holding a long position in foreign currency, which could be achieved by buying foreign T-bills. In this way a long carry trade position could hedge exposure to stock market risk.

These effects can be tested in an Arbitrage Pricing Theory setting, in which an asset's return is a linear function of k factors:

$$R^{j,e} = E[R^{j,e}] + \beta_1^j F_1 + ... + \beta_k^j F_k + \epsilon_j \tag{6}$$

and its expected return is given by

$$E[R^{j,e}] = R_f + \beta_1^j RP_1 + ... + \beta_k^j RP_k, \tag{7}$$

where R_f is the risk free rate, F is an underlying risk factor, and RP a risk premium. This model assumes the factors to be mean-zero random variables. It is less restrictive than the CAPM, as it assumes that each investor will hold a unique portfolio with its own array of betas, as opposed to the identical "market portfolio". A flight to quality effect which might weaken the dependence of carry trade returns on any fundamental target currency risk factor can be accounted for by conditioning the factor, in this case stock market returns, on a measure of risk aversion, such as the VIX volatility index (as is done by Lustig and Verdelhan (2008)).

U.S. Stock Market Risk

The APT framework allows for the simultaneous inclusion of other risk factors. Campbell et al (2007) show that for Australia, Japan, Canada and the U.K., local currency returns are positively correlated with a measure of global equity returns, while the correlation for Euroland and Switzerland is positive pre-1990, becoming negative thereafter. Lustig et al (2008) find empirical evidence that U.S. stock market returns, conditioned by a measure of stock market volatility, can explain returns to the carry trade at the monthly frequency. The authors find that allowing for time variation in the risk factor beta by conditioning it in this way is necessary, as unconditional U.S. stock market returns alone lead to excessive factor risk premia. This approach allows for a flight to quality effect, with low interest rate currencies appreciating during times of global financial crisis. Higher returns in the U.S. stock market could be associated with the depreciation of a country's exchange rate via the flight to quality effect or through a portfolio rebalancing effect (Hau and Rey, 2007).

Exchange Rate Risk

Several studies find evidence of a link between exchange rate volatility and carry trade returns. Intuitively, exposure to exchange rate risk suggests that carry traders should care about exchange rate volatility, and that returns to the carry trade may compensate for this risk. Koyama and Ichiue (2008) find evidence that high bilateral exchange rate volatility may be associated with the unwinding of carry trade positions, with periods of low volatility coinciding with failure of the Uncovered Interest Parity condition. Thus, regime changes in the exchange rate process may coincide with a switch from investing in carry trade positions to unwinding these investments. The authors find evidence for causality from volatility to unwinding and also the reverse.

Brunnermeier et al (2008) present evidence that exchange rates between low and high interest rate currencies are negatively skewed, due to the sudden unwinding of carry trades which occurs during periods of decreased liquidity, again arguing for causality from the carry trade to exchange rates. The authors further suggest that the possibility of these crashes may discourage speculators from taking on large enough positions to enforce UIP, supporting a causal link from exchange rate volatility to carry trade returns. In related work, Farhi and Gabaix (2008) show how a country's exposure to disaster risk may lead to a depreciated currency with a high interest rate, reflecting a currency disaster risk premium. According to Galati et al (2007), bouts of higher exchange rate volatility have lead to "significant ...

declines in the attractiveness of some target currencies", notably the South African Rand. This paper tests the importance of exchange rate volatility as an explanatory risk factor in carry trade returns.

Estimating Equation

An Arbitrage Pricing Theory framework permits the simultaneous inclusion of the above risk factors. Thus, the model being tested is:

$$E[R^{j,e}] = \alpha + \beta_v^j \lambda_v + \beta_{s,US}^j \lambda_{s,US} + \beta_{sv,US}^j \lambda_{sv,US} + \beta_{ve}^j \lambda_{ve} + \beta_s^j \lambda_{s,j} + \beta_{sv}^j \lambda_{sv,j} + \epsilon_j, \qquad (8)$$

where the v subscript indicates VIX, the Chicago Board Options Exchange Volatility Index, s, US indicates U.S. equity returns, the sv subscript refers to the multiplicative interaction term between stock market returns and VIX (for the case of U.S. stock market returns: $R_t^{s,US} Vix_t$), and s, j indicates the target portfolio's stock market returns. The stock market return variables are real excess returns over the relevant (U.S. or local) T-Bill yield.

3.2.2 Hypothesis 2: Aggregate Consumption Risk Explains Carry Trade Returns.

Lustig and Verdelhan (2007) find evidence that engaging in the carry trade exposes investors to aggregate consumption risk and that this risk explains the resulting returns. The authors use a CAPM-based model.

The U.S. investor's unconditional Euler equation approximately implies a linear factor model for the expected excess return on portfolio j:

$$E[R^{j,e}] = b_c cov(\Delta c_t, R_t^{j,e}) + b_d cov(\Delta d_t, R_t^{j,e}), \qquad (9)$$

where c stands for real per capita household consumption and d stands for real per capita durables consumption. This is the DCAPM (Capital Asset Pricing Model with non-durable and durable consumption) examined by Yogo (2006).

The $b_c cov(\Delta c_t, R_t^{j,e})$ term can be rewritten as $\beta_c^j \lambda_c$, where

$$\beta_c^j = cov(\Delta c_t, R_t^{j,e})/var(\Delta c_t) \tag{10}$$

are the factor loadings and

$$\lambda_c = b_c var(\Delta c_t) \tag{11}$$

the factor prices, and likewise for $b_d cov(\Delta d_t, R_t^{j,e})$, giving

$$E[R^{j,e}] = \beta_c^j \lambda_c + \beta_d^j \lambda_d. \tag{12}$$

In estimating the equation a constant can be included

$$E[R^{j,e}] = \alpha + \beta_c^j \lambda_c + \beta_d^j \lambda_d + \epsilon_j \tag{13}$$

because the risk free rate is imperfectly estimated as the real return on U.S. T-Bills (Burnside, 2008). Thus the constant can be interpreted as the model's pricing error for the risk free rate. It is the factor prices that are of primary interest. A significant factor price shows that investors are rewarded for exposure to the risk associated with that risk factor.

4 Empirical Tests

4.1 Data

End of year (or as close as available to end of year) observations of three month T-Bill yields are taken from Global Financial Data (GFD), as are exchange rate data. The only exceptions to this maturity term are Costa Rica (six months) and The Former Yugoslav Republic of Macedonia (one month). The consumption price indices for the United States, Japan and the United Kingdom are also taken from GFD. The stock market data are the total return indices with a Datastream mnemonic that starts with TOTMK (e.g. for the U.S., TOTMKUS) or, for countries not covered by the TOTMK series, the International Finance Corporation (IFC) indices, also available from Datastream. The countries for which IFC data are used are: United Arab Emirates, Bangladesh, Bahrain, Botswana, Cote d'Ivoire, Ecuador, Egypt, Arab Rep., Estonia, Ghana, Croatia, Jamaica, Kazakhstan, Kenya, Kuwait, Lebanon, Lithuania, Latvia, Morocco, Mauritius, Oman, Panama, Qatar, Slovakia, Tunisia, Ukraine, Vietnam. Equity returns are denominated in their local currency.

The capital openness ratio is taken from Sebastian Edwards (2008)[2]. Countries whose capital openness ratio is less than 20% are excluded, following Lustig and Verdelhan (2007). Countries that defaulted on bonds in year t are not included in a year t portfolio, and so not included in the returns in year $t + 1$. A recovery rate of 70% is applied to countries whose T-Bills are included in a portfolio and who default, following Lustig and Verdelhan (2007). Bond default data are taken from Reinhart et al (2003) and Reinhart and Rogoff (2008).

Exchange rate volatility was calculated as the standard deviation of the daily growth rate in the exchange rate over the relevant year. Consumption data were taken from Adrien

[2]These data extend to 2004. For regressions until 2007, the 2004 values were used.

Verdelhan's website[3]. For the purpose of selecting a sample of more developed countries, real per capita consumption in 2000 is taken from the Penn World Tables (Heston et al, 2006). Data were collected for 96 countries for at least one year, although a small number of these countries are never included in a portfolio, according to the above criteria. Argentine T-Bill data were not available due to the sporadic nature of T-Bill issues by the Argentine central bank over the period in question. The sample of countries used in this study is presented in Appendix B.

4.2 Estimation

The models are estimated using the Fama-Macbeth Asset Pricing Procedure:

- Stage 1: for each portfolio, run time series regressions of currency portfolio returns on the factors to estimate factor betas for that portfolio (Fama and Macbeth, 1973). For portfolio j, estimate

$$R^{j,e}_{t+1} = \alpha + \beta^j_{F1} F1_t + \beta^j_{F2} F2_t + \ldots + \epsilon_{t+1}, \tag{14}$$

  where $F1$ represents the first risk factor, for example the growth rate of excess stock market returns.

- Stage 2: run a cross-section regression of average portfolio returns on the betas in order to estimate factor prices.

$$E_T[R^e_t] = \gamma + \lambda_{F1}\beta^j_{F1} + \lambda_{F2}\beta^j_{F2} + \ldots + u_j \tag{15}$$

[3] http://people.bu.edu/av/Research.html

4.3 Results

Second stage (factor price) regressions are only of interest when the null hypothesis that the vector of first-stage factor betas is the same across portfolios is rejected, based on a Seemingly Unrelated Regression Chi-Squared test (Zellner, 1962). This is the case for Hypothesis 1 (equity and exchange rate volatility factors) but not for Hypothesis 2 (consumption factors). Table 1 in Appendix A presents the factor price estimates for Hypothesis 1. The risk factors explain a large proportion of the variation in returns across portfolios, and are jointly and individually significant. An interaction effect model naturally leads to collinearity among the explanatory variables, confounding somewhat the interpretation of the coefficients. This may help to explain the 14% premium on a carry trade portfolio whose excess return moves one for one with U.S. equity returns, which is somewhat higher than expected. The VIX interaction term serves to reduce this premium somewhat, as VIX/U.S. Equity interaction term betas are typically negative (the betas are discussed below).

The negative coefficient of VIX is as expected. The interpretation is that a carry trade portfolio whose returns rise one for one as the implied volatility of U.S. stock markets rise, pays a negative risk premium (that is, requires an insurance premium) of 4.45% per annum. A carry trade portfolio whose excess returns move one for one with the excess stock market returns of the target country yields an average risk premium of around 20% per annum, again without adjusting for interaction effects (which are time dependent). The second column of Table 1 presents a robustness check: the same regression is run over the period 1980-2007 (inclusive). This change in sample period has a negligible effect on the results. Target country equity returns and the interaction between this variable and VIX are also jointly significant at the 1% level. Confirming that the target currency equity risk factor adds explanatory power to the model, Table 2 in Appendix A presents the results for a sub-model in which this factor is excluded. The R^2 value is lower for the sub-model.

The second column of Table 2 presents results for the same model using 16 portfolios, effectively doubling the degrees of freedom in the cross sectional (second stage, factor price) regressions. Although the individual significance levels of the risk factors falls somewhat, they remain jointly significant at the 1% level. The Shanken correction factor, which corrects for the fact that the second stage regression is based on estimated instead of known betas, also falls significantly.

Table 3 presents results for Hypothesis 2 (Consumption-CAPM). The factor prices for Hypothesis 1 differ significantly from those reported by Lustig and Verdelhan (2007): 0.61 for durable consumption and 2.60 for non-durable consumption, as against the 4.60 and 1.98 reported in Table 5 of Lustig and Verdelhan, with only non-durable consumption appearing marginally significant. The betas for this hypothesis are not significantly different across portfolios, making the second stage regression irrelevant. The insignificance of the consumption betas concurs with the finding of Burnside (2007), but not that of Lustig and Verdelhan (2008). Differences in the samples used here and by Lustig and Verdelhan, although small (the present sample is shown in Figure B), may help to explain this discrepancy. The criteria on which the present sample is based are presented in Section 4.1. The factor betas from a model with consumption/VIX interaction terms also do not differ across portfolios, leaving no basis on which to estimate factor prices. In contrast, the Hypothesis 1 factors betas and prices remain jointly significant when estimated on the 1952-2002 sample period. This result is shown in the first column of Table 4, while the second column shows the results for a model with consumption factors in place of equity returns, retaining the other explanatory variables (U.S. equity returns, VIX and exchange rate volatility). The two consumption factors are jointly insignificant in this specification.

Table 5 shows the results when the model is run on a subsample of more developed countries, namely the fifty richest countries by GDP per capita in 2000. The results are qualitatively unchanged. The smaller factor price of target country equity risk reflects the omission of many of the riskiest countries in terms of volatility of equity returns. The target country equity returns factors are now also individually significant. As a further robustness check, Table 7 presents results for an investor domiciled in Japan and the U.K., instead of the U.S.. The significance of the factor prices weakens somewhat, but they remain jointly significant at the 5% level for both countries, as do the two target country equity return factors.

Table 6 shows the betas for Hypothesis 1. Although almost none are individually significantly different from zero, the betas do vary across portfolios at the 1% significance level, according to a Seemingly Unrelated Regression Chi-Squared test (Zellner, 1962). The portfolio 1 and portfolio 8 betas are also significantly different, with a p-value less than .01. The signs of the factor betas are consistent with expectations. Higher U.S. stock market volatility is associated with lower carry trade returns for high interest rate (Portfolio 8) currencies. This may be due to a flight to quality effect.

Target currency equity betas are negative for the highest interest rate currencies, which may be because the link from equity to carry trade returns works via inflation rates (Campbell et al (2007)), or because of a portfolio rebalancing effect between debt and equities within a country. For other countries the target currency equity beta is positive, possibly supporting the argument that movement in the discount rate, which affects both stock market and t-bill returns, provides the link. The VIX interaction term is typically opposed in sign to the target country equity beta, weakening the link between carry trade returns and the target country equity market during times of high volatility. The betas shown in Table 6 are valid when VIX is zero, which is to say they are never exactly valid, but they show the general pattern across portfolios during times of stability. U.S. equity betas increase in the interest rate but are positive for all countries (although the VIX interaction term could alter this during times of high volatility), suggesting a strong global factor in equity returns.

Section 3.2 identified a number of possible explanations for the correlation between carry trade and target country equity returns. This correlation could arise through the exchange rate or through t-bill returns. Table 8 shows the results of panel corrected standard error regressions of raw equity returns on T-bill and exchange rate returns. This is intended as a statistical exercise. The coefficients can be viewed as conditional correlation coefficients. With country as the cross sectional unit only the T-bill returns are significant, with the sign supporting the portfolio rebalancing argument given in Sections 3.2. This argument states that carry trade portfolios could gain exposure to target country equity market risk if investors alter their holdings of, and therefore the returns to, T-bills and stocks in response to changes in stock market risk. Using portfolios as the cross sectional unit, this interpretation remains valid, however the exchange rate is now also correlated with equity returns. The negative sign of this correlation could support the inflation argument of Campbell et al (2007) or the portfolio rebalancing argument of Hau and Rey (2007), both of which are discussed in Section 3.2. The fact that the exchange rate factor is significant on the cross-portfolio regression but not across countries underlines the usefulness of eliminating idiosyncratic sources of variation by averaging returns across countries within interest rate portfolios.

5 Conclusions

This paper studies annual returns to the carry trade for a broad sample of countries over the period 1952-2007. Exposure to global and target country stock market risk, both conditioned by U.S. stock market implied volatility, and to exchange rate risk appears to explain these returns. This is consistent with Lustig and Verdelhan's (2007) contention that a risk based explanation of carry trade returns is feasible, and contradicts the claim by other authors (for example, Burnside et al (2008)) that returns are not significantly correlated with risk factors. No support is found for the contention that consumption risk explains carry trade returns.

The links between equity and carry trade returns may provide hedging opportunities for global investors. The correlation of carry trade returns with target country equity market returns is negative for high interest rate currencies and positive for low interest rate currencies, so that an investor who is long equities in a portfolio of high interest rate countries should consider taking a long position in the T-bills of those countries, and vice versa. In a similar manner, carry trade investors who wish to reduce their exposure to exchange rate risk might consider increasing the weight of target country equity exposure in their portfolio, or taking a short position in the equity market of the funding currency. The correlation with equity markets appears to derive from two mechanisms, one operating via the exchange rate, and one via rebalancing between T-bill and equity holdings in response to equity market shocks. The exchange rate effect could be due to portfolio rebalancing between countries, consistent with the findings of Hau and Rey (2003). The T-bill/equity rebalancing effect could occur if a shock to future stock cash flows decreases stock prices and increases bond prices, as bonds become more attractive for hedging the increased stock risk. This would give rise to the observed, mainly negative correlation. To the best of the author's knowledge, this risk factor is new to the empirical literature on carry trade returns.

The correlation of carry trade returns with U.S. equity returns appears to increase in the cross section with the interest rate, which may be due to covering of carry trade positions during a fall in global equity markets. Such a flight to quality could lead to depreciation of high interest rate currencies, and hence falling carry trade returns from those currencies. Carry trade investors should be aware that a long position in a portfolio of high interest rate currencies provides exposure to U.S. stock market risk. Finally, the presence of exchange rate volatility as a significant explanatory factor supports the conclusions of Brunnermeier et al (2008), who claim that the possibility of currency crashes prevents arbitrageurs from completely eliminating carry trade returns.

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A Factor Prices and Factor Betas

Hypothesis 1 Factor Price Estimates

	1952-2007	1980-2007
VIX	-4.45* *(2.63)*	-5.88 *(3.96)*
Eq Ret_{US}	14.64*** *(4.08)*	17.21** *(6.56)*
VIX*Eq Ret_{US}	416.99*** *(105.91)*	485.40*** *(165.25)*
StD(Ex Rate)	0.19*** *(0.03)*	0.23*** *(0.04)*
Eq Ret_i	19.94*** *(5.67)*	23.12*** *(8.20)*
VIX*Eq Ret_i	405.16*** *(107.94)*	465.70*** *(156.73)*
Constant	4.97*** *(1.59)*	5.73 *(2.70)*
Betas Vary	<0.01	<0.01
R-Squared	97%	99%
Shanken Factor	3.67	4.85
Test FPs	<0.01	<0.01
Observations	440	224

Table 1: Standard errors are shown in parentheses. "Betas Vary" reports the p-value from testing the null hypothesis that the set of first-stage factor betas is the same across portfolios, based on a Seemingly Unrelated Regression Chi-Squared test (Zellner, 1962). "Test FPs" reports the p-value from a joint significance test of the explanatory variables (Factor Prices). Shanken (1992) correction factors, which corrects for the fact that the second stage regression is based on estimated instead of known betas, are somewhat lower than that reported by Burnside (2008) for the Consumption-CAPM model (6.79). Increasing the degrees of freedom by examining 16 portfolios instead of 8 reduces the factor significantly (results below). The fit is measured by the R-squared reported in Burnside (2007) (Equation 12) and used by LV. This R-squared statistic is based on a comparison of the model's predictions for the eight time series-averaged portfolio returns against a naive model which uses the average across all portfolios as the prediction. This R-Squared will be zero for a model for which the sum of the cross-sectional squared errors equals that of the naive model.

U.S. Equity Factor Prices, and Target country and U.S. Equity Factor Prices with 16 Portfolios

	1952-2007		1952-2007, 16 Portfolios
VIX	1.92*(1.61)*	VIX	-2.09**(1.15)*
Eq Ret_{US}	9.93****(3.22)*	Eq Ret_{US}	4.68*(2.81)*
VIX*Eq Ret_{US}	241.13****(77.71)*	VIX*Eq Ret_{US}	81.37*(62.13)*
StD(ER)	0.12****(0.02)*	StD(ER)	-0.02*(0.04)*
Constant	0.90*(1.34)*	Eq Ret_i	8.27**(4.33)*
		VIX*Eq Ret_i	203.78***(91.99)*
		Constant	0.33*(0.87)*
Betas Vary	0.03	Betas Vary	<0.01
R-Squared	90%	R-Squared	55%
Shanken Factor	1.86	Shanken Factor	1.34
Test FPs	<0.01	Test FPs	<0.01
Observations	440	Observations	826

Table 2: Factor Price Estimates for a sub-model of Hypothesis 1, where target currency equity returns are excluded. The drop in R^2 compared to the full model suggests that target currency returns are adding explanatory power. The second column shows the full model using 16 carry trade portfolios. Standard errors are shown in parentheses. The increase in degrees of freedom leads to a smaller Shanken correction factor. The explanatory factors remain highly significant in a joint test ("Test FPs"). The fit is measured by the R-squared reported in Burnside (2007) (Equation 12) and used by LV. This R-squared statistic is based on a comparison of the model's predictions for the eight time series-averaged portfolio returns against a naive model which uses the average across all portfolios as the prediction. This R-Squared will be zero for a model for which the sum of the cross-sectional squared errors equals that of the naive model.

Hypothesis 2 Factor Price Estimates

	1952-2002		1952-2002
Consumption (Non-dur)	0.61*(2.34)*	VIX	0.04*(1.65)*
Consumption (Durable)	2.60***(1.01)*	Consumption (Non-dur)	0.61**(0.34)*
Constant	-2.10*(1.28)*	Consumption (Durable)	0.73**(0.40)*
		VIX*Consumption (Non-dur)	14.18*(9.90)*
		VIX*Consumption (Durable)	10.93*(14.24)*
		Constant	1.17*(0.92)*
Betas Vary	0.97	Betas Vary	0.44
R-Squared	27%	R-Squared	78%
Shanken Factor	2.7	Shanken Factor	2.1
Test FPs	0.03	Test FPs	<0.01
Observations	400	Observations	400

Table 3: "Betas Vary" reports the p-value from testing the null hypothesis that the set of first-stage factor betas is the same across portfolios, based on a Seemingly Unrelated Regression Chi-Squared test (Zellner, 1962). According to this test there is no significant variation in betas across porfolios, thus invalidating the second stage regression and factor prices. A model with VIX based interaction effects included likewise fails to produce significantly different factor betas. There appears to be little evidence to support a CCAPM explanation of carry trade premia.

Target Country Equity and Consumption Factors compared on a Common Sample

	1952-2003		1952-2003
VIX	-0.28*(2.64)*	VIX	-2.56*(3.80)*
Eq Ret_{US}	12.55***(4.72)*	Eq Ret_{US}	20.82*(12.80)*
VIX*Eq Ret_{US}	311.04***(126.13)*	VIX*Eq Ret_{US}	566.62*(376.46)*
StD(ER)	0.12***(0.05)*	StD(ER)	0.15****(0.03)*
Eq Ret_i	5.19*(6.18)*	Consumption (Non-dur)	-0.45*(0.86)*
VIX*Eq Ret_i	195.37*(124.33)*	Consumption (Durable)	-0.33*(1.03)*
Constant	1.56*(1.56)*	Constant	3.88*(4.18)*
Betas Vary	<0.01	Betas Vary	<0.01
R-Squared	80%	R-Squared	88%
Shanken Factor	2.24	Shanken Factor	4.13
Test FPs	<0.01	Test FPs	<0.01
Test Target Eq FPs	0.01	Test Consmptn FPs	0.77
Observations	755	Observations	400

Table 4: This table compares the Consumption CAPM model against the target equity factors, controlling for exchange rate volatility and global equity returns. The two target country equity factors are jointly significant, while the two consumption factors are not (second from bottom row). Standard errors are shown in parentheses. The fit is measured by the R-squared reported in Burnside (2007) (Equation 12) and used by LV. This R-squared statistic is based on a comparison of the model's predictions for the eight time series-averaged portfolio returns against a naive model which uses the average across all portfolios as the prediction. This R-Squared will be zero for a model for which the sum of the cross-sectional squared errors equals that of the naive model.

Hypothesis 1, 16 Portfolios, 50 country sub-sample

	1952-2007
VIX	3.22****(0.69)*
Eq Ret_{US}	4.09***(1.99)*
VIX*Eq Ret_{US}	105.56***(44.69)*
StD(ER)	-0.03*(0.04)*
Eq Ret_i	6.63***(2.89)*
VIX*Eq Ret_i	160.52****(50.21)*
Constant	1.79*(1.23)*
Betas Vary	<0.01
R-Squared	62%
Shanken Factor	1.53
Test FPs	<0.01
Observations	754

Table 5: Factor price estimates for Hypothesis 1 when calculated on a sub-sample of the 50 richest countries by GDP per capita in 2000. The U.S. and target country equity factor prices are substantially lower, suggesting that the high values on the broad sample are due to collinearity between the U.S. and target country equity returns. The high volatility and levels of those returns for the excluded countries leads to high factor prices.

Hypothesis 1 Betas, 1980-2007

Portfolio	Avg Return	VIX	Eq Ret_{US}	VIX*Eq Ret_{US}	StD(ER)	Eq Ret_i	VIX*Eq Ret_i
1	-2.49	0.03	0.35	0.00	-30.61	0.37	-0.03
2	-0.21	0.02	0.97	-0.04	3.24	-0.38	0.01
3	0.29	0.05	0.52	-0.02	-7.78	0.15	-0.01
4	-1.65	0.46	0.41	-0.02	-9.33	0.17	0.00
5	0.98	0.04	0.36	-0.02	-9.9	-0.30	0.01
6	1.48	0.77	0.91	-0.04	3.6	0.39	-0.01
7	3.75	0.21	0.37	-0.01	17.79	-0.10	0.00
8	2.63	-0.05	1.45	-0.05	-7.84	-0.32	0.02

Table 6: Average carry trade returns and factor betas by portfolio for Hypothesis 1. The betas are not individually significant, but the null hypothesis that they are equal across portfolios is rejected at the 1% level. Portfolio 8 represents the highest interest rate currencies.

Hypothesis 1 Factor Price Estimates by Home Country of Investor, 1952-2007, 16 Portfolios

	Japan	United Kingdom
VIX	1.41*(1.15)*	1.29*(1.12)*
Eq Ret$_{US}$	7.42***(3.21)*	7.35***(3.15)*
VIX*Eq Ret$_{US}$	193.96***(73.54)*	191.33***(72.30)*
StD(ER)	0.02*(0.02)*	0.02*(0.02)*
Eq Ret$_i$	3.21*(5.26)*	3.89*(5.09)*
VIX*Eq Ret$_i$	131.54*(105.64)*	137.13*(102.23)*
Constant	-0.75*(1.16)*	-0.58*(1.13)*
Betas Vary	<0.01	<0.01
R-Squared	61%	61%
Shanken Factor	1.45	1.42
Test FPs	0.03	0.04
Test Target Eq FPs	<0.01	0.02
Observations	826	826

Table 7: This table shows results for a Japanese and United Kingdom based investor. Returns are calculated in yen or pounds discounted with the appropriate consumer price index series. The Japanese or British T-bill return is subtracted from the raw carry trade return. United States equity returns are converted to the appropriate currency (yen or pounds), while target currency equity returns remain in domestic currency. The results appear broadly robust to the choice of investor's home country. The point estimates of the factor prices change considerably, however this is not surprising in an interaction effect model with high collinearity. More important is that the explanatory factors remain jointly significant. The row "Test Target Eq FPs" reports the p-value from a joint F-test of the target equity returns factor and its interaction with VIX, the S&P volatility index. The change in sign of the VIX factor price suggests that U.S. equity volatility may be less important for Japanese and U.K. investors than for U.S. investors.

Panel Corrected Standard Error Regressions of Equity Returns on Exchange Rate and T-Bill Returns

	Across Countries	Across Portfolios
Ex Rate Ret$_i$	-0.08*(0.09)*	-0.30****(0.11)*
T-Bill Ret$_i$	-0.09****(0.02)*	-0.14***(0.06)*
Constant	10.88****(0.94)*	9.85****(1.28)*
R-Squared	1.5%	5.6%
Observations	1024	263

Table 8: These regressions are intended as a descriptive statistical exercise. They suggest that the significance of target country equity returns for carry trade returns could derive jointly from correlation with exchange rate changes and with T-bill returns. The correlation with exchange rates could be due to inflation or international portfolio rebalancing in response to changing exchange rate risk. The correlation with T-bill returns could be due to portfolio rebalancing between debt and equities in response to changes in equity risk. The regressions are run over the period 1952-2007.

B Data Sample

Figure 1: The above figure shows years for which each country is included in a portfolio. Countries are indicated by their three letter ISO codes. Countries were excluded if data were unavailable, if the capital openness ratio was less than 20%, or if the country defaulted on government bonds in the previous year (the decision to invest and portfolio allocation are made at the end of year t, with the return realised at the end of year $t+1$). Defaults are indicated with a red X. Government bond default data are from Reinhart et al (2003) and Reinhart and Rogoff (2008).

B.1 Countries and ISO Codes

Angola (AGO), United Arab Emirates (ARE), Argentina (ARG), Australia (AUS), Austria (AUT), Belgium (BEL), Bangladesh (BGD), Bulgaria (BGR), Bahrain (BHR), Bolivia (BOL), Brazil (BRA), Barbados (BRB), Botswana (BWA), Canada (CAN), Switzerland (CHE), Chile (CHL), China (CHN), Cote d'Ivoire (CIV), Colombia (COL), Costa Rica (CRI), Cyprus (CYP), Czech Republic (CZE), Germany (DEU), Denmark (DNK), Ecuador (ECU), Egypt, Arab Rep. (EGY), Spain (ESP), Estonia (EST), Finland (FIN), France (FRA), United Kingdom (GBR), Ghana (GHA), Greece (GRC), Hong Kong (HKG), Honduras (HND), Croatia (HRV), Hungary (HUN), Indonesia (IDN), India (IND), Ireland (IRL), Iceland (ISL), Israel (ISR), Italy (ITA), Jamaica (JAM), Japan (JPN), Kazakhstan (KAZ), Kenya (KEN), Korea, Rep. (KOR), Kuwait (KWT), Lebanon (LBN), Sri Lanka (LKA), Lithuania (LTU), Latvia (LVA), Morocco (MAR), Mexico (MEX), TFYR Macedonia (MKD), Malta (MLT), Mauritius (MUS), Malaysia (MYS), Namibia (NAM), Nigeria (NGA), Netherlands (NLD), Norway (NOR), Nepal (NPL), New Zealand (NZL), Oman (OMN), Pakistan (PAK), Panama (PAN), Peru (PER), Philippines (PHL), Poland (POL), Portugal (PRT), Qatar (QAT), Romania (ROU), Russia (RUS), Singapore (SGP), El Salvador (SLV), Republic of Serbia (SRB), Slovakia (SVK), Slovenia (SVN), Sweden (SWE), Swaziland (SWZ), Thailand (THA), Trinidad and Tobago (TTO), Tunisia (TUN), Turkey (TUR), Taiwan (TWN), Ukraine (UKR), Uruguay (URY), United States (USA), Venezuela (VEN), Vietnam (VNM), South Africa (ZAF), Zambia (ZMB), Zimbabwe (ZWE)

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