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The Era of Global Risk Premia

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FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

THE ERA OF
GLOBAL RISK PREMIA

A dissertation submitted in partial fulfillment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY

in

BUSINESS ADMINISTRATION

by

Derek-Dion D. Lee

2018

To: Dean Joanne Li
College of Business

This dissertation written by Derek-Dion D. Lee, and entitled The Era of Global Risk
Premia, having been approved in respect to style and intellectual content, is
referred to you for judgment.

We have read this dissertation and recommend that it be approved.

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The dissertation of Derek-Dion D. Lee is approved.

Dean Joanne Li
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Vice President for Research and Economic Development
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Florida International University, 2018

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DEDICATION

I would like to dedicate this dissertation to my beautiful fiancé, Emmy Lynn, and my family. I would like to especially thank my friends in the doctoral finance cohort whose help was paramount; Alex, Ivan, Anis and Zifeng. I would also like to thank Professor Daigler, Professor Dandapani, Professor Lawrence, Professor Xia, and Professor Wu, for all their research inspiration and professional support.

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ABSTRACT OF THE DISSERTATION
THE ERA OF GLOBAL RISK PREMIA

by

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Florida International University, 2018

Miami, Florida

Professor Krishnan Dandapani, Major Professor

I propose a global risk factor – Currency Traded Risk (CTR). This risk factor is the first to identify the directional link between currencies and equities. CTR captures the genesis of financial globalization, and contains the greatest predictive ability to date for monthly returns on a global stock portfolio.

Theoretically, return expectation is intimately linked to time-varying risk premia. Due to the intrinsic scope of currency values in integrating the world's financial markets, information on time-varying risk premia prices into currencies at greater speed, scale, and global consensus, relative other asset classes. High interest rate currencies proxy as a risk-on asset class. Low interest rate currencies proxy as a risk-off asset class. Innovations in these currencies' values summarize global risk premia and thereby forecast returns to a global stock portfolio.

CTR measures two sources of global risk premia; the difference between averaged spot returns of high interest rate currencies and low interest rate currencies, and the difference between implied and realized volatility of high interest rate currencies. Using recursive regressions, CTR predicts monthly returns to the MSCI World Index© out of

sample, with R^2 's consistent at 10% from 2008 to 2017. Currencies track global risk premia, whereas equities respond to it.

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CHAPTER 1: FORECASTING RETURNS ON A GLOBAL STOCK PORTFOLIO WITH CURRENCY RETURNS

1.1 Introduction

The literature connecting exchange rates and equity returns is far from conclusive. Both macroeconomic fundamentals and price history have demonstrated inconsistent empirical significance in relating stock returns to exchange rates. ‘There is theoretical consensus neither on the existence of a relationship ... nor on the direction of the relationship’ (Stavarek 2005). In this study, we formulate a new approach to this age-old hunt by recognizing the temporal effects global systematic risk premia have on both asset classes.

The forex markets are the largest financial markets. They trade continuously, across the widest spectrum of market participants. Investing in any market prerequisites investment in its currency. It is intuitive that information about time-varying global risk premia may be canalized by the forex markets to a rate and degree more explanatorily powerful than any other single asset class.

I hypothesize that innovations in forex values subsume information contained in fluctuating macro-economic variables, thereby signaling global risk aversion levels and forecasting risky asset returns. This hypothesis relies on three presuppositions. Firstly, temporal risk and return dynamics across the global economy dominate the stochastic processes manifesting asset prices. Secondly, there is fundamental cause for the empirical positive (negative) co-movement of high (low) interest rate currencies with the global economy. Thirdly, due to the intrinsic scope of currency prices in integrating the world’s financial markets, information on time-varying global risk premia appears in the forex

markets at greater speed, scale, or consensus, relative other asset classes. This hypothesis builds on studies of the carry trade and implications of its performance across time.

Empirically, carry trade returns have been shown to capture information underlying time varying global risk aversion. The carry trade consists of investing in high interest rate currencies and borrowing in low interest rate currencies, earning investors excess returns. The inherent risk is large; as every so often, investment currencies suddenly depreciate, causing large losses. A risk-based view would suggest that investment currencies offer a premium for higher risk exposure (Fama, 1984). Excess returns from the carry trade necessitate failure of uncovered interest parity, UIP. If high interest rate currencies deliver low returns in bad times, then currency excess returns compensate investors for higher risk-exposure and UIP deviations reflect time-varying risk premia (Fama, 1984; Engel, 1984). The empirical failure of UIP implies that the market's continuous systematic risk-return distillation supersedes its tight adherence to revolving idiosyncratic macro's. This may explain the difficulty in finding any consistent pairwise statistical relation between two countries' equity returns and exchange rate at short term frequencies.

Information embedded in currency values underlying the portfolio carry trade aggregates investors' outlooks on the global economy. By investing in the portfolio carry trade, US investors load up on global risk (Lustig, Roussanov and Verdelhan 2011). High interest rate currencies proxy as a 'risk-on' asset class while low interest rate currencies proxy as a 'risk-off' asset class. If the contemporaneous difference in returns between these two asset classes is positive, we propose the market is indicating expectations of a positive or strengthening global economic state. If the difference is negative, we propose the market is indicating expectations of a negative or worsening global economic state.

In the light of the findings noted above and motivated by their reasoning, we attempt to construct a traded risk factor that funnels global risk information embedded in currency movements into an observable real-time metric. We coin this risk factor, CTR.

1.2 Relevant Literature

Difficulty in understanding the mechanism connecting currencies and equities can be attributed to several occupational hazards plaguing the international financial economist. Firstly, the low frequency of observance of macro fundamentals and the latency of their translation into market prices. Secondly, the limits inherent to explaining one country's exchange rate and equity returns in a pairwise fashion with those of a single other country. Relating macroeconomic variable differentials between two-countries simply cannot tell the full story explaining the drivers of their stock and currency prices. Trade imbalance and interest rates have so far been the most successful in statistically linking the two, and not coincidentally, centers the economic theories around their relation. Reference Corte, Riddiough and Sarno (2016) for a compelling trade based asset pricing framework.

The stock return predictability literature has made strides with recent innovations in observing model-free implied volatility. The Variance Risk Premium, or the difference between implied volatility and realized volatility, has been found to predict stock returns better than the P/E ratio, the default spread, and the consumption-wealth ratio (Bollerslev, Tauchen, and Zhou 2009). The variance risk premium essentially measures a real-time market consensus of investor risk aversion. The fact that this has been found to outperform some of the most powerful forecasting metrics to date, is encouraging to our work in this paper relating currency and equity returns to global risk aversion.

Microstructure approaches, such as those put forth by Hau and Rey (2005), suggest there is a portfolio balancing channel dynamically integrating equity, bond and exchange rate markets. These approaches posit that excess returns to capital allocated in foreign equity markets drives up the value of home currencies when that capital is repatriated. This mechanical process may be generalized to the Microstructure theory linking forex and equity markets, wherein customer initiated order flows affect exchange rates.

Closely related to our work in this paper; recent studies have been successful in identifying risk factors that explain currency returns in the cross section. Katechos (2011) tests the explanatory power of a global equity factor (FTSE all World index) on individual currency returns. He finds that countries with high interest rates have exchange rates that are contemporaneously positively related to global equity returns while low interest rate currencies are contemporaneously negatively related with global equity returns. Lustig, Roussanov and Verdelhan (2011) document risk factors present in the cross section of currencies. They report a common slope factor in exchange rates. They show that high interest rate currencies load more on this slope factor than low interest rate currencies. They also show that changes in global equity market volatility is empirically related to common shocks in the cross section of exchange rates. They conclude, by investing in the portfolio carry trade, US investors load up on global risk. Menkhoff, Sarno, Schmeling and Schrimpf (2012), find that global FX volatility risk captures more than 90% of the cross-sectional excess returns in five carry trade portfolios, and performs well for pricing returns of the cross sections in U.S. equity, and corporate bond markets. They report their FX volatility risk factor does not beat LRV's slope factor in simulated "horse races" to explain currency prices in the cross section.

With the influence of Cochrane (2005) - "...a non-traded risk factor, cannot beat a (return-based) factor mimicking portfolio in a horse race" - we aim to develop a traded, currency risk factor that helps identify a robust link between currency movements and global equity returns.

1.3 Data Collection

We gather daily currency spot rates and daily 1-month forward data from Thomson Reuter's Datastream. Our sample set consists of the top 25 most traded currencies by volume. Our sample period starts January 1, 1990 with 13 currencies total and ends April 30, 2017 with 25 currencies total. Using the United States dollar as our base currency, the currency sample set by average daily turnover includes: Euro, Japanese yen, Pound sterling, Australian dollar, Canadian dollar, Swiss franc, Chinese yuan renminbi, Swedish krona, Mexican peso, New Zealand dollar, Singapore dollar, Hong Kong dollar, Norwegian krone, Turkish lira, Indian rupee, Russian ruble, Brazilian real, South African rand, Danish krone, Polish zloty, New Taiwan dollar, Thai baht and Malaysian ringgit. The beginning of the sample includes the Hong Kong dollar, Pound sterling, New Zealand dollar, Swiss franc, South African rand, Norwegian krone, Danish krone, Australian dollar, Canadian dollar, Swedish krona, Japanese yen, Singapore dollar, and the United States dollar. Currencies are added to the sample set as continual daily 1-month forward rates become available for them over time. We note the inclusion of the Euro at its commencement on the global trading stage January 1, 1999.

For our global equity proxy, we obtained daily closing prices for the MSCI World Index©, ticker symbol MXWO, from Bloomberg. We chose MXWO index as our proxy for global equity returns based on its greatest mutual correlation to other alternative global

equity indices. This index is value weighted across 23 developed countries, including nearly all of our sample of 25 total currencies. The methodology for construction of the MXWO index can be found at <https://www.msci.com/world>.

1.4 Methodology and Empirical Testing

1.4.1 CTR Construction

Our proposed currency traded risk factor, is comprised of the currency returns underlying a high-minus-low portfolio carry trade strategy. To construct CTR, we sort currencies by interest rates using forward discounts. We sort the top and bottom quintiles of currencies by interest rates at the first day of each month. We then take the end-of-month FX return relative the USD of the top quintile of currencies (average return of the 20% of currencies with the highest yielding interest rates) and subtract the FX return relative the USD of the bottom quintile of currencies (average return of the 20% of currencies with the lowest yielding interest rates). This difference in returns is our proposed currency traded risk factor. Notably, CTR is composed of the returns from currency exchange rate appreciations and depreciations alone. Forward returns and hence interest rate carry, do not enter the risk factor calculation. Merely, the fluctuating market values of the currencies are being tested to see if their evolutions contain information that precedes and helps explain international equity returns.

1.4.2 Carry Trade Returns

Lustig, Roussanov, and Verdelhan, (2011) identify a ‘slope’ factor in the cross section of exchange rates. This factor is defined as the excess returns from the portfolio

carry trade, coined “HML”. Interest rate carry enters the computation of this slope factor. They construct this factor as follows:

Let s denote the log of the spot exchange rate in units of foreign currency per US dollar, and f denote the log of the forward exchange rate, also in units of foreign currency per US dollar. An increase in s means an appreciation of the home currency. The log excess return rx from buying a foreign currency in the forward market and then selling it in the spot market after one month is:

$$rx_{t+1} = f_t - s_{t+1}.$$

The excess return is the log forward discount minus the change in the spot rate. Thus, interest rate carry contributes to the excess return. Akram, Rime and Sarno (2008) show that forward rates satisfy covered interest parity (CIP) at daily and lower frequencies. Therefore, forward rates reflect interest rate differentials:

$$f_t - s_t = i_t^* - i_t$$

where i_t^* and i_t denote the foreign and domestic nominal risk-free rates over the maturity of the monthly forward contracts. This gives the log currency excess return as:

$$rx_{t+1} \approx i_t^* - i_t - \Delta s_{t+1}$$

1.4.3 Transaction Costs

Given the investor buys the foreign currency or equivalently sells the dollar forward at the bid price (f^b) in period t , and sells the foreign currency or equivalently buys the dollar at the ask price (s_{t+1}^a) in the spot market in period $t+1$, the net log currency excess return for going long in foreign currency is:

$$rx_{t+1}^l = -f_t^b + s_{t+1}^a.$$

Similarly, the net log excess return from longing the dollar and shorting the foreign currency is:

$$rx_{t+1}^s = -f_t^a + s_{t+1}^b.$$

1.4.4 Exchange Rate Movements

We seek to isolate information contained in the exchange rate movements of the currencies underlying the portfolio carry trade. This means we must separate the exchange rate appreciations from the interest rate carry. We do this by transacting solely in the spot markets, removing the forward contracts from the computation of the currency returns. This leaves us with net log currency returns as:

$$rs_{t+1}^l = s_{t+1}^b - s_t^a.$$

1.4.5 Portfolio Construction

We sort currencies on forward discounts. We use H to denote the set of currencies in the portfolio comprising the highest 20% of interest rates in time t . We use L to denote

the set of currencies in the portfolio comprising the lowest 20% of interest rates in time t .

This defines our currency traded risk factor, CTR , as:

$$CTR_{t+1} = \frac{1}{N_H} \sum_{i \in H} rs_{t+1}^i - \frac{1}{N_L} \sum_{i \in L} rs_{t+1}^i$$

We also construct the returns to the portfolio carry trade, or the ‘slope’ factor “ HML ” from LRV(2011) to contrast the explanatory power of CTR and HML on global equity returns. This allows us to isolate interest rate carry from the portfolio carry trade to contrast the explanatory power of information embedded in exchange rate movements and interest rates. LRV (2011) define HML as:

$$HML_{t+1} = \frac{1}{N_H} \sum_{i \in H} rx_{t+1}^i - \frac{1}{N_L} \sum_{i \in L} rx_{t+1}^i$$

We can extract the interest carry returns embedded in the portfolio carry trade by simply subtracting CTR_t from HML_t .

$$i_t^* - i_t = \frac{1}{N_H} \sum_{i \in H} rx_{t+1}^i + \frac{1}{N_L} \sum_{i \in L} rs_{t+1}^i - \frac{1}{N_L} \sum_{i \in L} rx_{t+1}^i - \frac{1}{N_H} \sum_{i \in H} rs_{t+1}^i$$

1.4.6 Empirical Testing

Our empirical tests begin with estimating vector auto-regressions to determine if CTR is significant in explaining global equity returns. We then test for Granger causality to determine if currency movements explain subsequent equity movements, and vice versa. Following the determination of a statistical relation between CTR and global equity returns, we utilize unidentified components models to test if the series contain stochastic trends. The idea behind this is to shed more light on their intertemporal relation. If we can

decompose their time series into cyclical, seasonal, or idiosyncratic components, we may have a basis for comparing the stochastic components generating the evolutions of their market prices. Employing spectral density analyses from parameter estimates from the unidentified components models of the two series, we can obtain period estimates for both, in interpretable monthly units. If the existence of stochastic cyclical components from both series occur at similar frequencies, this could bare supporting evidence for currency and equity returns revolving around a common stochastic driver, IE: risk aversion.

First, we wish to determine the existence of a relationship between CTR and global equity returns.

Hypothesis 1:

H_{A1} : CTR is significant in explaining global equity returns

Second, we wish to determine if there is an intertemporal, or directional relation between CTR and global equity returns.

Hypothesis 2:

H_{A2} : CTR Granger causes global equity returns

Third, we wish to determine if such an intertemporal relation is bidirectional or unidirectional.

Hypothesis 3:

H_{A3} : Global equity returns Granger cause CTR

Fourth, we wish to determine if aggregate exchange rates is related to the interest rate carry earned from the portfolio carry trade and if interest rate carry is related to global equity returns.

Hypothesis 4:

H_{A4a}: CTR Granger causes Carry

H_{A4b}: Carry Granger causes CTR

H_{A4c}: Carry Granger causes MXWO

H_{A4d}: MXWO Granger causes Carry

Fifth, we wish to determine if there exists a common stochastic cyclical component that exchange rates and equity returns revolve around. Such an existence, would support a systematic link between currencies and equities, IE; risk aversion.

Hypothesis 5:

H_{A5a}: CTR contains a stochastic cyclical component

H_{A5b}: Global Equity returns contain a stochastic cyclical component

We control for global, lagged monthly forex and equity volatility. Equity volatility is the monthly volatility of daily returns for the MSCI World index. MXWO volatility is computed as the monthly realized volatility of the logged MXWO daily returns. The currencies volatility metric is computed using the framework of Menkhoff, Sarno, Schmeling and Schrimpf (2012). They're results indicate the superiority of an averaged forex volatility proxy to other microstructure and macro variable in explaining the cross

section of currency returns and shocks to equities volatility. These include a global bid-ask spread, the TED spread and Pastor/Stambaugh liquidity measure. The log daily return series are used for each currency k on each day τ in our sample. We then average over all currencies available on any given day and average daily values up to the monthly frequency. Unlike MSSS, we employ squared returns for our volatility calculations as opposed to absolute deviations. These values are averaged to obtain one global, monthly forex volatility metric, given by

$$\sigma_t^{FX} = \frac{1}{T_t} \sum_{\tau \in T_t} \left[\sum_{k \in K_\tau} \left(\frac{r_\tau^2}{K_\tau} \right) \right]$$

where K_τ denotes the number of available currencies on day τ and T_t denotes the number of trading days in month t .

Addressing the issue of stationarity in the time series, we perform Dickey Fuller tests for unit roots on the logged monthly return series of each of our variables, including controls: *mxw*, HML, CTR, Carry, *mxw_vol* and *fx_vol*.

To avoid assumption of joint log-normality between each of our series, we also estimate each of our return series and corresponding empirical tests in simple returns versus logged returns. This does not alter our results.

Toda and Yamamoto (1995) show how VARs can be estimated in levels and test general restrictions on the parameter matrices even if the processes may be integrated or cointegrated of an arbitrary order. Further, they demonstrate validity of standard asymptotic theory in usual lag selection procedure to a possibly integrated or cointegrated VAR (given the order of integration of the process does not exceed the true lag length of

the model). Our VAR is formulated in log returns. We test for cointegration on each combination of endogenous and control variables.

Fitting a vector auto regression of the correct order can be important for obtaining meaningful results. We employ several methods for choosing the lag order of the VAR to fit. These include Akaike's information criterion, Schwarz's Bayesian information criterion, and the Hannan and Quinn information criterion, and final prediction error. A sequence of likelihood-ratio tests statistics for all the full VARs of order 60, or five years, are tested.

A VAR models variables as linear functions of their own lags, lags of the other endogenous variables, and possibly additional exogenous variables. A VAR may be described as the reduced form of a system of dynamic simultaneous equations. In our vector auto-regressions and tests for Granger causality, we estimate regressions of the following form:

$$mxw_t = \gamma_0 + \sum_{i=1}^n \alpha_i CTR_{t-i} + \sum_{j=1}^n \beta_j mxw_{t-j} + \sum_{k=1}^n \rho_k X_{t-k} + \mu_{1t}$$

$$CTR_t = \partial_0 + \sum_{i=1}^n \omega_i CTR_{t-i} + \sum_{j=1}^n \delta_j mxw_{t-j} + \sum_{k=1}^n \varphi_k X_{t-k} + \mu_{2t}$$

and

$$mxw_t = h_0 + \sum_{i=1}^n \alpha_i HML_{t-i} + \sum_{j=1}^n \beta_j mxw_{t-j} + \sum_{k=1}^n \rho_k X_{t-k} + \mu_{1t}$$

$$HML_t = h_0 + \sum_{i=1}^n \alpha_i mxw_{t-i} + \sum_{j=1}^n \beta_j mxw_{t-j} + \sum_{k=1}^n \rho_k X_{t-k} + \mu_{2t}$$

and

$$mxw_t = c_0 + \sum_{i=1}^n \alpha_i Carry_{t-i} + \sum_{j=1}^n \beta_j mxw_{t-j} + \sum_{k=1}^n \rho_k X_{t-k} + \mu_{1t}$$

$$Carry_t = c_0 + \sum_{i=1}^n \alpha_i mxw_{t-i} + \sum_{j=1}^n \beta_j mxw_{t-j} + \sum_{k=1}^n \rho_k X_{t-k} + \mu_{2t}$$

where mxw , CTR , and HML are logged returns. $Carry$ is defined above as the difference between HML and CTR . X_t represents our control variables, and μ_{1t} and μ_{2t} are mutually uncorrelated white noise errors. Obtaining the coefficient estimates on mxw and CTR in the equations (1) and (2) will provide evidence for one of three empirical relationships: unidirectional causality, bi-directional causality, or independence between global equities and aggregate exchange rates.

Empirical researchers often employ Granger causality tests for determining if a time series helps forecast another. These regressions reflect mere correlations as opposed to true causality. Predictive causality remains a necessary condition for true causality. The objective of this study is to uncover a directional relationship between the forex and equity markets. To test for existence of such relation, we employ tests for Granger causality from our reduced form VAR equations and fitted parameter estimates. VARs allow researchers to investigate the usefulness of one variable in predicting another. We perform Wald tests to investigate Granger causality between endogenous and control variables in our VAR's.

1.4.7 Out-of-Sample Tests for Forecasting Power

Our forecasting methodology employs the common benchmark monthly OLS regressions with Newey West (1987) critical values for our t-statistics, account for serial correlation and heteroskedasticity. I regress monthly logged excess returns of the MSCI All World Index©, denoted mxw , on lagged monthly values of our predictive currency metric, CTR .

Our out-of-sample testing period begins January 1999 and ends May 2017. I utilize recursive rolling regressions that estimate coefficients starting with a 50-month window to forecast month 51, and progressing in one-month steps. By the end of our sample period, we use 220 monthly observations to predict month 221, May 2017.

Let mxw_{t+1} and CTR_t denote the continuously compounded return of the MSCI All World Index© and the continuously compounded spot return from a portfolio long high interest currencies and short low interest rate currencies, respectively. Our dependent variable – global equity returns - are computed using the mxw index values from day 1 in month t to the ultimate day in month t . Our independent variable, CTR , is computed in a similar fashion, currency spot values from day 1 in month t to the ultimate day in month t . This ensures all information used in computing our predictive variable is known entirely prior to the time span in which subsequent equity return values occur. To be precise, known at the close of the previous trading day. This means that our composite global risk aversion measure is known, say, at the close of last trading day in month 1, and may be used to enter a global stock portfolio position at the close of the following trading day – the first trading day in month 2.

Defining the unit time interval to be 1 month, the recursive rolling regressions of our return series on lagged values of our currency-traded-risk is as follows:

$$mxw_{t+1} = a(h) + b(h)CTR_t + u_{t+1} .$$

1.5 CTR and Equities over Time

We begin by visually inspecting the evolution of global equity returns and CTR. We graph CTR and global equity returns proxied by the MSCI all World index, MXWO. First, over our entire sample. Then we zoom in on the periods from 2000 – 2008 and 2008 – 2017.

Figure 1.1 CTR and MXWO Returns over Time, Full Sample 1990 - 2017

Figure 1.2 CTR and MXWO Returns over Time, 2000 – 2008

Figure 1.3 CTR and MXWO Returns over Time, 2008 – 2017

Next, we examine the Global Financial Crisis and most recent two-year history of CTR and MXWO returns. Below we graph an indexed CTR value by setting CTR's initial index value to MXWO's index value at the beginning of the period. We see the appearance of CTR portending the downtrend in global equity returns by its marked downturn in the first half of 2008. The bottoming out of CTR in the first months of 2009, appears to lead the rebound of global equities.

Figure 1.4 MXWO and CTR Indices: Global Financial Crisis

Figure 1.5 MXWO and CTR Indices: Recent Performance

We report summary statistics for CTR, MXWO returns, our controls, the returns to the portfolio carry trade, HML, and the isolated returns from the interest rate carry, denoted Carry.

Table 1.1 Summary Statistics

Summary statistics						
	CTR	<i>mxw</i>	<i>mxw_vol</i>	<i>fx_vol</i>	HML	Carry
Summary Statistics						
Mean	-0.0064	0.0028	0.00798	0.0053	0.0161	0.0225
Std. dev.	0.0277	0.0424	0.0046	0.0021	0.0404	0.0294
Skewness	-1.0892	-0.7163	2.937	2.9481	1.6911	4.2444
Kurtosis	5.9473	5.3578	17.5409	17.9177	10.842	23.901
Ar(1)	0.1499	0.0408	0.7127	0.6201	0.5501	0.9099
Correlation matrix						
CTR	1	0.3295	-0.249	-0.3497	0.6863	0.0032
<i>mxw</i>		1	-0.327	-0.2277	0.1815	-0.0603
<i>mxw_vol</i>			1	0.6897	0.0145	0.2542
<i>fx_vol</i>				1	-0.1209	0.1627
HML					1	0.7295
Carry						1

1.6 Results

Interpolating critical values based on tables reported in Fuller (1996), we reject the null hypothesis of a unit root for the logged and simple monthly return series of each of our endogenous and control variables: *mxw*, *HML*, *CTR*, *Carry*, *mxw_vol* and *fx_vol*. We note the strong rejection of each variable, with the exception of *Carry*, rejected with a Z-stat of -3.944. This implies a MacKinnon approximate p-value for $Z(t) = 0.0017$. This is clear rejection at all standard significant levels but remains the highest p-value we obtain in our Dickey Fuller tests of test variables. This is intuitive given the persistent nature of sovereign interest rates.

We strongly reject cointegration for each combination of our endogenous and control variables, both in logged and simple monthly returns. We report the Trace statistics for *CTR* and the *MXWO* logged return series.

Table 1.2 Tests for Cointegration

Johansen Tests for Cointegration					
Variables: <i>mxw</i> & <i>CTR</i>					
Trend:	Constant			Observations	321
Sample Period:	August 1990 - May 2017			Lags	2
Maximum Rank	Parms	LL	Eigenvalue	Trace Statistic	5% Critical Value
0	6	1171.5514		236.8277	15.41
1	9	1244.3613	0.36469	91.208	3.76
2	10	1289.9653	0.24734		

We obtain a strong consensus for lag-order (2) across Akaike's information criterion (AIC), Hannan and Quinn information criterion (HQIC), final prediction error (FPE), and likelihood-ratio tests (LR). We obtain similar consensus for *mxw* with *HML* and *Carry*.

Table 1.3 Selection Order Criteria

Selection-order criteria								
Sample: Dec1990 - May2017,					Number of Observations = 311			
Lag	LL	LR	d.f.	p-values	FPE	AIC	HQIC	SBIC
0	1234.31				1.20E-06	-7.92485	-7.91523	-7.9008 *
1	1242.61	16.599	4	0.002	1.20E-06	-7.9525	-7.92366	7.88035
2	1251.33	17.439	* 4	0.002	1.20E-06 *	-7.98285	* -7.93478	* -7.8626
3	1254.66	6.6504	4	0.156	1.20E-06	-7.97851	-7.91122	7.81016
4	1259.11	8.9018	4	0.064	1.20E-06	-7.98141	-7.89489	7.76496
5	1260.99	3.7543	4	0.44	1.20E-06	-7.96776	-7.86201	-7.7032
6	1262.24	2.5082	4	0.643	1.20E-06	-7.9501	-7.82513	7.63745

Endogenous: *mxw*, CTR

We proceed by fitting our VARs of lag order (2) as determined by consensus from the above selection-order criteria. The results are as follows:

Table 1.3 VAR Results

Vector Autoregression							
Sample Period:		Aug 1990 - May 2017			Observations		
Log likelihood		4394.416			AIC		
FPE		1.60E-17			HQIC		
Det(Sigma_ml)		1.27E-17			SBIC		
Equation	Parms	RMSE	R-squared	chi2	P>chi2		
mxw	9	0.041172	0.0902	31.6328	0.0001		
CTR	9	0.027573	0.0421	14.0309	0.081		
mxw_vol	9	0.003117	0.5634	411.611	0		
fx_vol	9	0.001598	0.4342	244.761	0		
Equation		Coefficient	Std. Err.	z	P>z	[95% Confidence]	
mxw	L1. mxw	-0.0524	0.0618	-0.85	0.397	-0.1735	0.0687
	L2. mxw	-0.0715	0.0609	-1.17	0.240	0.1908	0.0479
	L1. CTR	0.3129	0.0933	3.35	***	0.1300	0.4957
	L2. CTR	-0.2070	0.0933	-2.22	**	0.3899	-0.0241
	L1. mxw_vol	-1.7108	0.9062	-1.89	*	3.4869	0.0654
	L2. mxw_vol	0.2008	0.8567	0.23		1.4783	1.8800
	L1. fx_vol	0.5516	1.7421	0.32		2.8628	3.9659
	L2. fx_vol	3.0278	1.7280	1.75		0.3590	6.4147
CTR	L1. mxw	0.0556	0.0414	-1.34		0.1367	0.0255
	L2. mxw	0.0046	0.0408	-0.11		0.911	-0.0845
	L1. CTR	0.1589	0.0625	2.54	**	0.0364	0.2813
	L2. CTR	0.0903	0.0625	1.44		0.0322	0.2128
	L1. mxw_vol	0.6191	0.6069	1.02		0.5704	1.8086
	L2. mxw_vol	0.5314	0.5737	-0.93		1.6559	0.5931
	L1. fx_vol	1.3089	1.1667	-1.12		3.5955	0.9777
	L2. fx_vol	0.7378	1.1573	0.64		1.5304	3.0059
mxw_vol	L1. mxw	0.0195	0.0047	-4.16	***	0.0286	-0.0103
	L2. mxw	0.0075	0.0046	-1.63		0.102	0.0166
	L1. CTR	0.0207	0.0071	-2.93	***	0.0345	-0.0068
	L2. CTR	0.0134	0.0071	1.90	*	0.0005	0.0272
	L1. mxw_vol	0.4802	0.0686	7.00	***	0.3458	0.6147
	L2. mxw_vol	0.1977	0.0648	3.05	***	0.0706	0.3248
	L1. fx_vol	0.1394	0.1319	1.06		0.1191	0.3979
	L2. fx_vol	0.1710	0.1308	-1.31		0.4273	0.0854
fx_vol	L1. mxw	0.0034	0.0024	-1.43		0.0081	0.0013
	L2. mxw	0.0013	0.0024	-0.54		0.589	0.0034
	L1. CTR	0.0048	0.0036	-1.31		0.0119	0.0023
	L2. CTR	0.0029	0.0036	-0.81		0.416	-0.0100
	L1. mxw_vol	0.0543	0.0352	1.54		0.0146	0.1233
	L2. mxw_vol	0.0265	0.0333	0.80		0.0387	0.0917
	L1. fx_vol	0.3837	0.0676	5.67	***	0.2511	0.5162
	L2. fx_vol	0.1121	0.0671	1.67	*	0.0194	0.2436

We report an R^2 of 9.02% for the global equity index return series. We note that in 2nd order VARs excluding our volatility controls, and R^2 of 6.13%. When we run OLS of mxw on CTR , (excluding volatility control variables as well as lags of mxw itself) we obtain an R^2 of 3.17%.

Table 1.4 Granger Causality Results

Granger causality Wald tests				
Entire Sample				
Equation	Excluded	χ^2	df	Prob > χ^2
mxw	CTR	14.982 ***	2	0.001
mxw	mxw_vol	4.489	2	0.106
mxw	fx_vol	4.435	2	0.109
mxw	ALL	27.499 ***	6	0.000
CTR	mxw	1.805	2	0.406
CTR	mxw_vol	1.232	2	0.54
CTR	fx_vol	1.291	2	0.524
CTR	ALL	4.746	6	0.577
mxw_vol	mxw	18.933 ***	2	0.000
mxw_vol	CTR	11.293 ***	2	0.004
mxw_vol	fx_vol	2.018	2	0.365
mxw_vol	ALL	40.799 ***	6	0.000
fx_vol	mxw	2.213	2	0.331
fx_vol	CTR	2.588	2	0.274
fx_vol	mxw_vol	6.262 **	2	0.044
fx_vol	ALL	17.950 ***	6	0.006

Sample Period: August 1990 - May 2017, 319 monthly observations

We reject the null hypothesis that CTR does not Granger cause global equity returns with a p-value of χ^2 tests of 0.001%. Conversely, we cannot reject the null hypothesis that global equity returns do not Granger cause CTR . We note, we reject the null hypothesis that CTR does not Granger cause global equity volatility, while we do reject the ability of any variable in our test to explain subsequent FX volatility.

In similar tests with HML and Carry in place of CTR, we find that there is bidirectional association between HML and mxw, as well as Carry and mxw. The Chi-squared statistic for HML Granger causing mxw is 18.528, p-value of 0.000, while the Chi-squared statistic for mxw Granger causing HML is 13.355, p-value of 0.001. Interestingly, the Chi-squared statistic for Carry Granger causing mxw is 10.446, p-value of 0.005, while the Chi-squared statistic for mxw Granger causing Carry is nearly double, at 28.083, p-value of 0.000. These results support the mechanical link between exchange rates and global equity returns initializing in currencies and responding in equities, and this unidirectional association being independent of interest rates.

We note similar results obtained when replacing the level of equity volatility with the innovations in equity volatility. The Chi-squared statistic for CTR Granger causing innovations in mxw volatility is 9.0225, p-value of 0.011, while the Chi-squared statistic for mxw volatility Granger causing CTR is 1.8365, p-value of 0.399. We cannot reject the null hypothesis that CTR Granger causes innovations to global equity volatility, but not visa-versa. Interestingly, we also cannot reject the null hypothesis that FX volatility Granger causes innovations to equity volatility, with the Chi-squared statistic 25.146, p-value of 0.000. This relation is not bidirectional.

We now test CTR's forecasting power using out of sample tests. We report T-statistic's and R^2 's visually. Our results are robust to initial OLS window size in estimating our coefficients, in our rolling recursive regressions of expanding windows one in one-month steps. We report results both 50-month and 100-month starting windows to estimate our regression coefficients.

Figure 1.6 T-statistics of CTR_{t-1} on MXW_t , 50-Month Starting Window

Figure 1.7 T-statistics of CTR_{t-1} on MXW_t , 100-Month Starting Window

Figure 1.8 R^2 's Over Time: CTR_{t-1} on MXW_t , 50-Month Starting Window

Figure 1.9 R^2 's Over Time: CTR_{t-1} on MXW_t , 100-Month Starting Window

1.7 Conclusion

We construct a currency traded risk factor that forecasts returns of global equity indices and changes in global equity volatility. We show that this predictive power is not bidirectional. We find high interest rate currencies proxy as risk-on asset class. Low interest rate currencies proxy as a risk-off asset class. Innovations in these currencies values predict monthly returns on a global stock portfolio. We document this relationship coming into existence October 2008. Our findings support the hypothesis that innovations in currency values track time varying risk premia and forecast aggregate stock market returns of developed countries.

CHAPTER 2: FORECASTING RETURNS ON A GLOBAL STOCK PORTFOLIO WITH THE VARIANCE RISK PREMIUMS OF HIGH AND LOW INTEREST RATE CURRENCIES

2.1 Introduction

Forecasting stock market returns is one of the most sought pursuits in empirical finance. Many of the robust findings in the predictive literature stem from using macroeconomic variables to forecast long term, multi-year returns of the stock market. This long run predictability may be more attributable to mean reversion of risk premia in financial markets than to the ex-ante explanatory power of fluctuating macroeconomic variables (e.g. (Goyal and Welch 2006, Lee 2018)).

Risk premia priced into financial assets reflects the risk aversion levels of investors. To hone in on return variation at higher frequencies requires accurate tracking of time varying risk aversion levels. Risk aversion has been measured empirically by the Variance Risk Premium, VRP. VRP can be observed as the difference between implied volatility and realized volatility. The VRP in equity indices has been found to predict aggregate stock market returns. The volatility dynamics captured by VRP offer an observable measure of risk aversion levels. This volatility metric has been interpreted as incorporating the equilibrium effects of economic uncertainty and time-varying volatility of volatility (Bollerslev et al. 2009). Zhou et. al (2014) find that an aggregated global VRP adds to the predictive ability of country specific VRP's – emphasizing the forecasting power of a global perspective. A rising tide lifts all boats, so to speak.

The difference in implied volatility and realized volatility summarizes the difference between investors' expectations on future price movements, and their most

recent experience of them. Inherently, this spread between expectation and experience is the most precise measure of the expected change in price direction and next period economic state. Wherein, the most recent innovation of volatility is only one factor investors are computing into their immediate expectation of future volatility. In purchasing options at greater prices across the span of strike values, investors bid up implied volatility. This implied volatility must embed realized volatility as well as all other available information. When the difference between what happened and what is expected to happen spreads wider, the market is signaling increasing disagreement in beliefs. Importantly, this disagreement in beliefs cannot be observed by implied volatility alone. To accurately gauge the amount of disagreement, realized volatility must be accounted for as a natural input of the current state of the market. Therefore, the amount of uncertainty above this interpretable benchmark is the key driver behind the forecasting power of the variance risk premium.

As we see empirically, high (low) variance risk premia predict high (low) subsequent returns. In other words, when the market bids up implied volatility because it expects increasing return variation, most strikingly, subsequent positive returns materialize more so than negative returns. This empirical result may be rationalized by a random walk model of asset prices combined with the depression of prices at the onset of a perceived degrading economic period. Put another way, when the market is expecting surprises, subsequent returns are positive more often than they are negative. Going to the opposite logical extreme, say realized volatility overtakes implied volatility. This would cause a negative variance risk premium and forecast with statistical significance negative future returns. Put another way, when the market has just been surprised, subsequent returns are

negative more so than they are positive. Which infers that challenges don't kill us, surprises kill us.

2.2 Relevant Literature

Zhou et. al (2014) find that an aggregated global VRP adds to the predictive ability of country specific VRP's – emphasizing the forecasting power of a global perspective. Lee (2018) finds that spot returns of currencies underlying the portfolio carry trade track time varying global risk premia and forecast global equity index returns. Motivated by these findings, I extend the global equity VRP construction to the forex markets using implied and realized volatilities of currencies. I find the variance risk premiums of high interest rate currencies explain a significant amount of subsequent return variation in global equity indices. The currency VRP relation is congruent with the equity VRP relation, with high (low) premia predicting (high) low future equity returns.

This understanding of the predictive power of the variance risk premium is further corroborated by the negative asymmetry of the VIX model (Hibbert et al. 2006). Implied volatility is backed out from both put prices and call prices. Meaning, increasing implied volatility can come from the market bidding up put prices because it's expecting a negative return, or by bidding up call prices because it's expecting a positive return. Hibbert et. al (2006) find negative asymmetry in the S&P 500 VIX index. This would imply the market's aptness to over value put options – hence VIX's nickname “the Fear Gauge”. When implied volatility is high, it is more likely the market is bidding up put prices rather than call prices. Meaning, the market is expecting volatility to the downside and therefore depressing concurrent stock prices as investors are pricing in heightened risk premia. This follows the common perception that options investors and dealers bid up put prices to protect against

losses during market downturns due to the fear of additional future losses (e.g., Bollen and Whaley, 2004). This is congruent with the VRP's positive relation to future returns. If on average, an increasing VRP was caused by the market expecting positive price movements and therefore bidding up call prices, then lower risk premia would be priced into concurrent prices - raising them. Higher prices now induce lesser returns next period. The VRP's positive relation with future returns is vindicated by the empirical negative asymmetry in the S&P 500 VIX index. Giot (2005) finds that negative returns for the underlying index are associated with much greater relative changes in the corresponding implied volatility index than positive returns, supporting the behavioral postulation that investors suffer from fear.

Lee (2018) finds that high interest rate currencies proxy as a risk-on asset class, whereas low interest rate currencies proxy as a risk-off asset class. This is intuitive. By investing in the portfolio carry trade, US investors load up on global risk (Lustig, Roussanov and Verdelhan 2011). The forex markets allocate capital to these currencies under the assumption of collecting a risk premium. Excess returns from the carry trade necessitate failure of uncovered interest parity, UIP... currency excess returns compensate investors for higher risk-exposure and UIP deviations reflect time-varying risk premia (Fama, 1984; Engel, 1984). Thus, the world's markets' consensus of risk premia will be reflected in these currencies. As Lee (2018) shows, this risk premia in currencies reflects global risk aversion and leads global equity index returns.

2.3 Data Collection

Our sample set consists of the top 24 most traded currencies by volume – excluding the New Zealand dollar due to lack of implied volatility data. Our sample period starts

January 1, 1999 and ends April 30, 2017. I gather daily currency spot rates and daily 1-month forward data from Thomson Reuter's Datastream. I gather daily implied volatility values of individual currencies from Bloomberg. As standard in the literature, we use the United States dollar as our base currency. The currency sample set by average daily turnover includes: Euro, Japanese yen, Pound sterling, Australian dollar, Canadian dollar, Swiss franc, Chinese yuan renminbi, Swedish krona, Mexican peso, Singapore dollar, Hong Kong dollar, Norwegian krone, Turkish lira, Indian rupee, Russian ruble, Brazilian real, South African rand, Danish krone, Polish zloty, New Taiwan dollar, Thai baht and Malaysian ringgit.

For our global equity proxy, we obtained daily closing prices for the MSCI World index, ticker symbol MXWO, from Bloomberg. We chose MXWO index as our proxy for global equity returns based on its greatest mutual correlation to other alternative global equity indices. This index is value weighted across 23 developed countries, including nearly all of our sample of 24 total currencies. The methodology for construction of the MXWO index can be found at <https://www.msci.com/world>.

Two important notes: firstly, empirical findings of equity VRP's forecasting power rely crucially on employing model-free implied volatility observed through the VIX index. Black-Scholes assumes lognormality of underlying instrument prices. Whereas the VIX index is a model free measure that observes the market's ex ante risk-neutral expectations of future return variation. The best forecast of future volatility has shown to come from the market's expected volatility as analogue-d by the VIX "model-free" measure. The VIX is constructed in real time using put and call options with strike prices spanning zero to infinity (bounded by market liquidity at each strike price – when there are two consecutive

strikes at zero bids). This model-free measure does not rely on inversion of the Black-Scholes formula to back out implied volatility, and has shown empirically to give a strikingly accurate approximation to the true (unobserved) risk-neutral expectation of the future variation. In contrast, due to lack of available historical options data on currencies, we rely on model dependent implied volatility values observed through inversion of the Black-Scholes options pricing model.

Secondly, empirical findings of equity VRP's forecasting power employ high frequency intra-day returns to compute realized volatilities. It is well documented in the literature that higher speed measures generally afford significantly more accurate ex post observations of return variation than sample variances based on daily frequency (e.g., Andersen et al. 2001; Barndorff et al. 2002; Meddahi 2002). Due to lack of historical intra-day data on all 25 currencies in this study, we use daily returns to compute monthly realized volatilities. The results obtained with these cruder metrics of implied and realized volatilities underlying our VRP construction are encouraging.

Table 2.1 Summary Statistics

Table 1						
Summary statistics						
	mxw_t	$VRP(FX^{HI})_t$	$VRP(FX^{HI})_{t-1}$	$\Delta VRP(FX^{HI})_{t-1}$	$VRP(FX^{LO})_t$	$VRP(FX^{LO})_{t-1}$
Summary statistics						
Mean	0.0009	2.9677	-0.0019	2.0232	-0.01379	
Std. dev.	0.044	0.9431	0.8507	0.9902	0.7605	
Skewness	-0.7167	1.8026	2.9327	3.071	1.5697	
Kurtosis	5.4189	9.3791	23.0042	18.0229	13.3208	
AR(1)		0.5966		0.6991		
Correlation matrix						
mxw_t	1	0.1367	0.1921	0.2205	0.0461	0.0662
$VRP(FX^{HI})_t$		1	0.5966	0.2011	0.5392	0.4294
$VRP(FX^{HI})_{t-1}$			1	0.4494	0.308	0.5392
$\Delta VRP(FX^{HI})_{t-1}$				1	0.1903	0.4494
$VRP(FX^{LO})_t$					1	0.6991
$VRP(FX^{LO})_{t-1}$						1
$\Delta VRP(FX^{LO})_{t-1}$						1

The sample period extends from January 1999 to April 2017. All variables are reported in monthly percentages where appropriate.

2.4 Methodology and Empirical Testing

2.4.1 Constructing Currency Variance Risk Premiums

We sort currencies by their forward discounts on day 1 in month t into five portfolios. We use FX^{HI} to denote the set of currencies in the portfolio comprising the highest 20% of interest rates in time t . We use FX^{LO} to denote the set of currencies in the portfolio comprising the lowest 20% of interest rates in time t . Next, we compute their realized volatilities from month t 's daily spot returns. Then, we back out their implied volatilities from options prices by inversion of the Black-Scholes formula – as reported by Bloomberg. These implied volatilities reported from Bloomberg as annualized values, we convert to monthly values through dividing by the square root of twelve. Next, we take the difference between the implied volatilities average in day 1 of month t , and the realized volatilities average over the course of month t . Finally, we take the average implied and realized volatilities of the currencies in portfolios 1 and 5. Critical to eliminating the possibility for hindsight bias, all information to compute currency variance risk premiums are observed in month t and used to forecast equity returns in month $t+1$. We employ VRP averages from high and low interest rate currencies in our empirical tests, calculated as follows:

$$VRP(FX^{HI})_t = IV(FX^{HI})_t - RV(FX^{HI})_t,$$

and

$$VRP(FX^{LO})_t = IV(FX^{LO})_t - RV(FX^{LO})_t.$$

These two variants of forex VRP allow us to test more precisely, where the explanatory power is coming from. This is to ask, what currencies' volatilities are tracking

the world's markets' consensus of risk aversion – high interest rate currencies, or low interest rate currencies?

2.4.2 Forecasting Returns on a Global Stock Portfolio

Traditional forecasting variables such as the default spread, the price-dividend ratio, and the price-earnings ratio have been observed as highly persistent with first-order autocorrelations greater than .90. In contrast, the serial correlation for $VRP(FX^{HI})$ equals 0.5965. When we difference $VRP(FX^{HI})$, the first order autocorrelation drops to -0.2763. This alleviates the common pitfall in predictive modeling of highly persistent variables and the possibility of spurious regressions.

Our forecasting methodology employs the common benchmark monthly OLS regressions with Newey West (1987) critical values for our t-statistics. I regress logged excess returns of the MSCI All World index, denoted mxw , on lagged values of our variance risk premium metrics. Our t-statistics account for serial correlation and heteroskedasticity. In regressions with return horizons 2 months or greater, I account for overlapping regressions following Hodrick (1992). Our tests are all on monthly observations of both our mxw return series, and our forecasting variables, $VRP(FX^{HI})$, and $VRP(FX^{LO})$. I perform regressions on 1 to 12-month horizon returns. Our sample period begins January 1999 and ends May 2017.

Let $mxw_{t+\tau}$, $VRP(FX^{HI})_t$, and $VRP(FX^{LO})_t$ denote the continuously compounded return from time t to $t + \tau$, and the variance risk premium metrics at time t . The returns are computed using the mxw index values from day 1 in month $t + \tau$ to the ultimate day in month $t + \tau$. This ensures all information used in computing our predictive

variables are known prior to the time span in which our subsequent return values occur. Defining the unit time interval to be 1 month, the multi-period return regressions of our return series on lagged values of the three VRP variants may be expressed as

$$\frac{1}{h} \sum_{j=1}^h mxw_{t+j} = a(h) + b(h)VRP(FX^{HI})_t + u_{t+h,t} ,$$

and

$$\frac{1}{h} \sum_{j=1}^h mxw_{t+j} = a(h) + b(h)VRP(FX^{LO})_t + u_{t+h,t} .$$

Moving to out of sample testing, I utilize recursive rolling regressions that estimate coefficients starting with a 50-month window to forecast month 51, and progressing in one-month steps. By the end of our sample period, we use 220 monthly observations to predict month 221, May 2017.

Defining the unit time interval to be 1 month, the recursive rolling regressions of our return series on lagged values of our currency risk metrics comprising our global risk aversion measure are as follows:

$$mxw_{t+1} = a(h) + b(h)VRP(FX^{HI})_t + u_{t+1} ,$$

and

$$mxw_{t+1} = a(h) + b(h)VRP(FX^{LO})_t + u_{t+1} ,$$

for our univariate tests in predictive variable levels. Next, we conduct a multivariate test, utilizing both risk premium variables,

$$mxw_{t+1} = a(h) + b(h)VRP(FX^{HI})_t + c(h)VRP(FX^{LO})_t + u_{t+1}.$$

We test our risk premium variables further using their first differences,

$$mxw_{t+1} = a(h) + b(h)VRP(\Delta FX^{HI})_t + u_{t+1},$$

and

$$mxw_{t+1} = a(h) + b(h)VRP(\Delta FX^{LO})_t + u_{t+1}.$$

for our univariate tests, and

$$mxw_{t+1} = a(h) + b(h)VRP(\Delta FX^{HI})_t + c(h)VRP(\Delta FX^{LO})_t + u_{t+1},$$

for our multivariate test combining the variance risk premiums from both high interest rate and low interest rate currencies.

2.5. FX Variance Risk Premiums and Equities over Time

Figure 2.1 VRP's of High and Low Interest Rate Currencies

Figure 2.2 $VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 2.3 $VRP(\Delta FX^{HI})_{t-1}$ on MXW_t

Figure 2.4 $VRP(\Delta FX^{HI})_{t-1}$ on MXW_t , 2008 - 2010

2.6. Results

Interpolating critical values based on tables reported in Fuller (1996), we reject the null hypothesis of a unit root for the logged and simple monthly return series of each of our dependent and dependent variables: mxw , HML , CTR , $VRP(FX^{HI})$, and $VRP(FX^{LO})$. We note the strong rejection of each variable, with Z-statistics greater in absolute magnitude than -7.423. We strongly reject cointegration for each of our forecasting variables and logged return series.

Forecasting power strengthens when regressing $MXWO$ returns on changes in $VRP(FX^{HI})$. This would suggest the importance of surprises in affecting concurrent market prices and thereby subsequent returns.

The variance risk premiums of high interest rate currencies carry the greatest explanatory power on subsequent equity returns. We report our results visually.

Figure 2.5 T-statistics of $VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 2.6 T-statistics of $\Delta VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 2.7 R^2 's of $VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 2.8 R^2 's of $\Delta VRP(FX^{HI})_{t-1}$ on MXW_t

2.7 Conclusion

The innovations in variance risk premiums of high interest rate currencies, taken as first-differences, or rates of change contain predictive explanatory power on monthly returns of a global stock portfolio. The existence of this relation came into existence on October 2008. The statistical significance of the relation, measured both by R^2 's and Newey West (1987) standard error constructed T-statistics, has remained stable since the onset of the Global Financial Crisis.

CHAPTER 3: CURRENCY-TRADED-RISK; A GLOBAL RISK FACTOR

3.1 Introduction

Theoretically, return expectation is intimately linked to time varying risk premia. Finding ways to accurately estimate the evolution of risk premia across markets and time hold vast implications for portfolio managers, investors, and most notably central bank policy makers. Risk premia priced into financial assets reflect global risk aversion levels by distilling information connecting the financial positions of investors, liquidity risk in financial markets, expectations of systematic risk, and time varying economic uncertainty. I propose a new theory of estimating global risk aversion by combining the forecasting power of two sources of risk premia. The first source comes from the markets' consensus of global systematic risk canalized by spot returns in the forex markets. The second source comes from the global economic uncertainty characterized by volatility risk aggregated from the variance risk premiums in high interest rate currencies. I find this combined measure of risk aversion forecasts next period's monthly global equity index returns with out of sample adjusted R^2 's ranging from of 9.8% to 14.4% between December 2008 – May 2017.

Risk premia priced into the world's financial markets tracks time varying risk aversion. Does risk aversion subsume the information contained in real time macro variables pertinent to explaining the concurrent trajectory of the global economy? This question delves into the mass psychology of consumption underpinning the cyclical output of the global economy. Such a question may be beyond the scope of empirical finance. However critical substance may remain; if we can precisely measure global risk aversion

we are afforded the best contemporaneous tool for building expectations of subsequent market paths.

The theory that forex markets track stochastic risk premia, summarize global risk aversion, and lead equity markets illuminates our understanding of financial globalization. There is a vast literature examining empirical correlations over time across the world's financial markets. As we know, the Global Financial Crisis was marked by many post-War extreme event firsts. The first time the U.S. housing market declined. The first-time multiple uncorrelated asset classes dropped simultaneously. The first time, contagion from one market spread so rapidly and completely across the globe! The theoretical underpinnings linking Carry-Traded-Risk and equity returns are corroborated by the empirical findings of another event first; the world's coming to Jesus moment to the reality of undeniable financial globalization. October 2008 marks the first month in our empirical findings where both our predictive measures of equity returns come into blatant and severe significance. Not only tracking both sources of risk premia within currency evolutions, but these two sources becoming definitively related to each other. October 2008 marks the beginning of consistently significant lead-lag relationship between spot returns to the carry trade currencies and variance risk premiums of those currencies.

On Saturday, September 20, Secretary Paulson and Federal Reserve Chair Ben Bernanke sent their bank bailout bill to Congress. The Dow bounced around 11,000 until September 29, when the Senate voted against the bailout. The Dow fell 777 points, over 7%, the most in any single day in history. The global markets screamed in the wake of this precipitating gash in the U.S. stock market: the MSCI All World Index dropped 6% in a

single day, the most since its inception in 1970. Trading in Brazil's Ibovespa was halted after falling 10%. The London FTSE crashed 15 percent.

In a desperate effort to restore stability, the Fed doubled its currency swaps with foreign central banks in Europe, England, and Japan, to an unprecedented \$620 billion. The governments of the world were running to fire hose liquidity in frozen credit markets. This would prove too little too late in the immediate aftermath. The following month saw a 13% drop in the Dow. A continued 34% drop by the end of the year and an eventual 50% decline through March 2009 from an all-time high just 18 months prior.

Positive(negative) currency returns lead positive(negative) variance risk premiums. The negative risk and return relationship is well documented in equities. These findings, (IE Bollen and Whaley, 2004, Hibbert et al. 2005, Giot (2005), etc.) show this similar lead-lag relationship in the S&P 500 returns and the VIX index. However, the information contained in the VRP is radically separate from the VIX. Returns lead the implied volatility. But once realized volatility is subtracted from implied volatility (VRP) a predictive metric of returns is extracted, (see Bollerslev et al. 2009, Zhou et. al 2014). Contrastingly, in the forex market, we observe CTR returns to lead variance risk premiums of CTR currencies with striking significance, out of sample. Most strikingly, these intertwined directional relationships, between CTR returns, CTR VRP's, and equity returns, all come into definiteness at the onset of the GFC – October 2008. Definiteness in statistical significance and consistency. We document near constant values of out of sample robust t-stat's and adjusted R^2 's between October 2008 to the end of our sample, May 2017 from recursive, expanding window regressions.

3.2 Relevant Literature

The need for accurately quantifying the markets' perceptions of risk is borne from numerous motivations; investment timing and speculation, monetary policy and central planning, risk management, etc. Measuring risk aversion in real time remains an elusive goal of financial economists. Long run risk models have generally focused on consumption growth. Consumption growth has been shown in the literature difficult to track in real time. There are many sophisticated methodologies designed to gauge economic conditions in high frequency using low frequency macroeconomic variables, such as real activity stock and flow values of output; IE the Arouba, Diebold and Scotti (2009) Business Conditions Index published by the Federal Reserve Bank of Philadelphia. Other models amalgamate economic and financial market macro variables. Goyal and Welch (2006) point out that these cannot predict equity returns meaningfully out of sample, thereby failing to capture time varying risk premia.

There have been incredible strides made recently in the predictive literature. Bollerslev et al. (2009) find the variance risk premium of the S&P 500 index forecasts quarterly returns of the S&P 500. Zhou et. al (2014) extend this variance risk premium to a global construction and document the added forecasting benefits on country specific stock index returns afforded by a global perspective. Duarte and Kapadia (2016) construct their Goliath-vs-David, GVD, variable from the annual change in the weight of the largest 250 firms in the aggregate stock market. They show GVD forecasts quarterly market returns with an out-of-sample R^2 of 6.3% in the 1976-2011 evaluation period.

3.3 Data Collection

We gather daily currency spot rates and daily 1-month forward data from Thomson Reuter's Datastream. Using the United States dollar as our base currency, the currency sample set by average daily turnover includes: Euro, Japanese yen, Pound sterling, Australian dollar, Canadian dollar, Swiss franc, Chinese yuan renminbi, Swedish krona, Mexican peso, New Zealand dollar, Singapore dollar, Hong Kong dollar, Norwegian krone, Turkish lira, Indian rupee, Russian ruble, Brazilian real, South African rand, Danish krone, Polish zloty, New Taiwan dollar, Thai baht and Malaysian ringgit. The beginning of the sample includes the Hong Kong dollar, Pound sterling, New Zealand dollar, Swiss franc, South African rand, Norwegian krone, Danish krone, Australian dollar, Canadian dollar, Swedish krona, Japanese yen, Singapore dollar, and the United States dollar. Our full sample period starts January 1, 1999 and ends April 30, 2017. I gather daily implied volatility values of individual currencies from Bloomberg.

Two important notes: firstly, empirical findings of equity VRP's forecasting power rely crucially on employing model-free implied volatility observed through the VIX index. Black-Scholes assumes lognormality of underlying instrument prices. Whereas the VIX index is a model free measure that observes the market's ex ante risk-neutral expectations of future return variation. The best forecast of future volatility has shown to come from the market's expected volatility as analogue-d by the VIX "model-free" measure. The VIX is constructed in real time using put and call options with strike prices spanning zero to infinity (bounded by market liquidity at each strike price – when there are two consecutive strikes at zero bids). This model-free measure does not rely on inversion of the Black-

Scholes formula to back out implied volatility, and has shown empirically to give a strikingly accurate approximation to the true (unobserved) risk-neutral expectation of the future variation. In contrast, due to lack of available historical options data on currencies, we rely on model dependent implied volatility values observed through inversion of the Black-Scholes options pricing model.

For our global equity proxy, we obtained daily closing prices for the MSCI World Index©, ticker symbol MXWO, from Bloomberg. We chose the MSCI World Index© as our proxy for returns on a global stock portfolio based on its greatest mutual correlation to other alternative global equity indices. This index is value weighted across 23 developed countries, including nearly all of our sample of 25 total currencies. The methodology for construction of the MXWO index can be found at <https://www.msci.com/world>.

3.4 Methodology and Empirical Testing

3.4.1 CTR Construction

Our proposed currency traded risk factor, is comprised of the currency returns underlying a high-minus-low portfolio carry trade strategy. To construct CTR, we sort currencies by interest rates using forward discounts. We sort the top and bottom quintiles of currencies by interest rates at the first day of each month. We then take the end-of-month FX return relative the USD of the top quintile of currencies (average return of the 20% of currencies with the highest yielding interest rates) and subtract the FX return relative the USD of the bottom quintile of currencies (average return of the 20% of currencies with the lowest yielding interest rates). This difference in returns is our proposed currency traded risk factor. Notably, CTR is composed of the returns from currency exchange rate

appreciations and depreciations alone. Forward returns and hence interest rate carry, do not enter the risk factor calculation. Merely, the fluctuating market values of the currencies are being tested to see if their evolutions contain information that precedes and helps explain international equity returns.

3.4.2 Carry Trade Returns

Lustig, Roussanov and Verdelhan (2011) identify a ‘slope’ factor in the cross section of exchange rates. This factor is defined as the excess returns from the portfolio carry trade, coined “HML”. Interest rate carry enters the computation of this slope factor. They construct this factor as follows:

Let s denote the log of the spot exchange rate in units of foreign currency per US dollar, and f denote the log of the forward exchange rate, also in units of foreign currency per US dollar. An increase in s means an appreciation of the home currency. The log excess return rx from buying a foreign currency in the forward market and then selling it in the spot market after one month is:

$$rx_{t+1} = f_t - s_{t+1}.$$

The excess return is the log forward discount minus the change in the spot rate. Thus interest rate carry contributes to the excess return. Akram, Rime and Sarno (2008) show that forward rates satisfy covered interest parity (CIP) at daily and lower frequencies. Therefore, forward rates reflect interest rate differentials:

$$f_t - s_t = i_t^* - i_t$$

where i_t^* and i_t denote the foreign and domestic nominal risk-free rates over the maturity of the monthly forward contracts. This gives the log currency excess return as:

$$rx_{t+1} \approx i_t^* - i_t - \Delta s_{t+1}$$

3.4.3 Transaction Costs

Given the investor buys the foreign currency or equivalently sells the dollar forward at the bid price (f^b) in period t , and sells the foreign currency or equivalently buys the dollar at the ask price (s_{t+1}^a) in the spot market in period $t+1$, the net log currency excess return for going long in foreign currency is:

$$rx_{t+1}^l = -f_t^b + s_{t+1}^a.$$

Similarly, the net log excess return from longing the dollar and shorting the foreign currency is:

$$rx_{t+1}^s = -f_t^a + s_{t+1}^b.$$

3.4.4 Exchange Rate Movements

We seek to isolate information contained in the exchange rate movements of the currencies underlying the portfolio carry trade. This means we must separate the exchange rate appreciations from the interest rate carry. We do this by transacting solely in the spot markets, removing the forward contracts from the computation of the currency returns. This leaves us with net log currency returns as:

$$rs_{t+1}^l = s_{t+1}^b - s_t^a.$$

3.4.5 Portfolio Construction

We sort currencies on forward discounts. We use H to denote the set of currencies in the portfolio comprising the highest 20% of interest rates in time t . We use L to denote the set of currencies in the portfolio comprising the lowest 20% of interest rates in time t . This defines our currency traded risk factor, CTR, as:

$$CTR_{t+1} = \frac{1}{N_H} \sum_{i \in H} rs_{t+1}^i - \frac{1}{N_L} \sum_{i \in L} rs_{t+1}^i$$

3.4.6 Constructing Currency Variance Risk Premiums

We utilize portfolios 1 and 5, which we denote FX^{HI} and FX^{LO} as they contain the currencies with high interest rates and low interest rates, respectively. Next, we compute their realized volatilities from month t 's daily spot returns. Then, we back out their implied volatilities from options prices by inversion of the Black-Scholes formula – as reported by Bloomberg. These implied volatilities reported from Bloomberg as annualized values, we convert to monthly values through dividing by the square root of twelve. Next, we take the difference between the implied volatilities average in day 1 of month t , and the realized volatilities average over the course of month t . Finally, we take the average implied and realized volatilities of the currencies in portfolios 1 and 5. Critical to eliminating the possibility for hindsight bias, all information to compute currency variance risk premiums are observed in month t and used to forecast equity returns in month $t+1$. We employ the innovations to a monthly average VRP of high interest rate currencies in our empirical tests, calculated as follows:

$$\Delta VRP(FX^{HI})_t = IV(FX^{HI})_t - RV(FX^{HI})_t,$$

3.4.7 Global Risk Premia; Forecasting Returns on a Global Stock Portfolio

Traditional forecasting variables such as the default spread, the price-dividend ratio, and the price-earnings ratio have been observed as highly persistent with first-order autocorrelations greater than .90. In contrast, the serial correlation for $VRP(FX^{HI})$ equals .5965. When we difference $VRP(FX^{HI})$, the first order autocorrelation drops to -.2763. This alleviates the common pitfall in predictive modeling of highly persistent variables and the possibility of spurious regressions. I report first order autocorrelation of 0.10 for CTR , and -0.27 for first difference of $VRP(FX^{HI})$.

Our forecasting methodology employs the common benchmark monthly OLS regressions with Newey West (1987) critical values for our t-statistics, account for serial correlation and heteroskedasticity. I regress monthly logged excess returns of the MSCI All World Index©, denoted mxw , on lagged monthly values of our predictive currency metrics.

Our sample period begins January 1999 and ends May 2017. I utilize recursive rolling regressions that estimate coefficients starting with a 50-month window to forecast month 51, and progressing in one-month steps. By the end of our sample period, we use 220 monthly observations to predict month 221, May 2017.

Let mxw_{t+1} , CTR_t , $VRP(FX^{HI})_t$ denote the continuously compounded return of the MSCI All World Index©, the continuously compounded spot return from a portfolio long high interest currencies and short low interest rate currencies, at time t , respectively. Our dependent variable – global equity returns - is computed using the mxw index values from day 1 in month t to the ultimate day in month t . Our independent variables – our

currency risk premia metrics – are computed in a similar fashion, from values all intra-month. This ensures all information used in computing our predictive variables are known entirely prior to the time span in which subsequent equity return values occur. To be precise, known at the close of the previous trading day. This means that our composite global risk aversion measure is known, say, at the close of the last trading day in month 1, and may be used to enter a global stock portfolio position at the close of the following trading day, trading day 1 in month 2.

Defining the unit time interval to be 1 month, the recursive rolling regressions of our return series on lagged values of our Global Risk Premia, is defined as

$$mxw_{t+1} = a(h) + b(h)CTR_t + c(h)VRP(\Delta FX^{HI})_t + u_{t+1} .$$

3.5 Global Risk Premia over Time

Figure 3.01 Global Risk Premia over Time

Figure 3.02 Global Risk Premia over Time; 2007 to 2017

Figure 3.03 Global Risk Aversion over Time, the Global Financial Crisis

3.6 Results

We report our results visually. The following figures show the relationship between the two risk premia sources underlying Currency-Traded-Risk and monthly returns of the MSCI World Index©. There are several striking observations that are very apparent in the visual representation of our results. First, we can see the coming into existence of a global risk factor priced into currencies (CTR) precisely at the onset of the Global Financial Crisis, October 2008. Secondly, The existence of this global premia remains stable from 2008, forward. The Newey West test statistics, the slope coefficients, and the R^2 's remain relatively constant after the GFC. Thirdly, the significance of both sources of risk premia comprising CTR remain nearly unchanged when combining them in multivariate regressions on MSCI World Index© returns. The R^2 's add linearly, to 10%.

Figure 3.04 CTR_t on MXW_t : (NW) Test Statistics

Figure 3.05 CTR_{t-1} on MXW_t : (NW) Test Statistics

Figure 3.06 T-statistics of $VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 3.07 T-statistics of $\Delta VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 3.08 R^2 's of $VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 3.09 R^2 's of $\Delta VRP(FX^{HI})_{t-1}$ on MXW_t

Figure 3.10 $\Delta FX(VRP^{HI})_{t-1}$ on MXW_t : 100 Month Starting Window

Figure 3.11 Delta $\text{FX}(\text{VRP}^{\text{HI}})_t$ on MXW_t

Figure 3.12 Out-of-Sample BETA's: Delta $\text{FX}(\text{VRP}^{\text{HI}})_{t-1}$ on MXW_t

Figure 3.13 Out-of-Sample BETA's: CTR_{t-1+} on MWX_t

Figure 3.14 T-statistics of Global Risk Premia(t-1) on $MWX(t)$

Figure 3.15 R^2 's of Global Risk Premia($t-1$) on $MXW(t)$

Figure 3.16 Out-of-Sample BETA's: CTR_{t-1} on MXW_t

Figure 3.17 Out-of-Sample BETA's: $\Delta_{FX(VRP)HI_{t-1}}$ on MXW_t

3.7 Conclusion

The coming into existence of a stable, significant statistical relation between global risk premia, as canalized in innovations of currency values, and the world's stock market returns leaves no doubt that as of October 2008, the world's financial markets were definitively globalized. Wherein, global risk aversion is priced into currencies before it manifests in equity prices of developed economies.

There exists a directional link between aggregate currency values and equity returns. Information on time-varying risk premia prices into currencies at greater speed, scale, and global consensus, relative other asset classes. High interest rate currencies proxy as a risk-on asset class. Low interest rate currencies proxy as a risk-off asset class. Innovations in these currencies' values subsume information contained in fluctuating

macro-economic variables and summarize global risk aversion. Thereby, forecasting risky asset returns.

Global risk premia canalized in the currency markets lead equity markets - forecasting out of sample, next month's return on a global stock portfolio (MSCI World Index©) with R^2 's consistent at 10% from October 2008, on. Currencies track global risk premia. Equities respond to it.

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APR 30, 2018

INDEX CHARACTERISTICS

MSCI World	
Number of Constituents	1,648
Index	Mkt Cap (USD Millions) 40,060,744.77
Largest	848,496.40
Smallest	1,039.08
Average	24,308.70
Median	10,691.53

TOP 10 CONSTITUENTS

	Float Adj Mkt Cap (USD Billions)	Index Wt. (%)	Sector
APPLE	848.50	2.12	Info Tech
MICROSOFT CORP	685.40	1.71	Info Tech
AMAZON.COM	641.47	1.60	Cons Discr
FACEBOOK A	410.19	1.02	Info Tech
JPMORGAN CHASE & CO	377.44	0.94	Financials
JOHNSON & JOHNSON	339.82	0.85	Health Care
EXXON MOBIL CORP	329.43	0.82	Energy
ALPHABET C	319.98	0.80	Info Tech
ALPHABET A	303.82	0.76	Info Tech
BANK OF AMERICA CORP	296.48	0.74	Financials
Total	4,552.52	11.36	

SECTOR WEIGHTS

COUNTRY WEIGHTS

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