A Work Project, presented as part of the requirements for the Award of an International Master Degree in Finance from the NOVA – School of Business and Economics and INSPER.

CARRY TRADE RETURNS AND FOREIGN EXCHANGE RATE RISK

EMERSON MARQUES DA SILVA - 3129

A Project carried out on the International Master in Finance Program at Nova School of Business & Economics, under the supervision of Professor Dr. André Silva, and on the Master in Economics and Finance at INSPER under supervision of Professor. Dr. Marco Lyrio

MAY 26th, 2017

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Abstract

This paper analyses whether foreign exchange risk measures and its components have the ability to predict the return to the carry trade strategy. We employ a dynamic portfolio composed of 20 currencies. We first show that carry trade returns are related to the total variance of our portfolio of currencies. We then decompose the total variance of this portfolio in a component representing the average variance of this portfolio and another representing its average correlation. Since average correlation is not significantly related to carry trade returns, the predictive power of market variance is primarily attributable to average variance.

Keywords: carry trade, average variance, average correlation, quantile regression.

1. Introduction

The carry trade is a currency trading strategy that recommends borrowing in low-interest currencies and investing in high-interest currencies. This strategy exploits deviations from the Uncovered Interest Rate Parity (UIP). UIP implies that the expected carry trade return should be equal to zero. This is the case since the interest rate differential would on average be offset by a depreciation of the investment currency. There are a number of empirical evidences pointing to the rejection of the UIP (e.g., Bilson, 1981; Fama, 1984). If this is indeed the case, investors can expect to make a profit with the carry trade strategy since it is expected that the investing currency will depreciate less that what is predicted by the UIP. Since we assume that Covered Interest Rate Parity (CIP) holds, this empirical evidence is called the forward premium puzzle.

The natural interpretation for a high average payoff to the carry trade strategy is that it compensates agents for bearing risk. The analysis of the intertemporal tradeoff between currency risk and carry trade return has four objectives. The first objective is to evaluate if current portfolio volatility can predict future carry trade return. The second objective is to assess the predictive ability of exchange rate risk on the distribution of carry trade returns using quantile regressions. The changes in exchange rate risk are related to gains or losses with carry trade that are in the right tail or left tail of the return distribution, respectively. The third objective is to define a group of currency risk measures that explains the movements in aggregate volatility and correlation. The forth objective is to evaluate the economic gains of the analysis through a version of carry trade strategy that is conditioned by risk measures. This paper analyses these points for different portfolios.

2. Theoretical Motivation

Merton (1973, 1980) suggests that there is a linear relation between the expected excess return of a risky market portfolio and the conditional market variance. According to Merton (1973, 1980), risk-averse investors require a higher risk premium to hold aggregate wealth as systematic risk increases, so the expected return must rise. The empirical evidence of the sign and statistical significance of the intertemporal risk-return tradeoff in equity markets is inconclusive. This relation has been found insignificant and sometimes even negative (e.g., French et al., 1987; Goyal and Santa Clara, 2003). The Intertemporal Capital Asset Pricing Model (ICAPM) can be applied to the currency market as any risky asset in any market. Thus, the intertemporal risk return tradeoff of the carry trade can be expressed by:

$$r_{C,t+1} = \mu + kMV_t + \varepsilon_{t+1}, \tag{1}$$

where $r_{C,t+1}$ is the portfolio excess return of the *carry trade* from time t to $t+1$; MV_t is the conditional variance of the currency portfolio return at time t, denominated FX portfolio variance; and ε_{t+1} is the normally distributed error term at time $t+1$.

Equation (1) indicates a linear relation between the FX portfolio variance and future excess returns. The coefficient k represents the investors' risk aversion and the natural interpretation is that is positive, that is, as the risk increases, the risk-averse investor requires a higher risk premium and higher expected return.

Pollet and Wilson (2010) show that the variance can be decomposed in average variance and average correlation for equity returns. This decomposition is critical for determining whether the potential predictive ability of the market variance is due to movements in average variance or average correlation. Thus, the variance decomposition can be expressed by:

$$MV_t = \varphi_0 + \varphi_1 AV_t + \varphi_2 AC_t \, , \qquad (2)$$

where MV_t is the conditional variance of the currency portfolio return at time t, denominated FX portfolio variance; AV_t is the equally weighted cross-sectional average of the variances of all exchange rate excess returns at time t; AC_t is the equally weighted cross-sectional average of the correlation of each pair of all exchange rate excess returns at time t.

Equation (2) indicates a linear relation between FX portfolio variance and average variance and average correlation. Pollet and Wilson (2010) show that this relation is positive for average variance and average correlation ($\phi_1,\phi_2 > 0$). Thus, we have the following hypothesis.

Hypothesis 1: The FX portfolio variance is a predictor of future FX excess returns due to two components: average variance and average correlation.

Furthermore, this paper analyses if there is an intertemporal risk-return tradeoff of carry trade by quantile of the distribution. The functions conditioned to quantile τ implied by equations (1) and (2) are defined as:

$$Q_{r_{C,t+1}}(\tau \mid MV_t) = \mu + (k + Q_\tau^N) + (k + Q_\tau^N)\, MV_t$$

$$= \alpha(\tau) + \beta(\tau)\, MV_t\,, \tag{3}$$

$$Q_{r_{C,t+1}}(\tau \mid AV_t, AC_t) = \mu + \varphi_0(k + Q_\tau^N) + (k + Q_\tau^N)\varphi_1 AV_t + (k + Q_\tau^N)\varphi_2 AC_t$$

$$= \alpha(\tau) + \beta_1(\tau) AV_t + \beta_2(\tau) AC_t\,, \tag{4}$$

where Q_τ^N is the τ-th quantile of the distribution, which has a large negative value deep in the left tail and a large positive value deep in the right tail. As k>0 and $\phi_1, \phi_2 > 0$, it is expected that the risk measures have negative coefficients in the left tail and positive coefficients in the right tail.

In high volatility periods, the shocks (resulting in losses) are amplified when investors hit cash constraints and unwind their positions, which further depress prices and increase the cash problems and volatility. According to Cenedese, Sarno and Tsiakas (2014) this asymmetric effect indicates that volatility is negatively related to carry trade returns and high volatility has more effect on the left tail of the distribution of returns. Thus, we have the following hypothesis.

Hypothesis 2: The predictive power of risk measures (FX portfolio variance, average variance and average correlation) varies between quantile of the distribution of FX excess returns, and is strongly negative in the lower quantile.

3. Data sets

All currencies are quoted in amounts of domestic currency (US dollar) per unit of foreign currency. We use two data sets: one including spot exchange rates and the other forward exchange rates. The period of the data sets is from Feb-1999 to Jul-2016 and the data sets were collected from Bloomberg. The first data set includes 20 countries in advanced and emerging market economies. The second data set is formed by the 10 developed economies of the total data set: Australia, Canada, Denmark, Euro area, Japan, New Zealand, Norway, Sweden, Switzerland and United Kingdom. The third data set contains the remaining 10 emerging market economies: Brazil, Colombia, Czech Republic, Mexico, Philippines, Poland, Singapore, South Africa, Taiwan and Thailand. The first 3 years of the data set were used to make the first set to augmented strategies. So, the statistics and graphics comparing standard carry trade with augmented carry trade strategies start in Feb-2002.

4. Methodology

a) Carry trade for individual currencies

The carry trade strategy for individual currencies can be implemented in two ways. In the first, the investor takes a long position in a forward contract today in order to exchange the domestic currency into foreign currency in the future. The payoff of the forward contract can be converted into the domestic currency at the future spot exchange rate. The excess return to this strategy is defined as:

$$r_{j,t+1} = s_{j,t+1} - f_{j,t} \tag{5}$$

for $j=\{1,2,...,N\}$ where N is the number of currencies at time t; $r_{j,t+1}$ is the excess return of currency j for one-period; $s_{j,t+1}$ is the log of the nominal spot exchange rate defined as the domestic price of foreign currency j at time $t+1$; $f_{j,t}$ is the log of the one-period forward exchange rate *j* at time *t*, which is the rate established in the contract at time *t* for an exchange of currencies at *t+1*. A depreciation of the domestic currency (US dollar) is an increase in $s_{j,t+1}$.

In the second form of the carry trade strategy, the investor buys a foreign bond and sells a domestic bond at the same time. Both bonds are risk free in their currencies but the investor is exposed to FX risk in the foreign bond. The excess return to this strategy is defined as:

$$r_{j,t+1} = i^*_{j,t} - i_t + s_{j,t+1} - s_{j,t} , \quad (6)$$

where i_t and $i_{j,t}^*$ are the one-period domestic and foreign nominal interest rates, respectively.

According to the Covered Interest Rate Parity (CIP), in the absence of arbitrage, the following condition must apply:

$$f_{j,t} - s_{j,t} = i_t - i^*_{j,t} . \quad (7)$$

If UIP holds, on average, the excess return on the two forms will be equal to zero, so the carry trade strategy is not profitable. That is, the interest rate differential is on average offset by a depreciation of the invested currency. So, the *forward premium* ($f_{j,t} - s_{j,t}$) should be equal to the interest rate differential.

b) Portfolio of Currencies

All currencies are sorted according to the forward premium value ($f_{j,t} - s_{j,t}$) at the beginning of each month. IF CIP holds, the currencies are sorted from low to high forward premium, which is equivalent to sort from the low to high interest rate differential. The sample is divided into 5 portfolios (quintiles) each month. Portfolio 1 is the portfolio with the highest interest rate currencies and portfolio 5 is the portfolio with the lowest interest rate currencies. The carry trade portfolio goes long on portfolio 1 and short on portfolio 5. The carry trade portfolio monthly return from time t to $t+1$ is defined as $r_{C,t+1}$.

c) FX Portfolio Variance

The excess return to the FX portfolio is the equally weighted excess return of all currencies of the data set.

$$r_{P,t+1} = \frac{1}{N_t}\sum_{j=1}^{N_t} r_{j,t+1} \,. \tag{8}$$

The monthly MV is estimated using daily excess returns according to the following equation:

$$MV_{t+1} = \sum_{d=1}^{D_t} r_{P,t+d/D_t}^2 + 2\sum_{d=2}^{D_t} r_{P,t+d/D_t}\; r_{P,t+(d-1)/D_t} \,, \tag{9}$$

where D_t is the number of trading days in month t, typically $D_t = 21$. The sample mean is not subtracted from each daily return in calculating the variance because this adjustment is very small (Merton, 1980).

d) Average Variance and Average Correlation

The general formula of portfolio variance is:

$$\sigma_p^2 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j Cov\left(r_i, r_j\right) . \tag{10}$$

Considering the naive diversification strategy in which an equally weighted portfolio is constructed, meaning that $w_i = 1/n$. We break out the terms for which $i=j$ into a separate sum and we consider that $Cov(r_i,r_i)=\sigma_i^2$, so the eq. 10 may be rewritten as follows:

$$\sigma_p^2 = \frac{1}{n}\sum_{i=j}^{n}\frac{1}{n}\sigma_i^2 + \sum_{\substack{j=1 \\ j\neq i}}^{n}\sum_{i=1}^{n}\frac{1}{n^2} Cov\left(r_i, r_j\right) . \tag{11}$$

Note that there are *n* variance terms and *n*(n-1)* covariance terms. If we define the average variance as

$$\overline{\sigma}^2 = \frac{1}{n}\sum_{i=1}^{n}\sigma_i^2 \ , \tag{12}$$

and average covariance as

$$\overline{Cov} = \frac{1}{n(n-1)}\sum_{\substack{j=1 \\ j\neq i}}^{n}\sum_{i=1}^{n} Cov\left(r_i, r_j\right) \ , \tag{13}$$

the portfolio variance can be written as

$$\sigma_p^2 = \frac{1}{n}\overline{\sigma}^2 + \frac{n-1}{n}\overline{Cov} \ . \tag{14}$$

The portfolio becomes highly diversified as *n* increases. The specific risk, represented by the first term in eq. 14 is diversified away as *n* becomes greater. The second term simply approaches *Cov* as *n* becomes greater. Note that *(n-1)/n=1-1/n*, which approaches 1 for large *n*. Thus the irreducible risk of a diversified portfolio depends on the covariance of the returns, which in turn is a function of the importance of systematic factors in the economy.

To see further the fundamental relationship between systematic risk and security correlations, suppose for simplicity that all securities (currencies) have a common standard deviation, σ, and all pairs of them have a common correlation coefficient, ρ. Then the covariance between all pairs of securities is given by:

$$\overline{Cov} = \rho * \sigma^2 \ . \tag{15}$$

So the eq. 14 becomes:

$$\sigma_p^2 = \frac{1}{n}\sigma^2 + \frac{n-1}{n}\rho\sigma^2 \ . \tag{16}$$

As *n* increases, eq. 16 approximate to:

$$\sigma_p^2 = \rho\sigma^2 \ . \tag{17}$$

Note that ${\sigma_p}^2$ = MV, ρ = AC and σ^2 = AV. According to Pollet and Wilson (2010), MV is decomposed in cross-sectional average variance (AV) and cross-sectional average correlation (AC). So, MV is defined as:

$$MV_{t+1} = AV_{t+1} * AC_{t+1} . \tag{18}$$

If all exchange rates had equal individual variances, the decomposition above would be exact. The approximation of variance decomposition works very well for a large number of currencies.

The regression of the variance decomposition is defined as:

$$MV_{t+1} = \alpha + \beta(AV_{t+1} * AC_{t+1}) + u_{t+1} . \tag{19}$$

Similarly to Pollet and Wilson (2010), the variance decomposition can be estimated in addition to equation 19, according to the following regressions:

$$MV_{t+1} = \alpha + \beta AV_{t+1} + u_{t+1} , \tag{20}$$

$$MV_{t+1} = \alpha + \beta AC_{t+1} + u_{t+1} , \tag{21}$$

$$MV_{t+1} = \alpha + \beta_1 AV_{t+1} + \beta_2 AC_{t+1} + u_{t+1} . \tag{22}$$

Just as Cenedese, Sarno and Tsiakas (2014), this paper uses equation 22 to estimate the variance decomposition and to estimate predictive regressions.

The measures of AV and AC are defined as:

$$AV_{t+1} = \frac{1}{N_t} \sum_{j=1}^{N_t} V_{j,t+1} , \tag{23}$$

$$AC_{t+1} = \frac{1}{N_t(N_t-1)} \sum_{i=1}^{N_t} \sum_{j\neq i}^{N_t} C_{ij,t+1} , \tag{24}$$

where $V_{j,t+1}$ is the realized variance of the excess return to currency j at time $t+1$, and is defined as:

$$V_{j,t+1} = \sum_{d=1}^{D_t} r_{j,t+d/D_t}^2 + 2\sum_{d=2}^{D_t} r_{j,t+d/D_t}\ r_{j,t+(d-1)/D_t}\ , \tag{25}$$

and $C_{ij,t+1}$ is the realized correlation between the excess returns of currencies i and j at time $t+1$:

$$C_{ij,t+1} = \frac{V_{ij,t+1}}{\sqrt{V_{i,t+1}}\sqrt{V_{j,t+1}}}, \tag{26}$$

$$V_{ij,t+1} = \sum_{d=1}^{D_t} r_{i,t+d/D_t}\, r_{j,t+d/D_t} + 2\sum_{d=2}^{D_t} r_{i,t+d/D_t}\ r_{j,t+(d-1)/D_t}\ . \tag{27}$$

e) Predictive Regressions

Two predictive regressions for one-month horizon are estimated using ordinary least squares (OLS).

The first regression is a way to evaluate the intertemporal risk-return tradeoff in FX. The regression evaluates whether the carry trade has low or negative returns in times of high market variance.

$$r_{C,t+1} = \alpha + \beta MV_t + \varepsilon_{t+1} \tag{28}$$

The second regression includes the risk-return tradeoff of the variance decomposition proposed by Pollet and Wilson (2010). This regression makes a division between the AV and AC effects with the purpose of evaluating whether these effects bring a more precise signal of future carry trade returns. The constant α is the same for both regressions. Substituting eq. 22 into eq. 28, the regression is defined as:

$$r_{C,t+1} = \alpha + \beta_1 AV_t + \beta_2 AC_t + \varepsilon_{t+1}\ . \tag{29}$$

The first quantile regression (eq. 3) is given by:

$$Q_{r_{C,t+1}}(\tau \mid MV_t) = \alpha(\tau) + \beta(\tau)\, MV_t\,, \tag{3}$$

where $Q_{r_{C,t+1}}(\tau \mid .)$ is the τ-th quantile function of one-month ahead carry trade returns conditional on information available at month *t*.

Substituting eq. 22 into eq. 3, the second quantile regression (eq. 4) is given by:

$$Q_{r_{C,t+1}}(\tau \mid AV_t, AC_t) = \alpha(\tau) + \beta_1(\tau) AV_t + \beta_2(\tau) AC_t\,. \tag{4}$$

5. Empirical Results

We first present the descriptive statistics of the three data sets used in the analysis: global portfolio, advanced economies and emerging markets. We present the regressions of variance decomposition into AV and AC which will help us to explain the time variation in MV. The OLS regressions of one-month ahead carry trade returns into MV, AV and AC are discussed, as well as the quantile regressions of carry trade returns.

a) Descriptive Statistics

Descriptive statistics on the carry trade strategy (risk and return) for global portfolio, advanced economies and emerging markets are showed in Table 1. The first 3 years of the data set were used to make the first regression of each model. So, the statistics and regressions start in Feb-2002. Considering no transaction costs, the carry trade strategy had an average annualized return of 6.1% (global portfolio), 4.7% (advanced economies) and 6.8% (emerging markets). The annualized standard deviations are 9.5% (global portfolio), 10.9% (advanced economies) and 12.6% (emerging markets).

The interest rate differential is the principal component of the carry trade strategy with average annualized return of 5.4% (global portfolio), 3.0% (advanced economies) and 7.0% (emerging markets). The annualized exchange rate component had an average appreciation of 0.7% (global portfolio), an appreciation of 1.8% (advanced economies) and an average depreciation of 0.3% (emerging markets). These statistics show that exchange rates, on average, only partially offset the interest rate differential. The carry trade strategy has negative skewness and the kurtosis is higher than 3.

The descriptive statistics of the risk measures show that the mean of MV is about half the value of the AV. The mean of AC is 0.42 for global portfolio, 0.52 for advanced economies and 0.39 for emerging markets. MV and AV have high positive skewness and high kurtosis. The global portfolio has higher Sharpe Ratio and Information Ratio in relation to the advanced economies and emerging markets. The graphics of Figure 1 confirm the better performance of the global portfolio in relation to the advanced economies and emerging markets.

MV and AV are negative correlated with the carry trade and market returns for all three portfolios (Table 2). The correlation between MV and AV is positive and high for global portfolio (0.975), advanced economies (0.971) and emerging markets (0.965). The correlation between AV and AC is positive but moderate. Carry trade and interest rate returns are highly positive correlated for all three portfolios. This correlation is higher than the correlation between carry trade and FX returns for all three portfolios.

b) Variance Decomposition

The variance decomposition (MV) into AV and AC was described by equation 18. The variance decomposition is evaluated by some regressions that are presented in Table 3. The regression of

MV into product of AV and AC have a slope coefficient of 0.888 and R^2 = 99.4%. The regression of MV into AV and AC have slope coefficients of 0.593 and 0.001 respectively and R^2 = 96.3%. The analyses of the regressions shows that the AV component are more important to explain the variation in MV, and AV and AC are responsible for almost all of time variation in MV.

c) OLS Regressions

The OLS regressions of the carry trade strategies are shown in Table 4. The regression of the carry trade returns one-month ahead on MV shows that the relation is negative but not statistically significant for all three portfolios (global portfolio, advanced economies and emerging markets). These results refuse the first hypothesis (H1) that the FX portfolio variance is a predictor of future FX excess returns. There is not significant evidence in the regression of the carry trade return in relation to AV and AC (global portfolio, advanced economies and emerging markets). Thus, MV and its components cannot be used to predict carry trade returns.

d) Quantile Regressions

While OLS regressions analyses the relation between risk and mean returns, the quantile regressions of the carry trade returns one-month ahead on MV analyses the relation by τ-th quantile, as shown in Table 5. There is not significant evidence in the quantile regressions of the future carry trade return in the quantiles of the distribution. The coefficient has more negative values for the lower quantiles but is not statistically significant. These results refuse the second hypothesis (H2) that the predictive power of risk measures varies between quantile of the distribution of FX excess returns, and is strongly negative in the lower quantile.

Table 6 shows the quantile regressions of the carry trade returns one-month ahead on AV and AC. There is not a significant relation for AV and for AC. So, it is not possible to predict carry trade returns using the left tail of the distribution of MV and AV.

6. Augmented Carry Trade Strategies

We develop some augmented carry trade strategies conditioned on market variance. We compare these strategies to the standard carry trade strategy defined in the Portfolio of Currencies session.

a) Trading Strategies

The first carry trade strategy (augmented strategy 1) is conditioned on current market variance (MV). In this strategy, at each month t, if MV from $t\text{-}1$ to t is higher than its median value up to that point, the carry trade positions are closed and the excess return will be zero at $t+1$, otherwise the standard carry trade strategy is executed.

The second carry trade strategy (augmented strategy 2) is conditioned on left tail of the carry trade returns distribution. In this strategy, at each month t, only for carry trade returns those are lower than τ-quantile of the distribution at month t, if MV from $t\text{-}1$ to t is higher than its median up to that point, the carry trade positions are closed and the excess return will be zero at $t+1$, otherwise the standard carry trade strategy is executed.

The third carry trade strategy (augmented strategy 3) considers the quantile of returns and do not consider MV. In this strategy, at each month t, if carry trade returns are lower than τ-quantile of the distribution at month t, the carry trade positions are closed and the excess return will be zero at $t+1$, otherwise the standard carry trade strategy is executed.

These strategies are implemented out of sample. The strategies move forward recursively starting 3 years after the beginning of the sample.

b) The Performance of the Strategies

The augmented strategy 2 is the most important since it considers the left tail of the distribution of carry trade returns and MV. The performance of this strategy can be viewed at Table 7. Relative to the standard carry trade, this strategy has a higher average annualized return (6.70% vs 6.00%), lower annualized standard deviation (8.60% vs 9.50%) and higher Information Ratio (0.780 vs 0.631) for the global portfolio. This strategy has a higher average annualized return (5.60% vs 4.70%), lower annualized standard deviation (9.00% vs 10.90%) and higher Information Ratio (0.626 vs 0.431) for the advanced economies. This strategy has a higher average annualized return (7.70% vs 7.20%), lower annualized standard deviation (11.40% vs 12.50%) and higher Information Ratio (0.672 vs 0.575) for the emerging markets. Figure 2 shows the augmented strategy 2 for all three portfolios.

7. Conclusion

The carry trade strategy tries to exploit deviations from the UIP. The empirical evidence suggests that the interest rate differential across countries is not, on average, offset by the depreciation of the investment currency. So the carry trade strategy has large average returns by borrowing in low-interest currencies and investing in high-interest currencies.

We refuse the hypothesis that FX portfolio variance and its components have a significant effect on the left tail of the distribution of future carry trade returns. Carry trade returns cannot be predicted using market variance and return quantile. Augmented trading strategies combining market variance and return quantile can reduce drawdowns.

Table 1. Descriptive Statistics

The table shows descriptive statistics for the monthly excess returns of three carry trade portfolios: Global Portfolio, Advanced Economies and Emerging Markets. The global portfolio includes 20 exchange rates relative to the US dollar for the sample period of February 2002 to July 2016. The sample period for the Advanced Economies and for Emerging Markets is the same. The mean, standard deviation of returns, Sharpe Ratio and Information Ration are annualized. The Variances and Correlations are for monthly returns. The skewness and kurtosis are for monthly returns.

Table 1: Summary Statistics

	Global Portfolio					
	Mean	St. Dev.	Skewness	Kurtosis	Sharpe Ratio	Information Ratio
Portfolio Returns						
Carry Trade	0.061	0.095	-0.358	3.907	0.516	0.642
Market	0.025	0.082	-0.626	4.698	0.159	0.305
Carry Trade Components						
Exchange Rate	0.007	0.082	-0.640	4.679		
Interest Rate	0.054	0.093	-0.154	3.189		
Variances and Correlations						
FX Portfolio Variance	0.0008	0.000	7.320	75.460		
Average Variance	0.0017	0.001	7.727	82.275		
Average Correlation	0.4214	0.230	0.046	1.858		
	Advanced Economies					
	Mean	St. Dev.	Skewness	Kurtosis	Sharpe Ratio	Information Ratio
Portfolio Returns						
Carry Trade	0.047	0.109	-0.807	5.844	0.323	0.433
Market	0.023	0.089	-0.308	4.108	0.129	0.264
Carry Trade Components						
Exchange Rate	0.018	0.089	-0.312	4.075		
Interest Rate	0.030	0.104	-0.232	3.104		
Variances and Correlations						
FX Portfolio Variance	0.0010	0.000	5.189	44.396		
Average Variance	0.0016	0.001	6.307	60.464		
Average Correlation	0.5162	0.224	-0.165	2.531		
	Emerging Markets					
	Mean	St. Dev.	Skewness	Kurtosis	Sharpe Ratio	Information Ratio
Portfolio Returns						
Carry Trade	0.068	0.126	-0.211	4.070	0.443	0.539
Market	0.027	0.082	-0.773	4.956	0.179	0.326
Carry Trade Components						
Exchange Rate	-0.003	0.082	-0.787	4.912		
Interest Rate	0.070	0.106	0.013	3.819		
Variances and Correlations						
FX Portfolio Variance	0.0008	0.000	7.978	85.013		
Average Variance	0.0018	0.001	8.012	86.653		
Average Correlation	0.3922	0.284	0.177	1.901		

Table 2. Descriptive Statistics

The table shows the correlations for the monthly variables of three carry trade portfolios: Global Portfolio, Advanced Economies and Emerging Markets.

Table 2: Correlations

Global Portfolio

		Carry Trade Return	Market Return	Exchange Rate	Interest Rate	FX Portfolio Variance	Average Variance	Average Correlation
Portfolio Returns	Carry Trade Return	1.000						
	Market Return	0.453	1.000					
Carry Trade Components	Exchange Rate	0.454	0.999	1.000				
	Interest Rate	0.622	-0.415	-0.415	1.000			
Variances and Correlations	FX Portfolio Variance	-0.277	-0.271	-0.273	-0.043	1.000		
	Average Variance	-0.298	-0.306	-0.310	-0.032	0.975	1.000	
	Average Correlation	-0.086	0.056	0.058	-0.139	0.485	0.352	1.000

Advanced Economies

		Carry Trade Return	Market Return	Exchange Rate	Interest Rate	FX Portfolio Variance	Average Variance	Average Correlation
Portfolio Returns	Carry Trade Return	1.000						
	Market Return	0.457	1.000					
Carry Trade Components	Exchange Rate	0.458	0.999	1.000				
	Interest Rate	0.654	-0.373	-0.373	1.000			
Variances and Correlations	FX Portfolio Variance	-0.345	-0.172	-0.173	-0.213	1.000		
	Average Variance	-0.396	-0.233	-0.233	-0.215	0.971	1.000	
	Average Correlation	-0.003	0.138	0.136	-0.119	0.450	0.288	1.000

Emerging Markets

		Carry Trade Return	Market Return	Exchange Rate	Interest Rate	FX Portfolio Variance	Average Variance	Average Correlation
Portfolio Returns	Carry Trade Return	1.000						
	Market Return	0.543	1.000					
Carry Trade Components	Exchange Rate	0.545	0.998	1.000				
	Interest Rate	0.764	-0.126	-0.124	1.000			
Variances and Correlations	FX Portfolio Variance	-0.188	-0.287	-0.289	0.000	1.000		
	Average Variance	-0.204	-0.319	-0.326	0.010	0.965	1.000	
	Average Correlation	-0.068	-0.004	0.006	-0.085	0.468	0.324	1.000

Table 3. FX Portfolio Variance Decomposition

The table shows the OLS results for regressions on alternative decompositions of the FX portfolio variance. The dependent variable is the FX portfolio variance as defined in this paper. The table shows the regressions of the Global Portfolio, which includes 20 exchange rates relative to the US dollar for the sample period of April 1999 to July 2016. The FX portfolio variance (MV), average variance (AV), average correlation (AC) and the product of average variance * average correlation (AV * AC) are for monthly returns.

The regression 1 is given by: $MV_{t+1} = \alpha + \beta_1(AV_{t+1}) + u_{t+1}$.

The regression 2 is given by: $MV_{t+1} = \alpha + \beta_2(AC_{t+1}) + u_{t+1}$.

The regression 3 is given by: $MV_{t+1} = \alpha + \beta_1(AV_{t+1}) + \beta_2(AC_{t+1}) + u_{t+1}$.

The regression 4 is given by: $MV_{t+1} = \alpha + \beta(AV_{t+1} * AC_{t+1}) + u_{t+1}$.

Table 3: Variance Decomposition

	Regression 1	Regression 2	Regression 3	Regression 4
Constant	0.000	0.000	-0.001	0.000
t-stat	-10.191	-2.109	-19.450	3.608
Average Variance	0.637		0.593	
t-stat	51.944		62.404	
Average Correlation		0.003	0.001	
t-stat		8.330	13.554	
Average Variance * Average Correlation				0.888
t-stat				187.473
R^2 (%)	92.9%	25.2%	96.3%	99.4%

Table 4. OLS Predictive Regressions

The table shows the OLS results for regressions for two predictive regressions. The first regression is: $r_{C,t+1} = \alpha + \beta\, MV_t + \varepsilon_{t+1}$ as defined by equation 20. The second regression is: $r_{C,t+1} = \alpha + \beta_1\, AV_t + \beta_2\, AC_t + \varepsilon_{t+1}$ as defined by equation 21. The table shows the regressions of the Global Portfolio, which includes 20 exchange rates relative to the US dollar for the sample period of April 1999 to July 2016. The sample period for the Advanced Economies and for Emerging Markets is the same. All variables are annualized, with the exception of average correlation. Newey-West (1987) t-statistics with five lags are reported.

Table 4: Carry Trade Regressions

		Global Portfolio			
		Coefficient	St. Dev.	t-statistic	p-value
Regression 1					
Constant	α	0.087	0.026	3.400	0.001
FX Portfolio Variance	β	-9.710	20.985	-0.460	0.644
R^2 (%)		0.1%			
Regression 2					
Constant	α	0.110	0.049	2.230	0.027
Average Variance	β_1	-2.546	12.729	-0.200	0.842
Average Correlation	β_2	-0.066	0.102	-0.640	0.522
R^2 (%)		0.3%			
		Advanced Economies			
		Coefficient	St. Dev.	t-stat	p-value
Regression 1					
Constant	α	0.083	0.024	3.390	0.001
FX Portfolio Variance	β	-37.512	21.702	-1.730	0.085
R^2 (%)		1.9%			
Regression 2					
Constant	α	0.117	0.054	2.170	0.031
Average Variance	β_1	-18.713	17.144	-1.090	0.276
Average Correlation	β_2	-0.081	0.103	-0.780	0.435
R^2 (%)		1.5%			
		Emerging Markets			
		Coefficient	St. Dev.	t-stat	p-value
Regression 1					
Constant	α	0.095	0.035	2.760	0.006
FX Portfolio Variance	β	-13.851	24.400	-0.570	0.571
R^2 (%)		0.2%			
Regression 2					
Constant	α	0.094	0.054	1.750	0.082
Average Variance	β_1	-14.105	12.135	-1.160	0.246
Average Correlation	β_2	0.044	0.114	0.380	0.703
R^2 (%)		0.5%			

Table 5. Quantile Regressions using FX Portfolio Variance

The table shows the results for quantile regressions for predictive regressions $Q_{r_{C,t+1}}(\tau \mid MV_t) = \alpha(\tau) + \beta(\tau)\, MV_t$ as defined by equation 3. The table shows the quantile regressions of the Global Portfolio, which includes 20 exchange rates relative to the US dollar for the sample period of April 1999 to July 2016. The sample period for the Advanced Economies and for Emerging Markets is the same. All variables are annualized, with the exception of average correlation. Bootstrap t-statistics generated using 10,000 bootstrap samples are reported.

Table 5: Quantile Regressions for the Carry Trade Returns

Global Portfolio

		Quantile 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Constant	Coefficient	-0.270	-0.150	-0.077	0.003	0.056	0.156	0.259	0.370	0.474
	St. Dev.	0.061	0.036	0.030	0.031	0.029	0.053	0.045	0.046	0.033
	t-stat	-4.410	-4.190	-2.560	0.100	1.940	2.940	5.760	8.050	14.260
	p-value	0.000	0.000	0.011	0.917	0.054	0.004	0.000	0.000	0.000
FX Portfolio Variance	Coefficient	-67.876	-16.358	-0.330	-5.534	3.669	16.084	3.087	-16.578	9.682
	St. Dev.	110.876	58.562	40.363	39.568	42.079	43.708	36.741	44.252	41.482
	t-stat	-0.610	-0.280	-0.010	-0.140	0.090	0.370	0.080	-0.370	0.230
	p-value	0.541	0.780	0.993	0.889	0.931	0.713	0.933	0.708	0.816
R^2 (%)		2.0%	0.1%	0.0%	0.1%	0.0%	0.2%	0.0%	0.1%	0.2%

Advanced Economies

		Quantile 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Constant	Coefficient	-0.343	-0.122	-0.085	0.016	0.080	0.161	0.256	0.347	0.475
	St. Dev.	0.082	0.037	0.046	0.032	0.031	0.044	0.036	0.054	0.047
	t-stat	-4.190	-3.270	-1.860	0.480	2.530	3.700	7.090	6.420	10.180
	p-value	0.000	0.001	0.065	0.629	0.012	0.000	0.000	0.000	0.000
FX Portfolio Variance	Coefficient	-81.785	-101.544	-23.701	-24.153	-28.740	-34.587	-40.615	-14.600	8.459
	St. Dev.	49.994	52.686	52.713	36.476	29.115	29.169	31.656	43.171	59.451
	t-stat	-1.640	-1.930	-0.450	-0.660	-0.990	-1.190	-1.280	-0.340	0.140
	p-value	0.103	0.055	0.653	0.509	0.325	0.237	0.201	0.736	0.887
R^2 (%)		5.3%	2.8%	1.1%	1.0%	0.6%	0.3%	0.4%	0.2%	0.1%

Emerging Markets

		Quantile 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Constant	Coefficient	-0.433	-0.217	-0.086	0.038	0.123	0.220	0.270	0.421	0.537
	St. Dev.	0.040	0.066	0.052	0.037	0.038	0.044	0.037	0.065	0.065
	t-stat	-10.750	-3.310	-1.660	1.040	3.210	4.990	7.290	6.430	8.220
	p-value	0.000	0.001	0.099	0.302	0.002	0.000	0.000	0.000	0.000
FX Portfolio Variance	Coefficient	-63.401	-8.631	-16.208	-23.406	-21.365	-10.825	2.751	-27.197	104.888
	St. Dev.	65.431	66.173	53.160	42.801	39.716	38.526	49.406	78.572	81.893
	t-stat	-0.970	-0.130	-0.300	-0.550	-0.540	-0.280	0.060	-0.350	1.280
	p-value	0.334	0.896	0.761	0.585	0.591	0.779	0.956	0.730	0.202
R^2 (%)		0.6%	0.4%	0.5%	0.4%	0.1%	0.0%	0.0%	0.1%	1.1%

Table 6. Quantile Regressions using Average Variance and Average Correlation

The table shows the results for quantile regressions for predictive regressions $Q_{r_{C,t+1}}(\tau \mid AV_t, AC_t) = \alpha(\tau) + \beta_1(\tau)AV_t + \beta_2(\tau)AC_t$ as defined by equation 4. The table shows the quantile regressions of the Global Portfolio, which includes 20 exchange rates relative to the US dollar for the sample period of April 1999 to July 2016. The sample period for the Advanced Economies and for Emerging Markets is the same. All variables are annualized, with the exception of average correlation. Bootstrap t-statistics generated using 10,000 bootstrap samples are reported.

Table 6: Quantile Regressions for the Carry Trade Returns

Global Portfolio

		Quantile								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Constant	Coefficient	-0.173	-0.149	-0.074	0.003	0.049	0.148	0.259	0.421	0.481
	St. Dev.	0.097	0.062	0.057	0.054	0.053	0.087	0.074	0.079	0.050
	t-stat	-1.780	-2.390	-1.290	0.060	0.930	1.700	3.520	5.350	9.680
	p-value	0.076	0.018	0.198	0.949	0.353	0.091	0.001	0.000	0.000
Average Variance	Coefficient	-0.136	0.021	-0.010	0.001	0.058	-0.014	-0.079	-0.201	-0.247
	St. Dev.	0.220	0.117	0.116	0.124	0.144	0.213	0.184	0.144	0.140
	t-stat	-0.620	0.180	-0.080	0.010	0.400	-0.060	-0.430	-1.390	-1.760
	p-value	0.538	0.858	0.935	0.993	0.689	0.948	0.670	0.166	0.080
Average Correlation	Coefficient	-84.392	-13.255	-0.070	-3.538	-7.052	14.432	19.931	21.881	53.685
	St. Dev.	68.766	43.224	28.185	28.813	29.958	36.315	40.594	40.516	42.490
	t-stat	-1.230	-0.310	0.000	-0.120	-0.240	0.400	0.490	0.540	1.260
	p-value	0.221	0.759	0.998	0.902	0.814	0.691	0.624	0.590	0.208
R^2 (%)		2.7%	0.2%	0.0%	0.1%	0.1%	0.3%	0.3%	1.3%	1.8%

Advanced Economies

		Quantile								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Constant	Coefficient	-0.279	-0.109	-0.046	0.047	0.087	0.196	0.298	0.401	0.523
	St. Dev.	0.165	0.104	0.082	0.064	0.053	0.073	0.064	0.098	0.112
	t-stat	-1.690	-1.050	-0.560	0.740	1.630	2.670	4.650	4.080	4.670
	p-value	0.093	0.293	0.573	0.460	0.104	0.008	0.000	0.000	0.000
Average Variance	Coefficient	-94.684	-79.041	-10.551	-14.891	-18.868	5.425	4.856	22.575	43.916
	St. Dev.	40.858	45.864	48.849	43.652	42.122	39.350	35.187	40.461	39.222
	t-stat	-2.320	-1.720	-0.220	-0.340	-0.450	0.140	0.140	0.560	1.120
	p-value	0.021	0.086	0.829	0.733	0.655	0.890	0.890	0.577	0.264
Average Correlation	Coefficient	0.044	0.023	-0.083	-0.083	-0.006	-0.110	-0.128	-0.221	-0.193
	St. Dev.	0.276	0.206	0.189	0.165	0.134	0.129	0.138	0.189	0.208
	t-stat	0.160	0.110	-0.440	-0.500	-0.050	-0.850	-0.930	-1.170	-0.930
	p-value	0.874	0.913	0.661	0.615	0.963	0.396	0.353	0.243	0.353
R^2 (%)		5.9%	2.7%	1.1%	1.1%	0.5%	0.4%	0.5%	0.8%	2.2%

Emerging Markets

		Quantile								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Constant	Coefficient	-0.444	-0.196	-0.077	0.038	0.118	0.226	0.269	0.328	0.476
	St. Dev.	0.096	0.111	0.076	0.055	0.053	0.058	0.057	0.097	0.094
	t-stat	-4.610	-1.770	-1.010	0.680	2.240	3.880	4.740	3.380	5.080
	p-value	0.000	0.077	0.311	0.495	0.026	0.000	0.000	0.001	0.000
Average Variance	Coefficient	-69.567	-4.895	-11.573	-16.213	-18.370	-7.327	4.831	88.229	105.502
	St. Dev.	48.745	46.370	34.531	27.832	31.413	38.439	46.294	60.577	51.545
	t-stat	-1.430	-0.110	-0.340	-0.580	-0.580	-0.190	0.100	1.460	2.050
	p-value	0.155	0.916	0.738	0.561	0.559	0.849	0.917	0.147	0.042
Average Correlation	Coefficient	0.149	-0.044	0.034	0.049	0.023	-0.009	-0.018	-0.130	-0.195
	St. Dev.	0.199	0.198	0.141	0.115	0.135	0.116	0.112	0.158	0.194
	t-stat	0.750	-0.220	0.240	0.420	0.170	-0.070	-0.160	-0.820	-1.010
	p-value	0.455	0.825	0.811	0.672	0.862	0.941	0.875	0.411	0.315
R^2 (%)		1.6%	0.6%	0.9%	0.8%	0.4%	0.1%	0.1%	0.9%	4.1%

Figure 1. Carry Trade Return and Risk Measures

These figures show the time series cumulative carry trade return, FX portfolio variance, average variance, and average correlation. The left column is for a currency Global Portfolio, the middle one is for Advanced Economies and the right one for Emerging Markets.

Global Portfólio | **Advanced Economies** | **Emerging Markets**

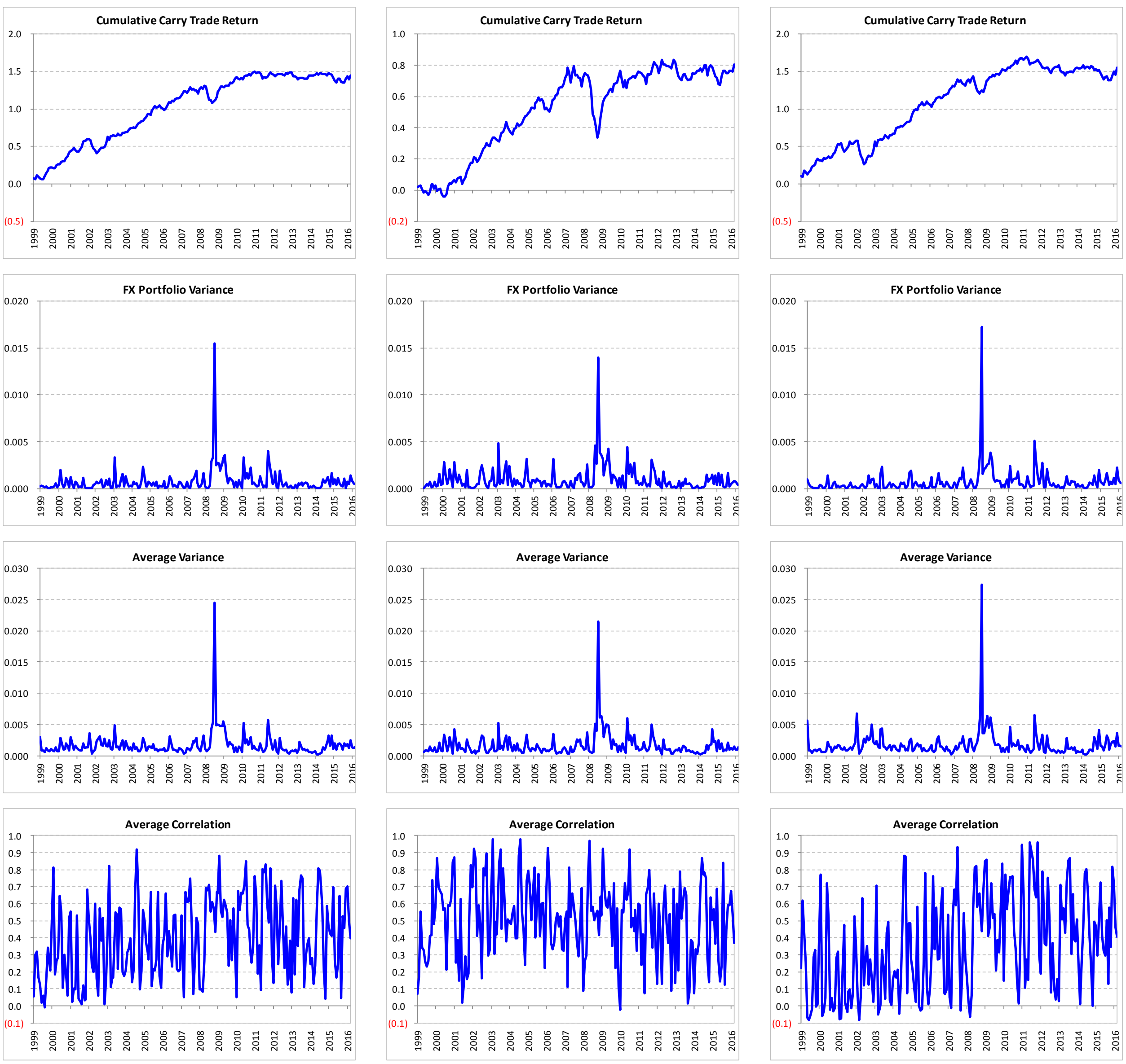


Table 7. Augmented Strategies

The table shows descriptive statistics for the monthly excess returns of three carry trade portfolios: Global Portfolio, Advanced Economies and Emerging Markets. The descriptive statistics if for standard carry trade and augmented strategy 2. The Global Portfolio includes 20 exchange rates relative to the US dollar for the sample period of April 1999 to July 2016. The sample period for the Advanced Economies and for Emerging Markets is the same. The mean, standard deviation of returns, Sharpe Ratio and Information Ration are annualized. The Variances and Correlations are for monthly returns. The skewness and kurtosis are for monthly returns.

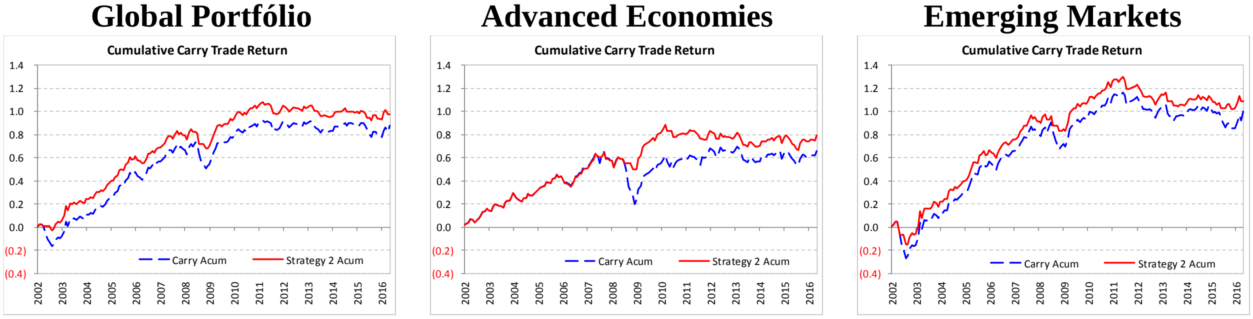
Table 7: Summary Statistics for Augmented Strategy

	Global Portfolio					
	Mean	St. Dev.	Skewness	Kurtosis	Sharpe Ratio	Information Ratio
Portfolio Returns						
Carry Trade	0.060	0.095	-0.349	3.904	0.506	0.631
Augmented Strategy 2	0.067	0.086	-0.103	4.197	0.642	0.780
	Advanced Economies					
	Mean	St. Dev.	Skewness	Kurtosis	Sharpe Ratio	Information Ratio
Portfolio Returns						
Carry Trade	0.047	0.109	-0.806	5.851	0.321	0.431
Augmented Strategy 2	0.056	0.090	-0.070	3.511	0.493	0.626
	Emerging Markets					
	Mean	St. Dev.	Skewness	Kurtosis	Sharpe Ratio	Information Ratio
Portfolio Returns						
Carry Trade	0.072	0.125	-0.233	4.122	0.479	0.575
Augmented Strategy 2	0.077	0.114	-0.217	4.890	0.568	0.672

Figure 2. Carry Trade and Augmented Strategy 2

These figures show the time series cumulative standard carry trade and augmented strategy 2 return. The left column is for a currency Global Portfolio, the middle one is for Advanced Economies and the right one for Emerging Markets.

Global Portfólio | **Advanced Economies** | **Emerging Markets**



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