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BEYOND THE FAMA REGRESSION

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ABSTRACT

We examine the factors that account for the returns on currency carry trade strategies. Using a dataset of daily returns spanning 18 years for 5 different long - short currency carry portfolios, we first document a robust empirical relationship between carry trade excess returns and exchange rate volatility, both realized and implied. Specifically, we extend and refine the results in Bhansali (2007) by documenting that currency carry trade strategies implemented with forward contracts have payoff and risk characteristics that are similar to those of currency option strategies that sell out of the money puts on high interest rates currencies. Both strategies have the feature of collecting premiums or carry to generate persistent excess returns that unwind sharply resulting in losses when actual and implied volatility rise.

We next also document significant volatility regime sensitivity for Fama regressions estimated over low and high volatility periods. Specifically we find that the well known result that a regression of the realized exchange rate depreciation on the lagged interest rate differential produces a negative slope coefficient (instead of unity as predicted by uncovered interest parity) is an artifact of the volatility regime: when volatility is in the top quartile, the Fama regression produces a positive coefficient that is greater than unity. The third section of the paper documents the existence of an intuitive and significant co-movement between currency risk premium and risk premia in yield curve factors that drive bond yields in the countries that comprise carry trade pairs. We show that yield curve level factors are positively correlated with carry trade excess returns while yield curve slope factors are negatively correlated with carry trade excess returns. Importantly, we show that this correlation is robust to the current crisis and to the inclusion of equity volatility in the model. What distinguishes carry trade returns in the current crisis from non crisis periods is not changed loading on yield curve factors but a much larger loading on the equity factor.

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1 Introduction

One of the enduring puzzles in international finance is the failure of uncovered interest parity (UIP). In a risk neutral world, the forward exchange rate should be an unbiased predictor of the future spot exchange rate. This prediction has been consistently rejected, starting with classic contributions by Meese and Rogoff (1981), Hansen and Hodrick (1981), Cumby and Obstfeld (1980), and most famously Fama (1984). Contrary to professional opinion at that time, the UIP puzzle has not been arbitraged away over time, nor has interest in it waned, as recent innovative papers by Burnside et. al. (2007) and Brunnermeier et. al. (2008) demonstrate.

Today, just as 25 years ago, papers continue to find that currencies in countries with high interest rates tend on average to appreciate relative to currencies in countries with low interest rates. This stylized fact constitutes the forward rate bias puzzle. The direct implication of the puzzle is that investors can make systematic profits by shorting the low yielding currency and taking a long position in the high yielding currency. This view is often expressed in terms of the apparent profitability of the carry trade, which has become a popular investment strategy in the asset management industry.

The key question is whether the excess returns associated with the carry trade can be justified by the economic risks associated with the strategy. Can the systematic excess return be rationalized in terms of a meaningful currency risk premium? More generally, are the excess return properties of FX rates consistent in a modern multi-country asset pricing framework? In this paper, we contribute to the literature on the carry trade and the forward exchange rate bias puzzle along several dimensions. First, we provide evidence that carry trade returns are strongly, systematically, and inversely related to both realized and actual exchange rate volatility. This is true for daily returns on a range of currency carry trade portfolios spanning 18 years, and, to a point, is robust to exclusion of the yen from the currency carry portfolio. Second, we document significant volatility regime sensitivity for Fama regressions estimated over low and high volatility periods. Specifically we find that the well known result that a regression of the realized exchange rate depreciation on the lagged interest rate differential produces a negative slope coefficient (instead of unity as predicted by uncovered interest parity) is an artifact of the volatility regime: when volatility is in the top quartile, the Fama regression produces a positive coefficient that is greater than unity. When volatility is high, UIP is violated but because low interest rate countries appreciate by more than the interest rate differential in favor of the high interest rate country. Third, we document the existence of an intuitive and significant co-movement between currency risk premium and risk premia in yield curve factors that drive bond yields in the countries that comprise carry trade pairs. Campbell and Clarida (1987) were among the first to model theoretically and empirically the joint determination of yield curve term premia and carry trade risk premia, but for a variety of reasons, since then the yield curve literature has, to some extent, become divorced from the currency risk premium literature[2].

We aim to rectify this divorce (amicably we hope!) by showing that yield curve level factors are positively correlated with carry trade excess returns while yield curve slope factors are negatively correlated with carry trade excess returns. Importantly, we show that this correlation is robust to the current crisis and to the inclusion of equity volatility in the model. What distinguishes carry trade returns in the current crisis from non crisis periods is not changed loading on yield curve factors but a much larger loading on the equity factor.

Our empirical investigation is related to those of Brunnermeier, Nagel & Pedersen (2008) and Ichiue & Koyama (2007). Brunnermeier et al. examines the relationship between volatility and FX returns and their conclusion is similar to ours. They also find that higher market volatility is associated with carry trade losses, whereas Ichiue & Koyama estimate regime-switching models for a select set of currency pairs. They find that two regimes are necessary to explain the currency carry trade strategy and these regimes appear consistent with the two sets of volatility dependent Fama-regression coefficients that we document in this paper. The empirical work in our paper significantly adds to these findings by showing their robustness across currency pairs and volatility measures.

[2] See however, Bekaert and Hodrick (2001) and Clarida, Sarno, Taylor, Valente (2002) for recent papers that study yield curves and currencies jointly.

Our findings are also related to a number of recent papers that have examined the risk return profile of the carry return strategy and explored underlying theoretical explanations. Backus, Foresi & Telmer (2001) derive restrictions on the pricing kernel between two countries that need to be satisfied for the forward exchange rate bias puzzle to be consistent with a two country exactly affine interest rate model. Bhansali (2007) is perhaps the most significant inspiration for our approach as it is this paper that clearly and directly focuses on the striking parallel between on currency carry trade strategies implemented with forward contracts and the payoff and risk characteristics of currency option strategies that sell out of the money puts on high interest rates currencies. Both strategies have the feature of collecting premiums or carry to generate persistent excess returns that unwind sharply resulting in losses when actual and implied volatility rise. A recent literature has given increased attention to the micro-structure of the currency market and the importance of the balance sheets of levered market participants. In Brunnermeier, Nagel & Pedersen (2008) levered market participants gradually build up positions in high yielding currencies causing the high yielding currencies to appreciate over time along with the speculators larger positions. The model is thereby consistent with a systematic violation of uncovered interest parity. Another key implication of their model is that FX movements are asymmetric, allowing them to focus on the skewness observed in the currency return data. Jurek (2008) uses options data and prices to show that crash risk in itself is unable to justify the expected return on the carry strategy; the costs of insuring the carry portfolio against major crashes of the carry currency only reduces excess returns by 30-40%.

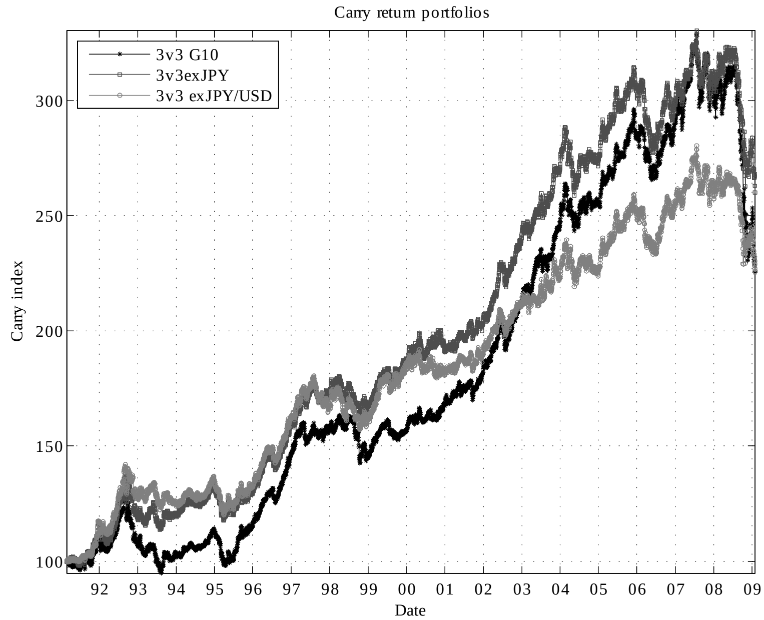


Figure (1a) shows the cumulative returns for the '3v3' carry portfolios.

2 Currency Carry Trade Returns and Exchange Rate Volatility

Our first dataset is from Bloomberg and contains realized carry returns on portfolios that invest in high yielding G10 currencies by borrowing in low yielding G10 currencies. Each of these portfolios is an equally weighted long/short basket. The distinguishing feature of each basket is the number and type of currencies included in the basket. For example, the single cross, 1 v 1, portfolio consists of a long position in the highest yielding currency at any given point in time and a short position in the lowest yielding currency. The 2 v 2 portfolio consists of equal weighted long positions in the two highest yielding currencies and short positions in the two lowest yielding currencies. The addition of another cross adds two more currencies, the long positions always being an equal weighted basket of the highest yielding currencies and the short positions taken in an equally weighted basket of lowest yielding currencies.

Table: Balanced G-10 Carry Trade Strategy

	All Currencies			Excl. JPY			Excl. JPY/USD		
	mean	vol	m/v	mean	vol	m/v	mean	vol	m/v
Time period 1990-2009									
Basket									
1	4.98	15.06	0.33	3.79	12.13	0.31	5.28	12.19	0.43
2	2.82	11.11	0.25	5.53	9.72	0.57	5.66	9.48	0.60
3	4.62	8.98	0.51	5.46	8.21	0.66	4.63	8.14	0.57
4	4.34	7.81	0.56	4.19	7.23	0.58	2.75	7.00	0.39
5	3.28	6.86	0.48	2.38	6.18	0.38			

Note: m/v is mean return divided by volatility

Table (1). Summary statistis for returns on five FX portfolios with and without USD and JPY.

Figure 1a displays the cumulative returns on portfolios that consist of three long FX positions and three short FX positions. The 3 v 3 portfolio is based on all G10 currencies, whereas the two other portfolios exclude respectively the JPY and the USD and JPY from the currency baskets. We do this because much of the existing carry trade evidence in the literature has been more or less exclusively derived from currency pairs involving either the US dollar or the Japanese yen. This is primarily because Japan has had one of the lowest interest rates in the world throughout the last 15-20 years, and the yen has therefore been included as the 'natural' choice of funding currency, whereas the dollar traditionally has been considered the benchmark investment currency. In our view it is nonetheless important to assess the forward bias anomaly in a broader light. Especially, because the dollar is 'different' from other G10 currencies in that it remains the global reserve and vehicle currency and therefore benefits from this status in flight to quality episodes (including the present).

It is evident from figure 1a, that currency carry trade strategies have provided positive returns on average over the sample period, but that there have been significant variation in the profitability of these strategies over time with several very large negative return 'events' during the course of the 18 year sample period. Some of the more dramatic changes in the carry returns or unwinds can be associated with specific and well-known crisis periods in the global economy such as the Asian Crisis, LTCM etc. The performance of the carry trade is further investigated in table 1, which shows overall summary statistics for the returns on all the strategies considered in this section. The table clearly shows, that there are diversification benefits from using more currencies in the carry trade portfolio. As the number of currencies in the portfolio baskets is increased the return volatility falls dramatically. At the same time, this diversification of risk across additional currencies in both the high yielding basket and the low yielding basket, invariable reduces the pure "carry" return component and this means that average returns tend to decline as more G10 currencies are included in the portfolio. For example, the 1 v 1 portfolio has a mean return of 5 percent whereas the mean return of the 5 v 5 portfolios is 3.3 percent.

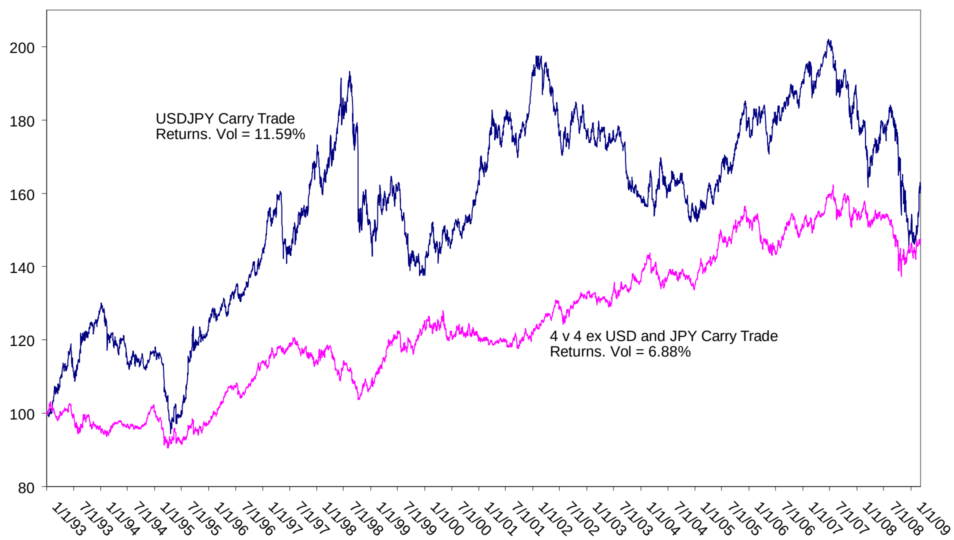


Figure 1b shows the returns of 4 v 4 against pure USD-JPY carry trade.

Overall, the returns to currency carry portfolios are positive with Sharpe ratios that are comparable or superior to those on equity investments (Burnside et. al.) with or without the inclusion of the yen or dollar.

The effects of including- or excluding JPY and USD in the set of currencies used in the carry strategy portfolios are interesting. Indeed from 1 v 1 through 3 v 3, the portfolios ex Japan and the US have higher mean returns and lower variance of returns. These differences are highlighted in figure 1b which shows the performance of the 4 v 4 strategy against the pure USD/JPY carry trade. A striking feature of the figure is that the short yen, long dollar trade has provided the same total return as 4 v 4 strategy over the sample period.

2.1 Volatility and carry trade returns

As a first illustration of the strong and robust relationship between carry returns and FX volatility, we examine the time series variation in realized carry return volatility and realized returns for the 3 v 3 portfolio. Let r_t be the carry return. We then define realized volatility, σ_t, and realized returns, μ_t, in the daily Bloomberg dataset as exponentially weighted moving averages (EWMA), such that,

$$\sigma_t = \frac{\sum_{i=0}^{T} \lambda^i \left(r_{t-i} - \overline{r}\right)^2}{\sum_{i=0}^{T} \lambda^i} \tag{1}$$

and

$$\mu_t = \frac{\sum \lambda^i r_{t-i}}{\sum_{i=0}^{T} \lambda^i} \tag{2}$$

We choose the exponential decay parameter λ to be 0.95 for the daily data series, which implies a half-life in the exponential weights of 14 days. In figure 2 we then relate the time series behavior of realized return volatility(in logs) to realized carry returns. To facilitate the comparison of the two series, we choose to Z-score both $\log(\sigma_t) = \sigma_{L,t}$ and μ_t and to depict the negative of the scaled volatility series. More precisely, we construct, the following series,

$$Z_\mu = \frac{\mu_t - \bar{\mu}}{s_\mu},\ s_\mu^2 = \frac{1}{N-1}\sum(\mu_t - \bar{\mu})^2 \tag{3}$$

$$Z_{\sigma_L} = \frac{\sigma_{L,t} - \bar{\sigma}_L}{s_{\sigma_L}},\ s_{\sigma_L}^2 = \frac{1}{N-1}\sum(\sigma_{L,t} - \bar{\sigma}_L)^2 \tag{4}$$

and we graph Z_μ against $-Z_{\sigma_L}$ for the 3 v 3 carry trade portfolio. These are therefore Z-scored with respect to the full sample moments. Figure (2) shows that the two scaled time series generally track each other closely over the full sample period. Overall, the correlation is 0.55, but the correlation actually increases over time and is 0.65 in the sub-sample period that starts in 1996. The implication of this co-movement is that when the carry returns are high, return volatilities are low and vice versa.

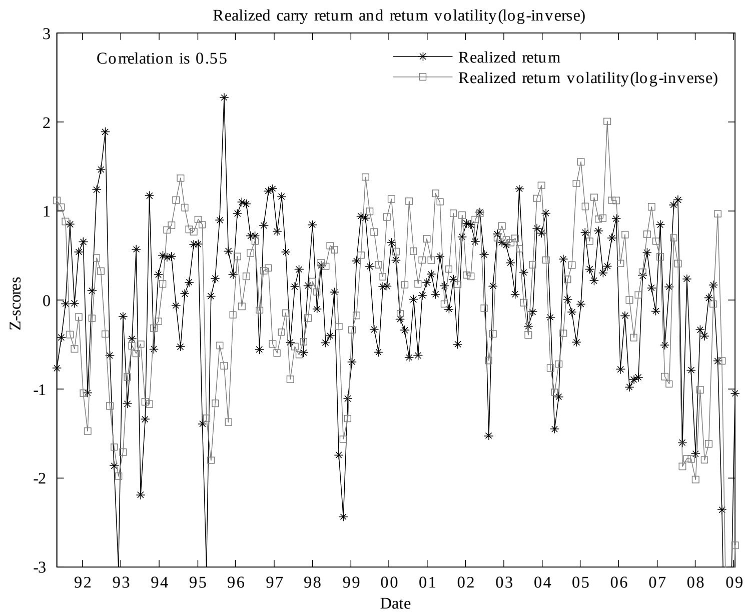


Figure (2) shows the relationship between realized return and realized FX-volatility for the '3v3' carry portfolio. Construction of series described in text.

Motivated by the apparent correlation between FX - volatility and returns on the carry strategy, we recompute the statistics from table 1, but divide the sample according to realized volatility. Specifically, we split the sample into two regimes; a 'high' volatility and 'low' volatility regime. These are defined in terms of the quartiles of the empirical distribution of volatility over the sample period. In particular, if realized volatility at time t is below the 25th percentile of the volatility distribution for the full sample, then period t is in a low- volatility regime. If realized volatility is above the 75th percentile, then period t is in a high volatility regime. In this way we assign one quarter of the days in the sample to the high volatility state and one quarter of the sample to the low volatility state. Table 2 shows the very strong dependency on carry returns on volatility. In the low volatility states, subsequent returns are much higher than in high volatility states. Indeed for both the 1 v 1.,.2 v 2.,3 v 3. portfolios the average carry return is negative in the high volatility regimes. We also experimented with changing the threshold levels of volatility that defines high and low volatility regimes and found the results to be consistent across a wide range of threshold levels. The results are in other words robust to changes in the threshold. For this reason, we keep the threshold fixed at the 25th/75th percentile throughout this paper.

Table: Balanced G-10 Carry Trade Strategy in high and low volatility states

	All Currencies			**Excl. JPY**			**Excl. JPY/USD**		
	mean	vol	m/v	mean	vol	m/v	mean	vol	m/v
High Volatility State									
(above 75th percentile)									
Basket									
1	-9.75	20.72	-0.47	-2.76	15.61	-0.18	1.14	16.00	0.07
2	-5.01	15.55	-0.32	-1.48	12.75	-0.12	2.30	12.24	0.19
3	-1.89	12.47	-0.15	3.46	10.76	0.32	4.72	10.17	0.46
4	3.37	10.72	0.31	1.26	9.31	0.14	-0.67	8.60	-0.08
5	2.34	9.15	0.26	0.35	7.79	0.04			
Low Volatility State									
(below 25th percentile)									
Basket									
1	13.61	10.25	1.33	2.87	7.59	0.38	6.85	7.54	0.91
2	6.06	7.45	0.81	8.41	6.82	1.23	6.40	6.78	0.94
3	6.52	6.21	1.05	6.39	6.00	1.07	3.42	6.11	0.56
4	5.76	5.27	1.09	6.97	5.30	1.32	7.23	5.39	1.34
5	5.97	4.76	1.25	4.13	4.51	0.92			

Note: m.v is mean divided by volatility

Table (2) reports summary statistics for the 5 FX portfolios for the sub samples split into high volatility and low volatility states. Daily data.

In fact the average return is minus 9.75 percent (annualized) for the quarter of the sample period that belong to the high volatility regime for the 1 v 1 portfolio. In contrast, the corresponding average return for the low volatility regime is 13.61

percent. In this particular case however, the inclusion/exclusion of JPY and USD from the currency universe is important. This reflects the large; rapid unwinds of the yen funded carry trade during several episodes. These unwinds can be clearly identified in figure (1b) above.

To be robust against model misspecification and potential non-linearities, we also estimate non-parametric relationships between realized volatility and FX returns using kernel regressions(see appendix for a description). We construct boot-strapped standard errors and associated confidence intervals by re-sampling from the distribution of residuals. The results are shown in figure (3) and confirms the empirical relationship between volatility and returns.

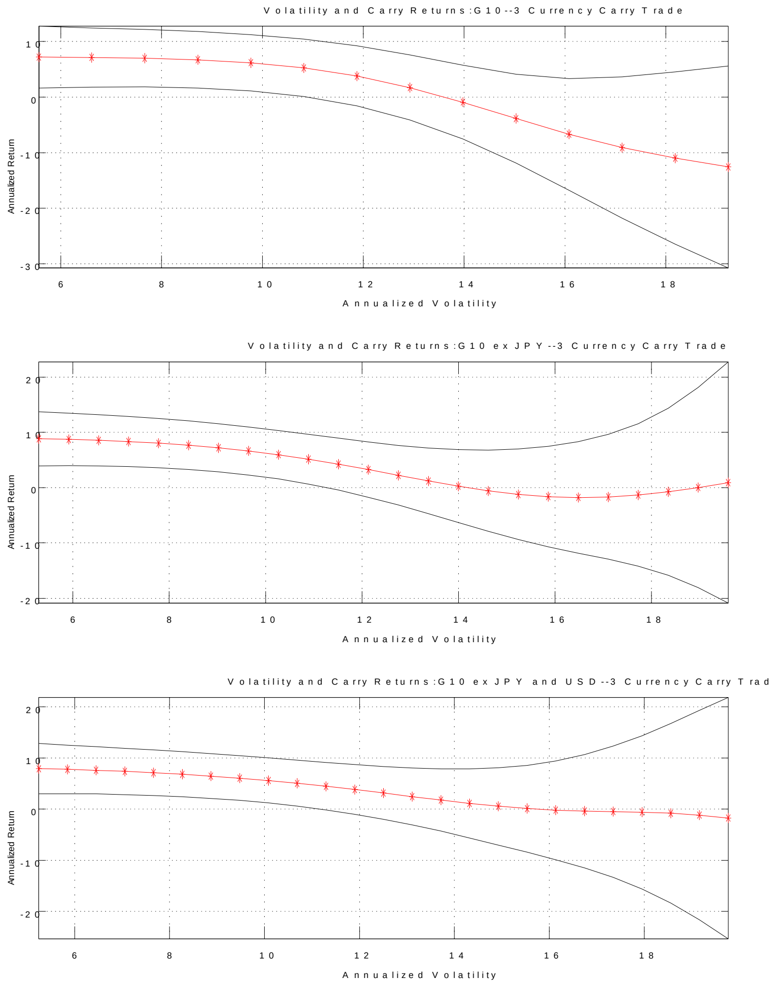


Figure (3) shows the relationship between return/FX-volatility and returns for the '3v3' carry portfolio. Non-parametric, kernel regression estimates.

We next investigate the link between carry trade returns and implied exchange rate volatility from option prices, using a dataset obtained from Citibank. This dataset contains spot rates, implied volatilities and traded option prices for at-the-money strikes with 1 month maturities on all G10 crosses against the USD daily from October 1 1996 to 14 January 2009. Using this dataset we can back out the implied interest rate differential from the current spot and negotiated strike (the forward rate) from these options using covered interest parity :

$$i_t^F - i_t^{US} = -(f_t - x_t) \tag{5}$$

where $i_t^F - i_t^{US}$ is the implied interest differential between the foreign country and the US, f_t is the (log) forward exchange rate and x_t is the (log) spot exchange rate in units of US currency pr. foreign currency.

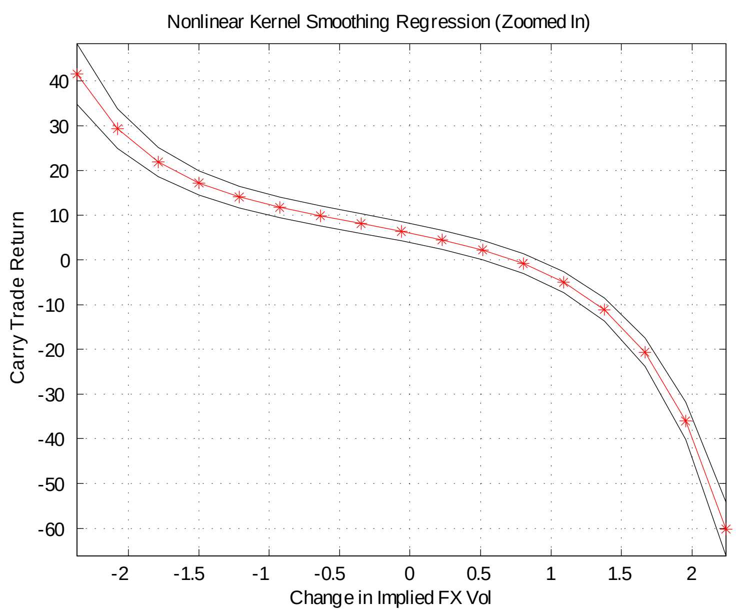


Figure 4: Panel kernel regression of realized carry returns on the change in implied volatilities.

The Citibank dataset suggests that there is a tight link between changes in Black-Scholes implied volatilities and average returns on the carry trade strategy. Increases in implied volatility lead, on average, to lower returns on the carry trade, with the kernel regression identifying a strong relationship as shown in figure (4). Likewise, in a nearly symmetric fashion, declines in implied volatility are associated with an appreciation of the high carry currency against the low carry currency. The figure leaves a striking impression as it highlights the way changes in forward looking volatilities from the option market are contemporaneously associated with returns from the carry trade.

We finally estimate exponential Garch models (Nelson (1991) of returns on carry trade baskets using weekly data, where the volatility of returns is dominated by exchange rate volatility. Specifically, we estimate models of the form,

$$r_t = \kappa + \beta r_{t-1} + \theta h_t + u_t \tag{6}$$

where r_t is the return on a basket of carry trades and h_t is the conditional variance of u_t based on $t-1$ information. We assume h_t obeys

$$\log h_t = c + a\left|u_{t-1}\right| h_{t-1}^{-1/2} + b \log h_{t-1} + d u_{t-1} h_{t-1}^{-1/2} \tag{7}$$

A special case is $d = 0$, in which case the model is symmetric. A value $d < 0$ implies that lagged negative returns on the carry trade are associated with a larger increase in conditional volatility than are lagged positive returns. The models are estimated with maximum likelihood for the 4 long v 4 short basket excluding the USD and JPY as well as for the USDJPY basket separately. We estimate both the symmetric version of the E-Garch model (with $d = 0$) as well as versions that allow for asymmetry. Motivated by our results for implied volatility, we also estimate a more general model that allows for *the change in conditional volatility* to be negatively correlated with carry trade returns.

$$r_t = \kappa + \beta r_{t-1} + \theta_1 h_t + \theta_2 h_{t-1} + u_t \tag{8}$$

The results are shown in Table (2b) on the next page, and they provide a compelling confirmation of our findings above. An increase in the conditional volatility of exchange rates (based on time t -1 information) in the basket is associated with a decline in the expected return on the carry trade. Moreover, we can't reject the hypothesis that $-\theta_1 = \theta_2$, so it is the *change in conditional volatility* that accounts for the predictable component of carry trade returns.

E-Garch models of carry portfolios Period 1993-2009, weekly data	**Four vs Four Portfolio**			**Japanese Yen vs US dollar**		
Level specification	**coefficient**	**std.error**	**t-stat**	**coefficient**	**std.error**	**t-stat**
Symmetric model						
Constant	-0.020	0.002	-10.676	-0.004	0.013	-0.270
FVF{1}	-0.094	0.035	-2.673	-0.020	0.036	-0.565
GARCH-V	-0.002	0.000	-11.272	-0.001	0.002	-0.328
C	-1.509	0.703	-2.147	-0.300	0.102	-2.949
A	0.151	0.052	2.897	0.129	0.032	4.046
B	0.851	0.073	11.668	0.976	0.011	90.114
Asymmetric model						
Constant	-0.064	0.000	-245.588	-0.004	0.000	-15.653
FVF{1}	-0.140	0.034	-4.086	-0.022	0.034	-0.626
GARCH-V	-0.007	0.000	-19656.504	-0.001	0.000	-16.706
C	-3.530	0.005	-754.653	-0.309	0.002	-144.017
A	0.116	0.024	4.922	0.129	0.026	4.980
B	0.632	0.001	1071.148	0.974	0.002	449.346
D	-0.055	0.029	-1.895	-0.008	0.016	-0.495
Dynamic specification	**coefficient**	**std.error**	**t-stat**	**coefficient**	**std.error**	**t-stat**
Symmetric model						
Constant	-0.014	0.009	-1.618	-0.001	0.010	-0.151
FVF{1}	-0.090	0.035	-2.552	-0.030	0.023	-1.277
GARCH-V	-0.003	0.002	-1.562	-0.009	0.002	-4.736
GARCH-V{1}	0.001	0.001	1.424	0.008	0.001	12.337
C	-2.284	0.022	-101.854	-0.286	0.101	-2.835
A	0.179	0.052	3.419	0.127	0.030	4.200
B	0.770	0.002	360.551	0.977	0.011	89.702
Asymmetric model						
Constant	-0.018	0.007	-2.563	-0.002	0.014	-0.161
FVF{1}	-0.323	0.056	-5.783	-0.025	0.035	-0.704
GARCH-V	-0.031	0.003	-11.347	-0.003	0.001	-2.384
GARCH-V{1}	0.029	0.003	8.296	0.003	0.000	6.956
C	-0.692	0.073	-9.453	-0.306	0.128	-2.395
A	0.031	0.013	2.325	0.130	0.031	4.182
B	0.929	0.008	114.802	0.975	0.014	70.397
D	-0.068	0.016	-4.199	-0.008	0.018	-0.438

Table (2b) shows relationship between E-Garch estimates of volatility and returns to carry trade

Table: Fama Regressions for 3v3 baskets of high and low yielding currencies			
Time period 1991-2009	**Low Volatility**	**High Volatility**	**All**
Constant	0.19	-0.08	0.12
std. error	0.38	0.27	0.27
Coefficient on forward premium(b)	-3.29	2.73	-1.21
std. error	4.31	2.41	2.92
R-square	0.00	0.01	0.00

Note: Low volatility states are below 25th percentile. High volatility states above the 75th percentile

Table (3) reports Fama-regression results for low and high volatility states for 1 month holding period conditional on realized volatility regime. For the '3 v 3' carry trade portfolio.

3 Revisiting the Fama Regression

The most popular method to assess whether uncovered interest parity holds has been to estimate the following regression,

$$\Delta x_{t+1} = \alpha + \beta f_t^H + \varepsilon_t = \alpha + \beta(i_t^H - i_t^L) + \varepsilon_t \tag{9}$$

Again x_t, is the log of the spot exchange rate. UIP or no forward bias implies that $\beta = 1$. As reported by Froot (1992) and confirmed by Burnside et. al. (2007) the average estimate for β is -0.85 across the countless studies that focus on this equation. It is therefore useful to restate our findings in the context of this regression. We then run one-month versions of regression (3) for these two subsamples as well as the full sample. The results are reported in Table 3. As implied by the equal weighted portfolios we use in this section, the average yield difference across the 3 v 3 portfolio is used in place of the interest differential; and the equal weighted depreciation of the high yielding basket against the currencies in the low yielding basket is used. Inspection of Table 3 reveals that the estimated coefficient on the interest differential changes from being significant and very negative for the low volatility state to significant and very positive in the high volatility state. In accordance with the previous studies the sign for the whole sample period is negative.

These results are consistent with the analysis above. The negative estimate for β in low volatility environments implies enhanced returns from carry strategies in low volatility states, whereas the positive coefficient in high volatility environments is consistent with potentially very negative returns to the carry trade in high volatility states.

Table: Fama regression for FX pairs against the US Dollar.

	Slope			Constant		
	All	Low vol.	High vol.	All	Low vol.	High vol.
AUD	**-1.40**	**-7.12**	**5.65**	**-0.001**	**0.000**	**0.000**
	2.69	4.09	6.89	**0.001**	**0.004**	0.002
CAD	**-1.14**	**-0.72**	**-2.39**	**0.001**	**0.002**	**-0.001**
	2.98	4.84	11.40	**-0.002**	**0.000**	0.001
CHF	**-2.78**	**-3.84**	**3.55**	**0.001**	**0.000**	**-0.004**
	2.56	4.64	6.22	**0.001**	**0.002**	0.003
EUR	**-3.07**	**-2.81**	**-1.13**	**0.001**	**0.003**	**0.003**
	2.17	3.49	5.27	**-0.002**	**-0.001**	0.001
GBP	**0.87**	**-0.44**	**6.50**	**0.000**	**-0.002**	**0.001**
	2.49	3.68	6.60	**0.001**	**0.003**	0.001
JPY	**-2.56**	**-1.21**	**-1.34**	**0.002**	**0.004**	**-0.001**
	1.89	3.39	4.66	**0.000**	**0.002**	0.003
NOK	**0.43**	**-1.67**	**11.27**	**0.000**	**0.000**	**-0.002**
	1.59	2.21	6.46	**0.000**	**0.000**	0.001
NZD	**-1.52**	**-9.21**	**1.72**	**0.000**	**0.000**	**-0.004**
	2.54	5.26	6.18	**0.000**	**0.000**	0.004
SEK	**-1.52**	**-2.46**	**5.33**	**0.000**	**0.000**	**-0.002**
	1.79	3.24	5.06	**0.000**	**0.000**	0.001

Note: Table reports coefficient on forward premium and standard error

Table 4. Fama Regression for 1 month holding period conditional on implied 1 month volatility. Low volatility regime is 25th percentile. High volatility regime is 75th percentile.

Next we look at the Fama regression conditioning on the level of implied volatility in each of the G10 currency crosses with the dollar, using the matched dataset of carry returns and implied ATM 1 month volatility from Citigroup. We regress 1 month log changes in spot rate on the lagged 1 month interest rate differential. The low volatility regime is defined as any period where implied volatility from options are below their 25th percentile as measured over the whole sample for each particular cross. Similarly, the high volatility regime is defined by being above the 75th percentile. The Fama regression results are consistent with those documented from the Bloomberg dataset using realized volatility. The unconditional regression displays a clear violation of UIP. In accordance with the $\beta-$estimates obtained in the previous section that were based on realized volatility, these coefficients show a clear pattern when conditioning on the level of implied volatility. In low volatility environments the high yielding currency tends to appreciate, resulting in a large violation of UIP during low volatility episodes and large profits to the carry trade. In high volatility environments the low yielding currency tends to appreciate much more than implied by uncovered interest parity(coefficient far greater than 1) causing large negative returns to the carry trade strategy as the short position in the low yielding currency result in losses.

4 Empirical Relationship between Currency and Yield Curve Factors: Interpreting the Current Financial Crisis

We have already established that FX volatility is a major determinant of carry returns. In this section we relate currency carry returns to movements in key risk factors that have been found to be important in pricing yield curves and credit spreads. Toward this end, we examine simple, reduced form regression models on the form,

$$return_t = (i^H - i^L) + \sum_{s=1}^{K} \beta_s \Delta f_{st} + \varepsilon_t \tag{10}$$

where f is a vector of risk factors and $\beta's$ are loadings on these risk factors, that may vary over time or over different regimes. To anticipate our main results, we document the existence of an intuitive and significant co-movement between currency risk premium and the 'level' and 'slope' factors that drive bond yields in the countries that comprise carry trade pairs. Campbell and Clarida (1987) were among the first to model theoretically and empirically the joint determination of yield curve term premia and carry trade risk premia, but for a variety of reasons, since then the yield curve literature has increasingly become divorced from the currency risk premium literature. We aim for a reconciliation and indeed are able to show that relative yield curve level factors are positively correlated with carry trade excess returns while relative yield curve slope factors are negatively correlated with carry trade excess returns. Moreover, we show that this correlation is robust to the current crisis and to the inclusion of equity volatility in the model. What distinguishes carry trade returns in the current crisis from non crisis periods is not changed loading on yield curve factors but a much larger loading on the equity factor. It should be explicitly noted, that we do not attempt to separate movements in yields due to time varying risk premium from pure expectations components of the changes in yields in the present analysis. There is no question that this is highly desirable from a theoretical point of view and it is an important task for future work. However, we simply view our results as an encouraging starting point for such further work on a full fledged estimation/formulation of a structural asset pricing model that generates an internally consistent, joint process for endogenous currency- and yield curve excess returns.

Table: Local(fx pair) factors and exchange rate movements

Dependent variable is currency carry trade returns. Weekly data.

Bond factors and equity returns	JPYUSD	CHFUSD	JPYNZD	CHFNZD	JPYAUD	CHFAUD	All
1: July 1997-Decemvber 1998							
VIX(percent)	-0.43	**-2.44**	**-1.66**	**-2.34**	-1.52	**-2.76**	**-2.07**
t-stat	-0.39	-4.06	-1.79	-2.78	-1.50	-3.31	-5.68
Yield Curve Levels	-0.37	-0.16	0.78	-0.15	0.39	-0.75	-0.15
t-stat	-0.36	-0.26	1.15	-0.22	0.50	-1.16	-0.49
Yield Curve Slopes	**-2.67**	-0.82	0.85	**1.55**	-0.25	**2.31**	**0.68**
t-stat	-1.74	-0.92	1.15	2.37	-0.24	2.54	1.88
R-square	0.05	0.16	0.07	0.19	0.03	0.20	0.06
2: July 2007-Now							
VIX(percent)	**-2.66**	0.50	**-8.34**	**-5.51**	**-7.55**	**-5.68**	**-4.10**
t-stat	-4.25	0.78	-7.00	-6.39	-6.68	-6.70	-14.58
Yield Curve Levels	**2.91**	**4.11**	**2.85**	1.16	**9.11**	**6.27**	**1.70**
t-stat	4.48	5.18	2.03	1.21	6.54	5.41	6.22
Yield Curve Slopes	**-1.73**	**-1.64**	**-3.91**	**-1.82**	**-3.55**	**-2.51**	**-1.13**
t-stat	-2.38	-2.51	-2.36	-1.60	-3.34	-2.87	-3.83
R-square	0.46	0.26	0.49	0.37	0.64	0.54	0.20
3: Non-Crisis Periods							
VIX(percent)	**-0.64**	**-1.09**	**-1.69**	**-2.13**	**-1.54**	**-2.15**	**-2.51**
t-stat	-2.02	-3.46	-4.23	-5.79	-4.31	-6.63	-18.71
Yield Curve Levels	**1.20**	**1.30**	**1.59**	**1.07**	**2.02**	**1.80**	**1.60**
t-stat	4.37	3.54	3.81	2.44	6.54	5.27	12.15
Yield Curve Slope	**-0.79**	**-1.44**	-0.61	**-0.74**	**-1.43**	**-1.37**	**-1.15**
t-stat	-1.98	-3.49	-1.23	-1.69	-3.40	-3.57	-7.52
R-square	0.06	0.07	0.08	0.08	0.14	0.15	0.13

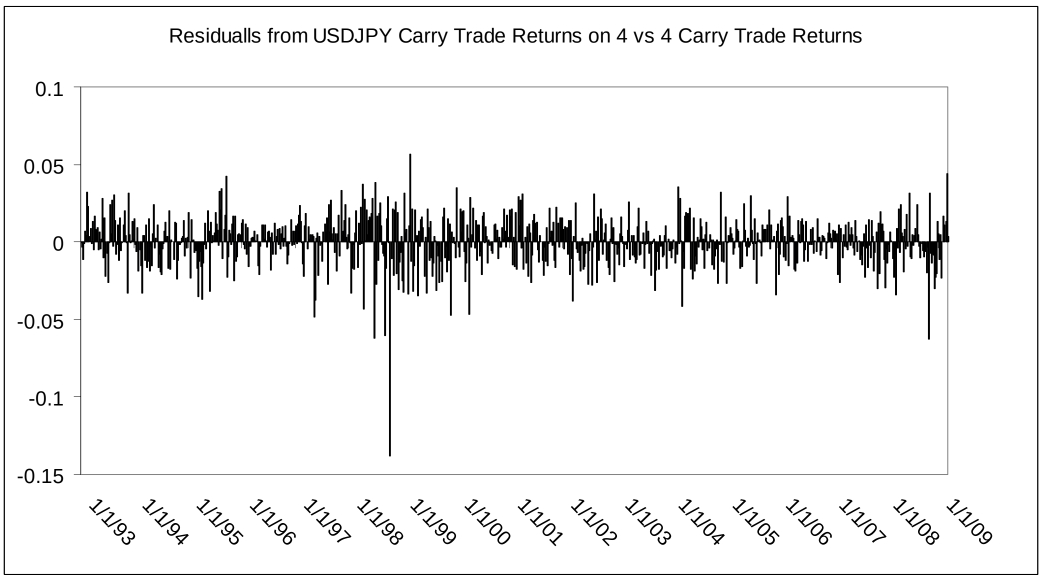
Note: VIX is percentage change in the US implied volatility index. 'Yield Curve Levels" and "Yield Curve Slopes" refers to relative change in levels and slopes in high yield currency country relative to low yield currency. Level is defined as the 10 year treasury yield and slope is defined as 10 year minus 2 year treasury yield.

Since our ultimate goal is to relate carry returns to movements in yield curves and general risk premia, we choose to include the VIX, the respective yield curve slopes and the yield curve levels in the regression. The VIX is often used as a measure of global investors risk aversion and has been shown in a number of studies to be an observable proxy for an important factor that drives investment grade credit spreads and EM debt returns. Table (5) compares the loadings on the three sets of risk factors in the current crisis with the loadings obtained for the 1997-1998 period as well as the period in between 1999 and 2007.

5 Yield Curve, Equity Factors and Realized Returns to Carry Trades

Several conclusions seem to be warranted based on the empirical evidence presented in Table (5). First, when we compare the non-crisis period and the latest episode, we observe that the loadings on the relative yield curve factors as well as the VIX remain significant across the board with the same respective signs, but also that the loadings increased dramatically for the VIX in the crisis period, while the loading on the yield curve factors are little affected. The VIX has a significantly negative coefficient in the regression, which implies that a spike in the VIX tends to be associated with depreciation of the high yielding currency and a lower carry return. An increase in the 'level' factor in the high interest rate country relative to the level factor in the low interest rate country is positively correlated with carry trade returns within the same week. This has an intuitive interpretation. Research has shown the level factor to be a proxy for persistent movements in real interest rates and/ or inflation (depending on the sample period) which result in parallel shifts in the yield curve. When expectation of inflation rise, a credible inflation targeting central bank will be expected to raise the time path of short term interest rates, shifting up the entire yield curve and also, as shown in Clarida, Gali, Gertler (2002) and Clarida and Waldman (2008) appreciating the nominal exchange rate. By contrast, an increase in the slope factor in the high interest rate country relative to the slope factor in the low interest rate country is negatively correlated with carry trade returns within the same week. This again has an intuitive interpretation. Research has shown the slope factor to be a proxy for the business cycle , with the yield curve getting steeper (because of an easing of monetary policy) during an expected economic contraction and with the yield curve getting flatter (because of a tightening of monetary policy) in an expected economic expansion.

Note that the 1997-98 crisis period that encompasses the global turmoil that followed in the wake of the Asian financial crisis as well as the Long Term Capital Management meltdown, looks very different from both the full sample and the most recent crisis. It is not possible to span the returns during the 97-98 crisis with the same risk factors that seems to 'drive' the behavior of the exchange rate in the current crisis.



As another way to assess the current crisis in light of previous unwinds of the currency carry trades, we regress the returns on the yen dollar carry trade against the returns on 4 long 4 short portfolio excluding the yen and the dollar. From Figure 1(b) we see that in both magnitude and timing, the current unwind of the yen/dollar carry trade is very typical of previous unwinds in 1994, 1998, and 2002. Regression results confirm that this episode is not statistically unusual conditional on the realized returns on from a carry trade basket that excludes the yen and the dollar. Figure 5 plots the residuals from a regression of realized weekly returns on the yen/dollar carry trade on realized returns on the 4 v 4 basket excluding the yen and dollar. The correlation in weekly returns is 0.27 and the slope coefficient is 0.46 with a highly significant t-statistic of 8.14.

We end this section by pointing to a couple of potential caveats in the part of our analysis that pertains to the most recent episode in 2007-2008. Baba & Packer (2008) document significant deviations from covered interest parity in the recent crisis period. These deviations imply that the one-to-one correspondence between forward premia- and interest rate differentials broke down, yet we use these interchangeable in our paper. Similarly there is empirical evidence of under-reporting of US Libor rates which may also affect our results. We acknowledge that these issues might raise some concerns about the robustness of the findings in this section, but have not explored this further.

6 Concluding Remarks

In this paper we have examined the factors that can account for the returns on currency carry trade strategies. Drawing on previous work by Bhansali (2007) we documented a robust empirical relationship between carry trade excess returns and exchange rate volatility, both realized and implied, and showed this result is robust to exclusion of the yen which for virtually our entire 18 year sample has been a funding currency for carry trade strategies. We next documented significant volatility regime sensitivity for Fama regressions estimated over low and high volatility periods. Specifically we found that the well known result that a regression of the realized exchange rate depreciation on the lagged interest rate differential produces a negative slope coefficient (instead of unity as predicted by uncovered interest parity) is an artifact of the volatility regime: when volatility is in the top quartile, the Fama regression produces a positive coefficient that is greater than unity. The third section of the paper documented the existence of an intuitive and significant co-movement between currency risk premium and risk premia in yield curve factors that drive bond yields in the countries that comprise carry trade pairs. We showed that yield curve level factors are positively correlated with carry trade excess returns while yield curve slope factors are negatively correlated with carry trade excess returns. Importantly, we show that this correlation is robust to the current crisis and to the inclusion of equity volatility in the model. What distinguishes carry trade returns in the current crisis from non crisis periods is not changed loading on yield curve factors but a much larger loading on the equity factor.

Our future research agenda is focused on developing an asset pricing model that can account for these results. More broadly, we believe that too much attention has been devoted to the fact that carry trade returns are difficult to relate to observed macro factors like consumption growth or Fama – French equity factors. While this may be true, it is potentially misleading because it ignores the fact that currency carry returns are related(and robustly so) to yield curve factors which in turn do have an intuitive macro economic interpretation in terms of modern monetary policy and exchange rate research. Finally, given the widespread finding that US equity volatility is a proxy for an important factor in pricing not only equities, but also investment grade bonds and emerging market credits, the tight link we find between carry returns and the VIX is also supportive of a fundamental explanation for currency risk premia.

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8 Appendix. Kernel Smoothing Regression

In a nonparametric regression, the conditional expectation of a variable Y relative to a variable X may be written

$$E[Y|X] = m(X)$$

The Nadaraya (1964) and Watson (1964) approach is to estimate m as a locally weighted average using the kernel K as a weighting function

$$\widehat{m}(x) = \frac{\sum_{i=1}^{n} K_h(x - X_i) Y_i}{\sum_{i=1}^{n} K_h(x - X_i)}$$

where K is the Gaussian kernel

$$K_h(x - X_i) = \frac{\exp\left(-\left(\frac{x-X_i}{h}\right)^2/2\right)}{\sqrt{2\pi}}$$

and h is the optimal bandwidth suggested by Bowman and Azzalini (1997). The standard errors are obtained via bootstrap as follows. First we back out the implied nonparametric residual for each of our observations

$$u_i = Y_i - E[Y|X_i]$$

Then we construct a set of pseudo-observations as follows

$$\widetilde{Y}_i = \widehat{m}(X_i) + \widetilde{u}$$

where $\widetilde{u}$ is a randomly drawn member from the set of regression residuals u_i. Based on these new observations we calculate another estimator of the mean $\widetilde{m}(X_i)$. The standard error is then simply the sample standard deviation of these resampled mean statistics.