Examining the dependence structure between carry trade and equity market returns in BRICS countries

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Abstract

This paper contributes to the literature on carry trade by investigating the dynamic correlation and the dependence structure between the US-dollar carry trade and equity markets in the BRICS economies during sample observations that include regular and crisis periods. Furthermore, the nonlinear Granger causality test based on the feed-forward neural networks (FFNN) model is used to assess how global volatility predicts the dynamic correlation between the US-dollar carry trade and equity markets in BRICS. The paper finds that the dynamic correlations between carry trade and equity markets in BRICS are more pronounced during most global crises. Moreover, the results of the SJC model showed that the lower tail dependence between the two series is higher during the various crises. Furthermore, the results of the empirical analysis show that global volatility predicts the dynamic correlations between carry trade and equity markets in BRICS only during crises. Asset managers and investors can benefit from this paper's findings regarding portfolio diversification, risk management, asset allocation, and hedging when dealing with equity assets and carry trades.

Keywords: *Carry trade, stock markets, BRICS, VAR-DCC-GARCH model, SJC copula model, dynamic conditional correlations, VIX index.*

1. Introduction

Given their exchange rates, the interest rate differential between developing, emerging, and developed economies has created an environment where investors contemplate arbitrage strategies to earn profit at low risk. In this case, investors use the carry trade strategy to reach this objective. The carry trade strategy refers to the situation in which investors move funds from a low-interest currency to invest in a high-interest currency. The profitability of a carry trade strategy is seen in a situation where the gains from an interest rate differential exceed the exchange rate movements. It implies the violation of the theory of uncovered interest rate parity (UIP), which refers to the idea that the difference in interest rates between two countries equals the expected change in exchange rates between the countries' currencies. It is worth noting that if the UIP condition is not met, an investor could potentially make a risk-free profit through a carry trade strategy by borrowing a currency with a low-interest rate and then converting to and investing in a currency with a higher interest rate. If the exchange rate does not change as expected (based on the interest rate difference), the investor can then make a profit (see Galati, and Heath, 2007).

Studies show that the carry trade strategy leads to capital flows moving from the funding currencies to the investment's currency (Tse & Zhao, 2012). Therefore, the carry trade strategy might strengthen the investing currency in the short term by channelling funds into high-yielding financial asset markets, such as equity markets. This reality supports the view that equity markets and currency carry trade may be related. It is in that context that Tse and Zhao (2012) investigated the relationship between currency carry trade and US stock markets. The authors find that there is a significant volatility spillover effect running from the US equity market to carry trade. Lee and Chang (2013) found that significant positive relations existed between US equity returns and currency trade; meanwhile, the relationship appeared stronger in bear markets than in bull markets. Wu et al. (2021) investigated the dynamics of the asymmetric dependencies between the carry trade, the bonds and equity markets and found a significant increase in the dependence between the carry trade and stock prices, while the carry trade and bonds were negatively related. Meanwhile, the interdependence between the carry trade and stock returns was more pronounced during the 2008 global financial crisis.

While the above-cited studies focused on the dynamic correlation and dependence between carry trade and equity market returns, none of the past studies has yet to assess the drivers of the correlation or dependence between the two markets, especially the role of global volatility in predicting their correlation. Given that global volatility may affect the source and investment countries differently in the context of carry trade, asset managers and investors should be interested in how to allocate portfolios made of positions in carry trade and equity markets during periods of high or low global volatility. Moreover, past studies are silent on how dynamic correlation or the dependence structure between carry trade and equity markets fare during the different crisis periods in BRICS economies. Being the leading emerging markets, BRICS countries have been attracting interest from investors and asset managers who should be interested in conditions defining the dynamic correlations between carry trade and equity returns.

This study will fill these gaps by investigating the dynamic correlations between carry trade and equity markets in the BRICS economies and assessing the role of global volatility in driving these correlations. To this end, the paper uses a multivariate VAR-DCC-GARCH to investigate the dynamic conditional correlations between the US dollar carry trade returns and equity returns for each BRICS economy. Furthermore, the time-varying symmetrised Joe-Clayton (SJC) copula model is employed to investigate the dynamic tail dependence between US dollar carry trade returns and equity returns of the BRICS economies. Nonlinear Granger causality tests are used to assess the role of global volatility in predicting the conditional correlations between the carry trade and stock market returns in BRICS economies.

The rest of the paper is organised as follows: Section 2 provides a literature review; section 3 outlines the methodology; section 4 discusses the data and the estimation results; and section 5 concludes the study.

2. Literature Review

The theory of the currency carry trade stipulates the situation where investors use a strategy of moving funds from a low-interest-rate currency to invest in a high-interest-rate currency. Burnside et al. (2008) argued that this strategy is not only applicable to two economies, meaning investors can create a portfolio of currencies on both the investment and funding sides. The carry trade strategy allows investors to optimise returns as the interest rate differential between countries changes. Burnside et al. (2008) further argued that the carry trade strategy eventually depends on the failure of the uncovered interest rate parity (UIP theory).

The violation of the UIP theory is mainly driven by unexpected events, especially those associated with a currency crisis. In the study by Berg and Mark (2017), it is stated that carry trade investors experience significant uncertainty due to the many global risk factors that have a spillover effect on the currency markets. They also find that positive carry trade returns are usually high during regular periods and significantly low during crises. Their results, like the conclusion reached by Burnside et al. (2011), show that investors expect significant compensation to avoid the substantial losses that could occur when they invest in emerging markets during periods of uncertainty.

Fong (2010) investigated the profitability of the yen carry trade using the stochastic dominance analysis from 2001 to 2009. He found that the yen carry trade generated high returns before the 2008 global financial crisis and reached the conclusion that yen carry trade returns outperformed the stock markets of many developed economies. Furthermore, Fung (2010) applied a non-parametric test using stochastic dominance to assess whether high carry trade returns comove with the risk as reflected in global stock market indices.

Cheung et al. (2012) examine the relationship between the yen carry trade and the equity markets of different investment currencies, including the AUD, GBP, CSD, MXN, and NZD, using weekly data from 2001 to 2008. the authors employed a regression equation, where the error term exhibits GARCH effects and incorporated three different control variables like commodity prices, the VIX index, and US stock returns. The authors found that carry trade returns and stock market returns are positively related. Tse and Zhao (2012) investigated the relationship between US equity returns and yen-dominated carry trade by employing the VAR model and the Exponential GARCH (EGARCH) model to investigate the volatility spillovers between the US stock returns and the yen carry trade. They found a significant unidirectional spillover of the volatility from the US equity returns to the carry trade market, and the correlation between these markets is strong during the period of high volatility. Lee and Chang (2013) supplemented the study by Tse and Zhao (2012) to investigate the relation between the spillover of currency carry trade and equity returns of the US market using G10 currencies as the target currency and the S&P 500 index. Lee and Chang (2013) employed the generalised VAR model and a Markov-switching model to compute the magnitude of spillovers of currency-carry trade returns and their impact on equity returns under bear and bull market conditions. They found that a significant positive relationship exists between equity returns and spillovers of currency trades. Meanwhile, the relationship appeared stronger in bear markets than in bull markets.

Christiansen, Ranaldo, and Söderlind (2011) employed the logistic smooth transition regression (LSTR) model to show that the relationship between the carry trade returns and equity returns depends on different economic regimes. Using the daily data from 1995 to 2008, Christiansen et al. (2011) found that the carry trade strategy depends heavily on different economic regimes. The authors argued that investment currencies had experienced a positive exposure to equities, and the exposure is even more significant during crisis periods. They further found that the carry trade returns and stock returns are positively correlated and somewhat negatively correlated with bond markets. Lettau, Maggiori and Weber (2014) employed the downside-risk capital assets pricing model (CAPM) to examine the link between carry trade and different assets (which includes currency returns, sovereign bonds, commodity returns, and equity returns) using monthly data running from June 1974to March 2010. Lettau et al. (2014) reached a similar conclusion to

Brunnermeier et al. (2008) and Stathopoulos et al. (2012) to find that the correlation between carry trade and assets returns appears to be strong during market downturns than in upswings.

Maake and Bonga-Bonga (2021) investigated the volatility spillovers between currency carry trade and assets markets (stock and bond markets) in South Africa using the multivariate VAR-BEKK-GARCH method. They found significant volatility spillover between currency carry trade and assets markets' returns in South Africa. Maake and Bonga-Bonga provide evidence that carry trade transmits more shocks to the stock market than the bond market. This study expanded on this result by investigating the volatility spillover and conditional correlation between US dollar carry trade and the BRICS stock markets.

Wu et al. (2021) investigated asymmetric dependencies and their dynamics across returns to bonds, stocks, and carry trade. They applied conditional copula models using the weekly data running from January 1994 to December 2014, which was then divided into three sub-periods: pre-crisis (from 1994 to 2006), the crisis (from 2007 to 2008), and post-crisis (from 2009 to 2014). The authors used interest rates and currencies of the G10 economies; the Deutsche Bank G10 Currency Future Harvest (DBCFH) Index as a proxy for a carry trade strategy; US 10-year treasury bonds; and the S&P 500 index. Wu et al. (2021) found a significant increase in the dependence between carry trade and stock prices, while carry trade and bonds were negatively related. Meanwhile, the interdependence between carry trade and stock returns was more pronounced during the 2008 global financial crisis. The authors also performed the out-of-sample forecast of dependence between the selected assets and carry trade. The authors found that risk-averse investors benefited more by incorporating asymmetry and dynamics into dependencies' timing, specifically during the 2008 financial crisis.

The studies by Tse and Zhao (2012) and Fung et al. (2013) focused mainly on the volatility spillovers between carry trade returns and stock markets. Although the study by Tse and Zhao (2012) and Fung et al. (2013) analysed the volatility spillovers between carry trade returns and stock market returns during different periods, which included the 2008 global financial crisis period, the studies did not analyse the relationship between the carry trade returns and stock markets using time-varying methods. Dynamic correlations could show how global and country-specific crises have impacted the relationship between carry trade and stock returns.

3. Methodology

This paper employs a multivariate VAR-DCC-GARCH and the SJC-copula model to investigate the dynamic conditional correlation and the dependence structure, respectively, between the BRICS equity returns and US dollar carry trade returns. Furthermore, the Nonlinear Granger Causality test based on the feed-forward neural networks (FFNN) model is employed to assess the predictive power of global volatility on the dynamic correlation between carry trade and equity returns.

In the VAR-DCC-GARCH model , the mean equations are obtained from a VAR model expressed as

$$CT_t = \mu_1 + \sum_{i=1}^{p} c_{1i} CT_{t-i} + \sum_{i=1}^{p} \delta_{1i} SR_{t-i} + \varepsilon_{1,t} \quad (1)$$

$$SR_t = \mu_2 + \sum_{i=1}^{p} c_{2i} CT_{t-i} + \sum_{i=1}^{p} \delta_{2i} SR_{t-i} + \varepsilon_{2,t} \quad (2)$$

where $CT_{j,t}$ and $SR_{j,t}$ represents the returns of US dollar carry trade and BRICS equities, respectively. The error term at period t is represented by $\varepsilon_{j,t}$. c_i, and δ_{1i} and are estimated parameters for VAR model. μ_i is the constant parameter used in the VAR model. The study applies the VAR model owing to its ability to account for interdependence between equity returns and carry trade returns for all the selected countries.

From the obtained residuals in Equations 1 and 2, a univariate GJR-GARCH (1,1) model is obtained such as[1]

$$\sigma_{i,t}^2 = \omega_i + \alpha_i \sigma_{i,t-1}^2 + \beta_{i,j} \varepsilon_{j,t-1}^2 + \gamma_{i,j} \varepsilon_{j,t-1}^2 I_{t-1} + \mu_t \quad (3)$$

where $I_{t-1} = 1 \text{ if } \varepsilon_{j,t-1}^{i} < 0, 0 \text{ otherwise},$

Parameter α_i measure the GARCH effects or simply lag coefficient. $\beta_{i,j}$ measures the spillover of the volatility from carry trade to equity returns and contrariwise. $\lambda_{i,j}$ measure the asymmetric volatility. $\sigma_{i,t}^2$ measures the conditional variables, $\varepsilon_{j,t-1}^2$ captures the shocks and μ_t is residuals. The effect of ε_{t-1}^2 on $\sigma_{i,t}^2$ is measure by $\beta_{i,j} + \gamma_{i,j}$ when $I_{t-1} = 1$ (negative shocks) and $\beta_{i,j}$ when $I_{t-1} = 0$ (positive shocks).

From Equations 1, 2 and 3, the DCC-GRCH model is obtained such as

$$H_t = D_t R_t D_t \quad (4)$$

With H_t representing the square matrix of conditional variance, D_t shows the square diagonal matrix of conditional standard deviations and R_t is a square conditional correlation matrix . it is worth noting that R_t is expressed as

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (5)$$

where Q_t^* represent the rescaled elements of Q_t, with $Q_t \geq 0$ to ensure that R_t is positive define. Q_t is known as the correlation matrix, expressed as

$$Q_t = (1 - a - b)\bar{Q} + a\epsilon_{t-1}\epsilon_{t-1}^T + bQ_{t-1} \quad (6)$$

In Equations 6, $a, b > 0$ and $a + b < 1$. The parameters a, b shows that conditional correlation differs with volatility as measure by $\epsilon_{t-1}\epsilon_{t-1}^T$ and lag factor Q_{t-1}. $\bar{Q}$ represent the unconditional covariance matrix of the standardised errors.

The parameters of the DCC-GARCH model are obtained from the maximisation of the loglikelihood function given as:

$$ln\big(L(\theta)\big) = -\frac{1}{2}\sum_{t=1}^{T}(nln(2\pi) + 2ln\,(D_t) + ln(R_t) + a_t^T H_t^{-1} a_t \quad (7)$$

where θ represent the parameters of the model.

[1] The choice and the order of the model is determined from Akaike Information Criteria.

It is worth noting that the paper uses a copula model to supplement the correlation analysis. The SJC copula is used due to its ability to model the data that appear to be asymmetrical on both the upper and lower tail of the distribution.

The SJC-copula model which is derived from the Joe-Clayton copula (C^{JC}) is expressed as:

$$C^{SJC}(u, v, \tau^L, \tau^U) = 0.5 * (C^{JC}(u, v, \tau^L, \tau^U) + C^{JC}((1-u, 1-v; \tau^L, \tau^U) + u + v - 1) \quad (8)$$

Where τ^L, τ^U is lower and upper tail dependencies, respectively and u, v represent the variables. In this paper, these variables are carry trade returns and BRICS stock market returns. The lower and upper tail are expressed as follows:

$$\tau_t^L = \Delta(\omega + \beta\tau_{t-1}^L + \alpha\frac{1}{10}\sum_{i=1}^{n}|u_t^L - v_t^L|) \qquad ; \; 0 \leq \tau_t^L \leq 1 \quad (9)$$

$$\tau_t^U = \Delta(\omega + \beta\tau_{t-1}^U + \alpha\frac{1}{10}\sum_{i=1}^{n}|u_t^U - v_t^U|) \qquad ; \; 0 \leq \tau_t^U \leq 1 \quad (10)$$

The estimation procedure for the dynamic asymmetric copula model as shown in Wu et al. (2021) uses the following log-likelihood function:

$$\begin{aligned} L(\theta_M, \theta_c; r_t) &= \sum_{i=1}^{n} L_{Mi}(\theta_M) + L_C(\theta_c; r; \theta_M) \\ &= \sum_{i=1}^{n}\sum_{t=2}^{T} log\, f_{i,t}(r_{i,t}; \theta_{Mi}) + \sum_{t=2}^{T} log\, c_t(u_{1,t\dots,}u_{n,t}; \theta_c) \quad (11) \end{aligned}$$

Where L_{Mi} and L_C represent the log-likelihood functions for the marginal process and copula, respectively. Meanwhile, θ_M denotes parameters that correspond to the marginal distributions and θ_C represent the parameters used in the copula density function.

4. Data, estimation and discussion of results

4.1. Data

The paper uses daily data from 03 January 2000 to 30 June 2021. The sample includes periods related to major economic crises, such as the 2001 Dot-Com recession, the 2008 global financial crisis, and the Covid-19 pandemic. Data are collected from DataStream and include the short-term interest rates for all BRICS and the US economies, BRICS economies' exchange rates against the US dollar, and stock market prices. The BRICS currencies per US dollar are as follows: Brazilian real, Russian ruble, Indian rupee, Chinese yuan, and South African rand. The stock market indices for BRICS countries are as follows: iBovespa Index; RTS Index; Bombay Stock Exchange; Shanghai Stock Exchange All-Share Index; and Johannesburg Stock Exchange (JSE) All-Share Index. The VIX index is sourced from Bloomberg. The collected data is transformed to compute the carry trade and equity returns. The carry trade returns calculation follows the method suggested by Brunnermeier (2009) and is described as follows:

$$CT_t = \left(i_{t-1}^d - i_{t-1}^f\right) - (fx_t - fx_{t-1}) \quad (18)$$

CT_t represents the carry trade returns, $\Delta fx_t = (fx_t - fx_{t-1})$ represents the returns in the exchange rate. The situation whereby $CT_t \neq 0$ suggests the "failure of uncovered interest rate parity" (Fung et al. 2013). $(i_{t-1}^{d} - i_{t-1}^{f})$ represents interest differential between the domestic economic, BRICS in our case, and the foreign economy, the US in our case.

Table 1 reports the descriptive statistics of the different variables. The average carry trade returns ranged between 0% for all BRICS economies except for Russia, with an average of 0.01%. The average stock price returns ranged from 0.030% for China to 0.039% for Russia. The skewness of the US dollar carry-trade returns is negative for Brazil and India and positive for all other BRICS economies. The stock returns for all the BRICS economies exhibit a negative skewness. This negative skewness indicates that the stock returns exhibit a fatter tail on the left side of the distribution for all the BRICS economies except for South Africa. Kurtosis for both carry trade and stock returns across all the BRICS economies is higher than the value of 3, which indicates that overall, returns are characterised by fat tails.

Table 1: Descriptive Statistics

	Carry Trade Returns						
	Minimum	Median	Mean	Maximum	St.dev	Skewness	Kurtosis
Brazil	-0.2011	0.0001	0.0000	0.1738	0.0065	-0.0154	102.8932
Russia	-0.1261	0.0000	0.0001	0.1461	0.0070	1.6484	117.8296
India	-0.0360	0.0000	0.0000	0.0362	0.0025	-0.1259	60.4271
China	-0.0153	0.0000	0.0000	0.0151	0.0009	0.3636	98.7513
South Africa	-0.0653	0.0000	0.0000	0.0650	0.0061	0.0420	34.7912
	Stock Market Returns						
	Minimum	Median	Mean	Maximum	St.dev	Skewness	Kurtosis
Brazil	-0.12815	0.00041	0.00037	0.09952	0.00689	-1.11279	72.75130
Russia	-0.10243	0.00067	0.00039	0.12286	0.00888	-0.06499	48.07210
India	-0.16654	0.00060	0.00033	0.11117	0.00757	-1.88670	91.92157
China	-0.12388	0.00033	0.00030	0.10477	0.00816	-1.17720	67.60950
South Africa	-0.05445	0.00047	0.00036	0.07283	0.00492	0.76495	55.16280
	VIX Index						
	Minimum	Median	Mean	Maximum	St.dev	Skewness	Kurtosis
VIX Index	9.14	17.69	19.94	82.69	8.83	2.18	7.52

Source: BRICS central banks, International Finance Statistics, and Bloomberg

4.2. Estimation Results

The VAR-DCC-GARCH model is estimated following the procedure described above. The results are reported in the appendix, showing the stability of the model. Moreover, Figures 1 to 5 report the dynamic conditional correlations between US dollar carry trade returns and the BRICS economies' stock returns. The dotted areas show significant global crises, such as the global financial crisis in 2008 and the COVID-19 crisis.

Figure 1: Dynamic correlation between currency carry trade returns and Brazilian stock returns.

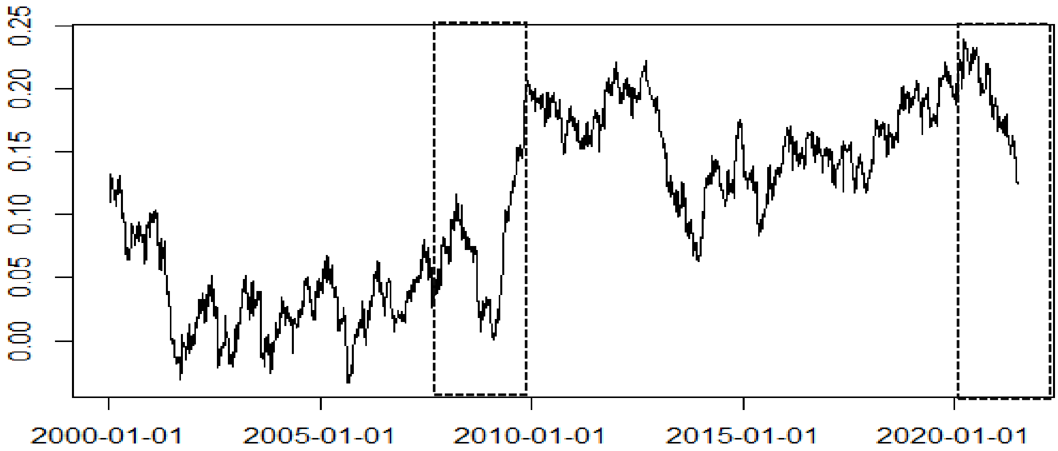


Figure 1 shows that there is an overall positive conditional correlation between US dollar carry trade returns and Brazilian stock returns over the selected sample. However, the dynamic correlation series displayed in Figure 1 show a delayed increase in correlation during the global financial crises and a delayed decrease during COVID-19 crises. This outcome shows that the dynamic correlation between the carry trade and equity returns do not behave the same way during all the crises. The delayed positive trend of the dynamic correlation between the variables is due certainly to the negative carry trade returns during the pick of the 2008 global financial crisis coupled with the negative equity returns due to the global negative sentiment by global investors. In fact, as the 2008 financial crisis was triggered by the US, the ensued depreciation of the US dollar led to the negative returns of the US dollar carry trade at the time equity market was negative. Nonetheless, during the COVID-19, the US was mostly seen as a safe haven for many investors (see Disli et al., 2021; Cheema et al., 2022). The negative return of global equity market that ensued coincided with the appreciation of the US dollar that lead to the positive returns of the US carry trade and thus, the negative correlation between the carry trade and equity returns. This same pattern of the correlation trends is observed with all the BRICS countries as depicted from Figures 2 to 5, except in CHINA where the pattern is not as pronounced as in other BRICS countries, especially during the COVID-19 period. The outcome is expected given that COVID-19 crisis was triggered by CHINA.

The changing pattern of the correlation between the carry trade ad equity markets show that the correlation between the two markets do not behave the same way during all the crisis periods. Asset managers and investors need first to identify the nature and type of crisis before anticipating the trend of the correlation between the two markets, which correlation is information for asset allocation and portfolio optimisation.

Figure 2: Dynamic Correlation between currency carry trade returns and Russian stock returns.

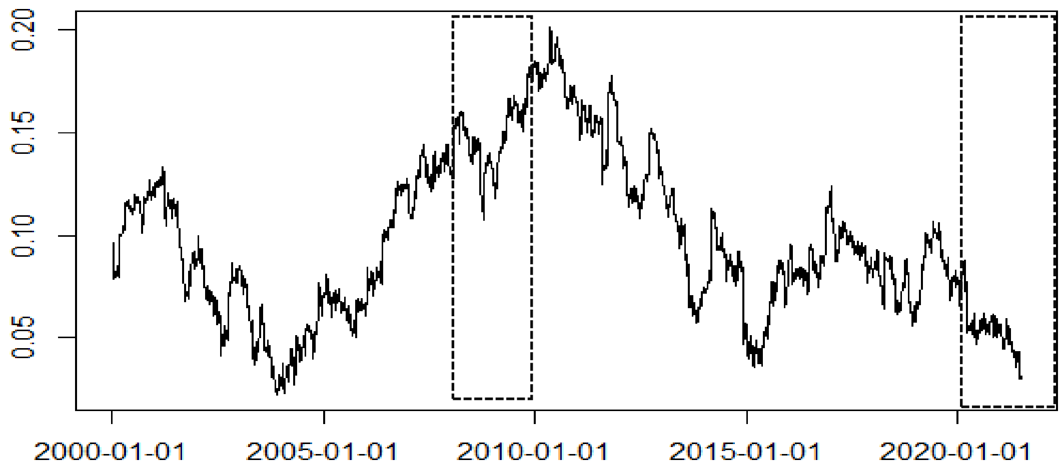


Figure 3: Dynamic Correlation between US dollar carry trade returns and Indian stock returns.

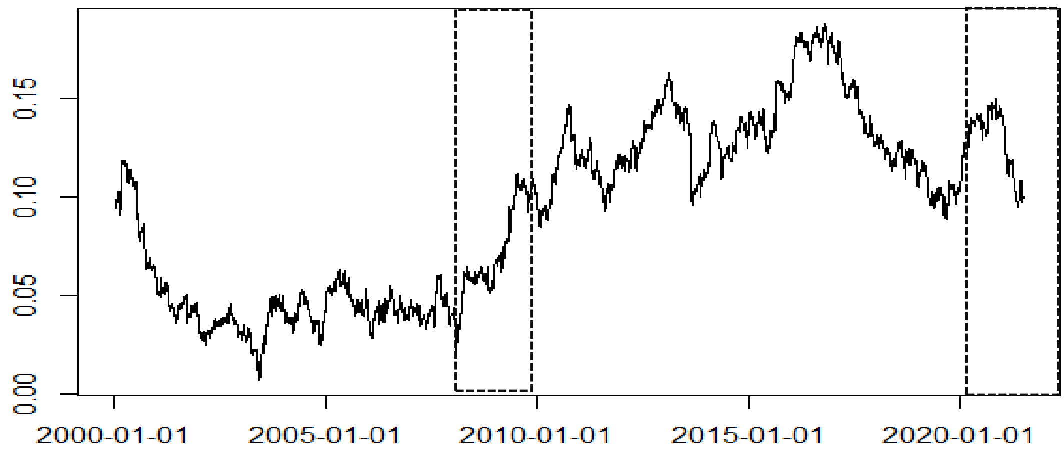


Figure 4: Dynamic Correlation between US dollar carry trade returns and Chinese stock returns.

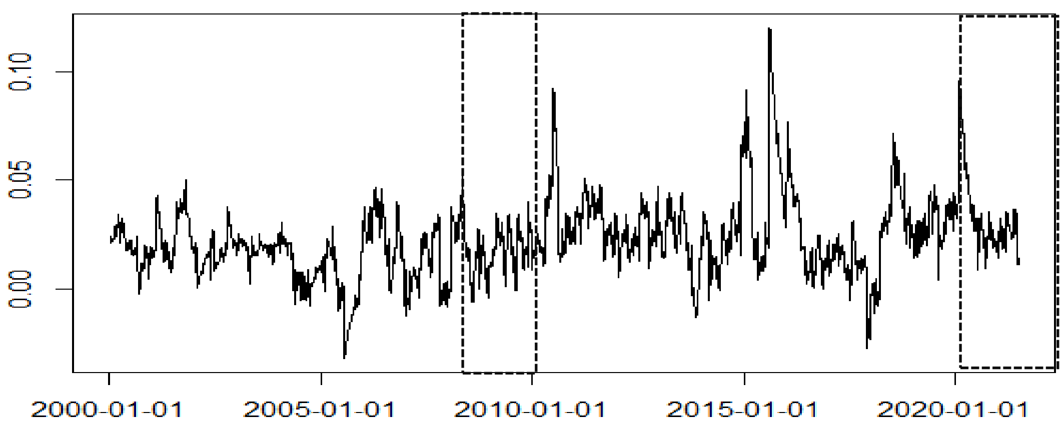
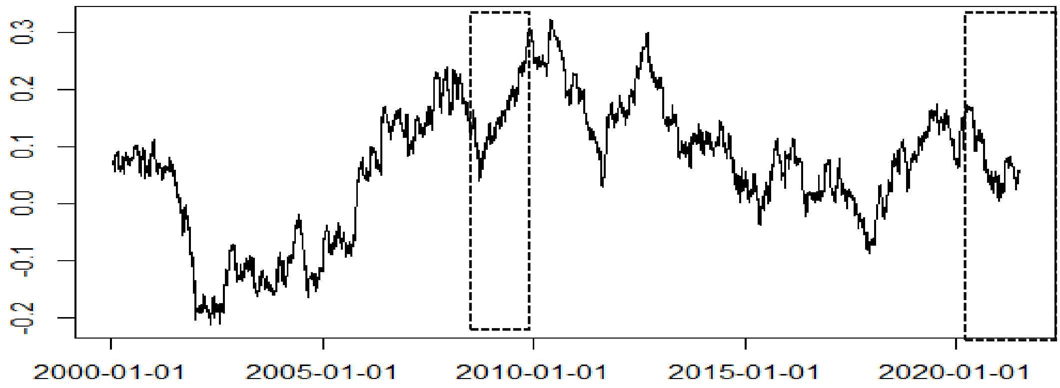


Figure 5: Dynamic Correlation between US dollar carry trade returns and South African stock returns.



4.3. SJC-Copula Model Estimation Results

While the results of the dynamic correlation between carry trade and stock returns provide insight into how the two series correlate during specific periods, they are short of providing insight into how the two series fare when both are in the lower quantile or tails (during through or recession) and in upper quantile or tails (during boom periods). To this end, the study makes use of the SJC-copula methodology. The SJC-copula model's relevance is due to its ability to capture the asymmetric dependence of time series in the lower and upper tails. The results obtained from this copula method are shown in Table 6. Figures 6 to 10 report the time-varying lower and upper tail dependence between the carry trade returns and stock returns of the BRICS economies.

Table 2: The estimation of SJC Copula parameters

Full sample (January 2000 to June 2021)					
SJC-Copula					
	Brazil	***Russia***	***India***	***China***	***South Africa***
ω^U	0.2389	1.5769*	-1.0421	-17.5660**	2.2253***
α^U	-9.7643***	-21.5273***	-8.4557***	-3.7138	-24.9996***
β^U	-0.2401	0.4783	4.6336***	-0.0082	-1.2966*
ω^L	-1.7816	-2.9865***	-1.9805	1.8489	1.5586
α^L	-2.1992	-1.7725	-2.2727	-24.999***	-6.5406
β^L	4.4254***	10.8626***	4.9434	-5.1089	4.4307*
Log-likelihood	-260.5244	-79.6039	-164.5007	-10.4575	-82.5067

***,**,* represent 1%,5%, and 10% level of significance, respectively.

Table 6 reports the results from the SJC-copula model, which is also used to investigate the lower and upper tail dependence between the carry trade returns and stock returns of BRICS economies.

As shown in Table 6, most parameters are statistically significant, which provides evidence that there is generally a tail dependence between the carry trade returns and stock returns of BRICS economies. The log-likelihood is higher for China, Russia, and South Africa, which means the upper and lower tail dependence between the carry trade returns and stock returns is highly significant for those economies compared to Brazil and India.

Figures 6 to 10 display the results of the asymmetric dependence between the carry trade and stock returns. Panel A on each figure reports the lower tail dependencies, while panel B reports the upper tail dependencies.

Figure 6 shows that in Brazil, the correlations between carry trade returns and stock returns are generally higher in the lower tail than the upper tail. The lower tail dependence between the two series is higher during the various crises, showing that the high correlation observed during crisis periods with the DCC model is owing to negative returns for both carry trade and stock returns. The high dependence on lower tails during crisis periods is evident for most of the BRICS countries, as shown in most figures below.

However, it is essential to note that the upper tail dependence between carry trade and equity market returns shows high spikes, reflecting the boom periods characterised by positive dependence between the two returns. The excellent performance of equity and carry trade returns, primarily after the global financial crisis, was the prime driver of this positive dependence.

Figure 6: Tail dependence between carry trade returns and stock returns for Brazil

Panel A: Lower tail dependence

Panel B: Upper tail dependence

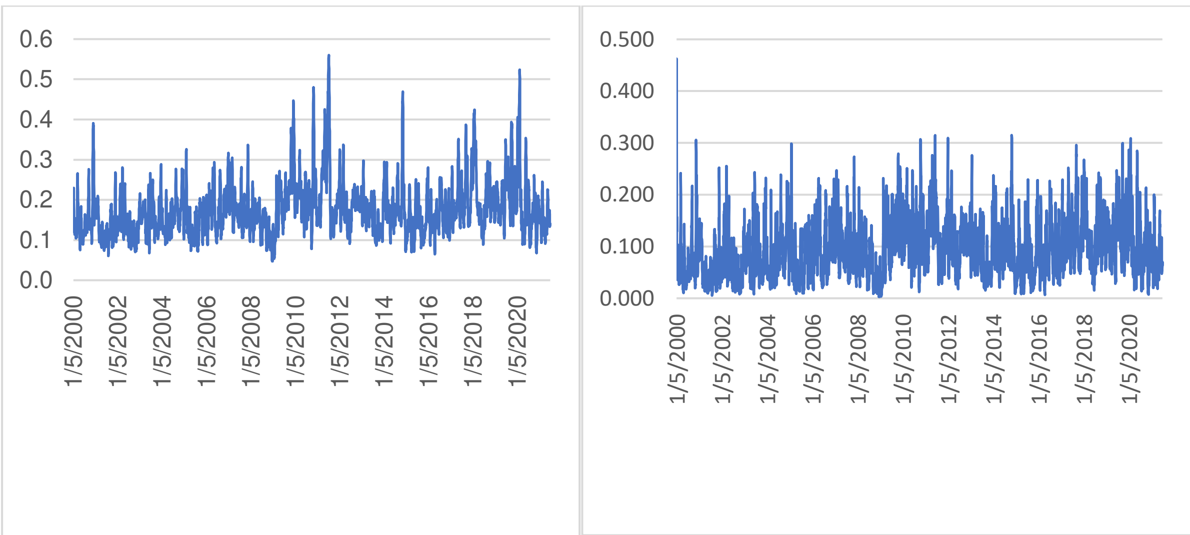


Figure 7: Tail dependence between carry trade returns and stock returns for Russia

Panel A: Lower tail dependence

Panel B: Upper tail dependence

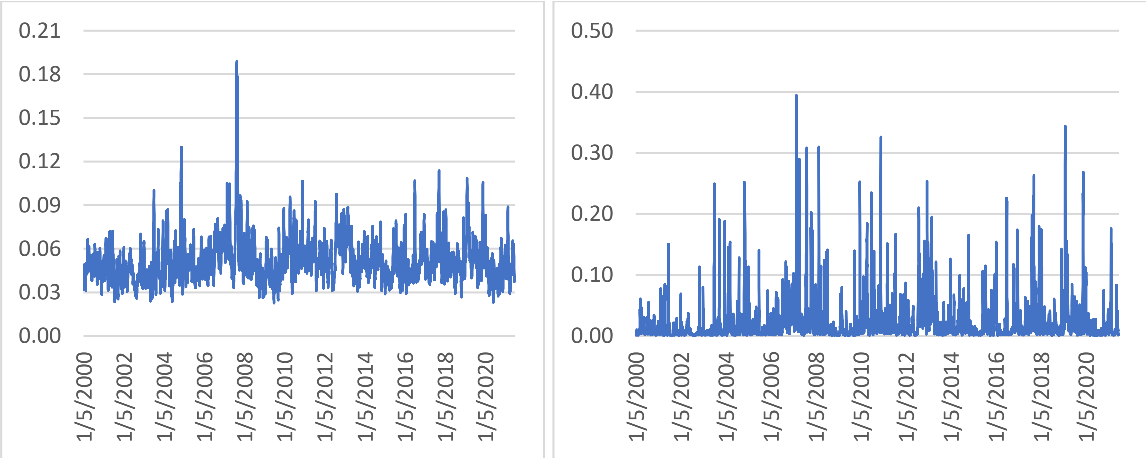


Figure 8: Tail dependence between carry trade returns and stock returns for India

Panel A: Lower tail dependence

Panel B: Upper tail dependence

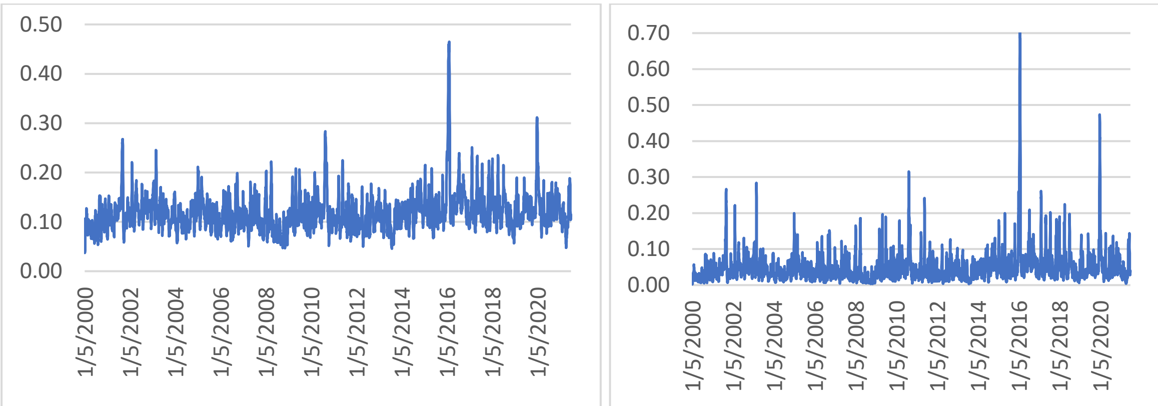


Figure 9: Tail dependence between carry trade returns and stock returns for China

Panel A: Lower tail dependence | Panel B: Upper tail dependence

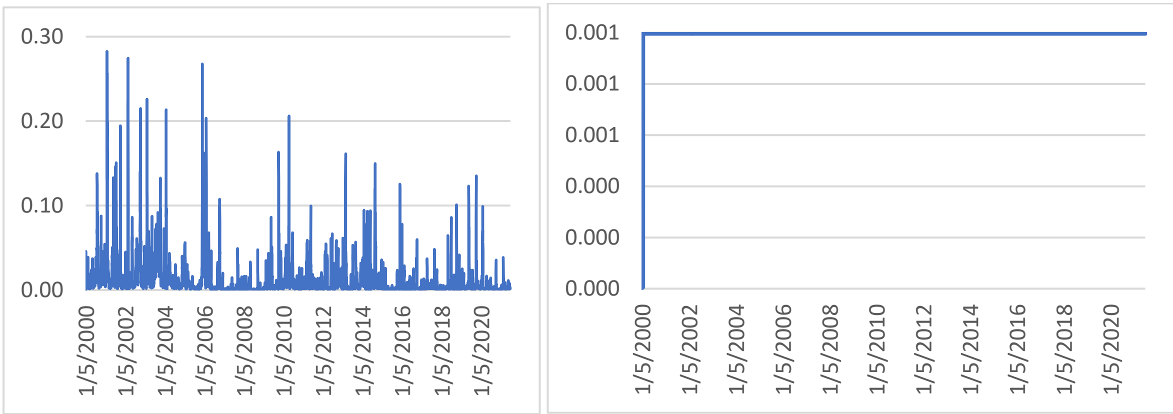
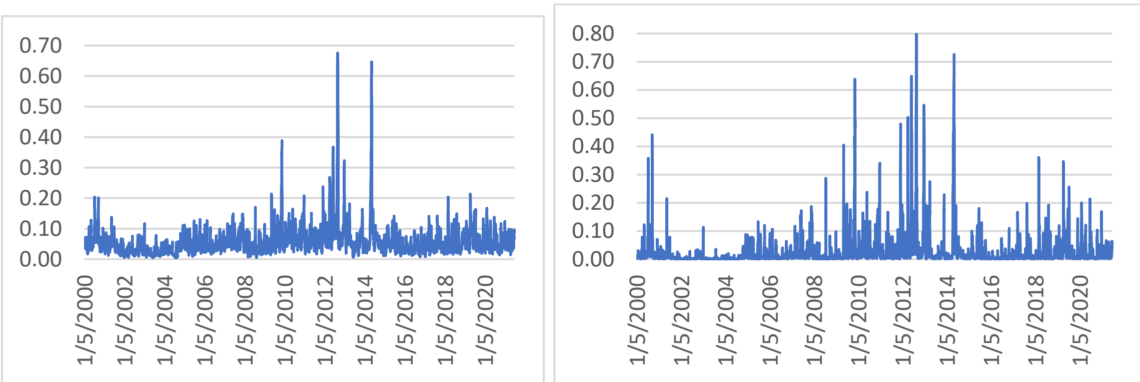


Figure 10: Tail dependence between carry trade returns and stock returns for South Africa

Panel A: Lower tail dependence | Panel B: Upper tail dependence



4.4. Causality between global volatility and the dynamic correlation between carry trade and stock returns

While studies show that global volatility, as measured by the VIX index, can significantly impact carry trade returns (Chen & Qi, 2018; Bonga-Bonga & Rangoanana, 2022), no literature ever assessed how global volatility could predict or affect the dynamic correlation between carry trade and equity returns. Such insight is vital for investors and asset managers who rely on the correlation between assets to optimise portfolios successfully.

Given the nonlinear trend of the dynamic correlation between carry trade and equity returns, as depicted in Figures 2 to 4, we use the nonlinear Granger causality based on the feed-forward neural networks (FFNN) model to assess how global volatility predicts the correlation between the two returns. The FFNN is a data-driven approach to test for causality between two time series data. It uses artificial neural networks (ANNs) to model the relationships between the variables. It consists of input, output, and hidden layers of nodes that process the data and learn to make predictions based on the patterns in the data. The null hypothesis of the FFNN is that one variable does not predict the other (see Oreshkin et al., 2020).

Table 5 presents the results of the nonlinear Granger causality between the global volatility, proxied by the VIX index, and the different dynamic correlation series.

Table 3: Nonlinear Granger causality test

Full Sample period (Jan 2000-June 2021)		Brazil	Russia	India	China	South Africa
VIX Index to DCC	F-Statistics	0.239	-3.769	-29.008	-49.728	-76.814
	p-value	0.999	1.000	1.000	1.000	1.000
Sub-sample -period (Oct 2007-Dec 2009)						
VIX Index to DCC	F-Statistics	-0.3530	1.0486	2.2268	2.8954	0.7086
	p-value	1	0.4022	0.0038	0.0001	0.7868
Sub-sample period (Jan 2020-June 2021)						
VIX Index to DCC	F-Statistics	-0.2768	7.7476	1.5655	0.3598	0.5330
	p-value	0.9968	0.0003	0.9899	0.9292	0.9991

Note: Null hypothesis- H_0: The VIX index does not Granger cause the dynamic conditional correlation between carry trade returns and BRICS stock returns.

The results depicted in Table 5 show that the null hypothesis, which is "VIX index does not Granger cause DCC between carry trade and stock returns", is not rejected for the entire sample for all the countries. However, the null hypothesis is rejected during the global financial crisis and COVID-19 for some specific BRICS countries. Based on these results, we argue that global volatility only impacts the correlation between carry trades and equity returns during periods of high volatility. Furthermore, we argue that global volatility shocks can influence the correlation between the two returns if they react similarly or differently to them. For example, the impact of the global financial crisis on the dynamic correlation between carry trade and equity returns in India during the global financial crisis s the result of the negative response of the global financial crisis on both carry trade and equity returns. Studies show that India's currency, the Rupee, lost its value considerably during the global financial crisis, thus, reducing possible carry trade profits.

Moreover, India's equity markets experienced a significant downturn during the global financial crisis (Muthukumaran et al., 2011). As a result, the carry trade and equity returns during the global financial crisis are positively correlated. During COVID-19, the Reserve Bank of India decreased the repo rate to support its economy. This move reduced the attractiveness of the Indian currency for carry trade. At the same time, the equity market's performance was mixed during COVID-19, recovering sharply at the later stage due to the stimulus monetary policy (Singh et al., 2020). This outcome explains the negative trend of the dynamic correlation between the carry trade and equity market returns at the later stage of 2020, as depicted in Figure 3.

Information on how the correlation between the carry trade and equity returns responds to global volatility shocks are vital for asset manager and investors in terms of portfolio diversification, risk management, asset allocation and hedging. Regarding portfolio diversification and asset allocation, the understanding of the response of the correlation between carry trade and equity returns to global volatility shocks can help portfolio managers and investors in deciding on whether to add and reduce carry trade investments to an equity portfolio in order to reduce the overall portfolio risk and improve risk-adjusted returns, as part of their risk management activities. Asset managers and investors can use the information on the response of the correlation of carry trade and equity returns to global volatility shock to be assisted in hedging the portfolio made of the two assets against market risk. This hedging activity may consist in using put options or other derivatives to hedge their equity exposure, for example, and protect against potential loss.

5. **Conclusions and Recommendations**

This paper investigated the dynamic correlation and dependence structure between the US dollar-funded carry trade and stock markets of the BRICS economies from January 2000 to June 2021 by using the VAR-DCC GARCH and SJC copula models, respectively. Furthermore, the paper assessed how global volatility could predict the correlations between the two markets.

The results of the dynamic correlation model show that there is generally a positive dynamic correlation between stock returns and US dollar carry trade returns for all BRICS countries. Meanwhile, these dynamic correlations appeared more pronounced during most global crisis periods, such as the global financial crisis in 2008 and the COVID-19 crisis. Moreover, the results of the SJC model showed that the lower tail dependence between the two series is higher during the various crises, showing that the high correlation observed during crisis periods with the DCC model is owing to negative returns for both carry trade and stock returns.

A nonlinear Granger causality based on the feed-forward neural networks (FFNN) model was used to assess whether global volatility predicts carry trade and equity returns. The nonlinear Granger causality test results showed that the null hypothesis of “VIX index does not Granger cause the conditional correlation between carry trade and stock returns” is rejected only during crisis periods and only in specific countries. We postulate that global volatility shocks influence the correlation of the two returns when they respond to these shocks in the same or different directions during specific crises. The results of this paper are vital for asset managers and investors in terms of portfolio diversification, risk management, asset allocation and hedging.

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Appendix

Table 1A. VAR-DCC-GARCH estimation results

Full sample (January 2000 to June 2021)

Mean Equation

	Brazil		*Russia*		*India*		*China*		*South Africa*	
	CT	**SR**	**CT**	**SR**	**CT**	**SR**	**CT**	**SR**	**CT**	**SR**
μ	-0.0000	0.0002**	0.0000	0.0002**	0.0000	0.0002*	0.0000	0.0002	0.0000	0.0000
$c_{i=1}$	-0.7298***	-0.6113***	-0.5794***	-0.4701***	-0.5954***	-1.0280***	-0.5177***	-0.0701	-0.6376***	-0.0038
$c_{i=2}$	-0.3489***	-0.2833***	-0.2467***	-0.2131***	-0.2688***	-0.4573***	-0.2094***	-0.0506	-0.3098***	-0.0015
$\delta_{i=1}$	0.1039***	0.3194***	0.0885***	0.3071***	0.0205***	0.2616***	0.0036***	0.2233***	0.0062	0.2060***
$\delta_{i=2}$	0.1140***	0.2896***	0.0450***	0.2651***	0.0158***	0.2382***	0.0008	0.2090***	0.0042	0.1918***

Volatility Spillover

	Brazil	Russia	India	China	South Africa
ω_{CT}	0.0000	0.0000*	0.0000	0.0000	0.0000
ω_{SR}	0.0000	0.0000	0.0000	0.0000	0.0000
α_{CT}	0.1881**	0.2347***	0.1940***	0.0504***	0.1662***
α_{SR}	0.0209*	0.0664**	0.0250***	0.0563***	0.0133
β_{CT}	0.8467***	0.8039***	0.8395***	0.8911***	0.8806***
β_{SR}	0.9142***	0.9046***	0.8941***	0.9285***	0.9129***
γ_{CT}	-0.0810***	-0.0927***	-0.0691***	0.0683***	-0.1288***
γ_{SR}	0.0865***	0.0474**	0.1264***	0.0283**	0.1153***
a	0.0033**	0.0022***	0.0017**	0.0065***	0.0065***
b	0.9956***	0.9964***	0.9976***	0.9731***	0.9918***