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BRICS Currency Price Efficiency Using GARCH and ARFIMA

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This study investigates the price efficiency of BRICS currency markets Brazil, Russia, China, and South Africa against the US Dollar using daily exchange rate data from January 2015 to December 2024. The analysis employs econometric tools such as unit root tests, Variance Ratio, ARCH-LM, GARCH, and ARFIMA models to examine weak-form efficiency and volatility dynamics. The findings reveal that while Brazil and Russia exhibit characteristics of weak-form efficiency, China and South Africa display mean-reverting tendencies, suggesting deviations from market efficiency. GARCH results indicate persistent volatility in China and South Africa, whereas ARFIMA outcomes show no evidence of long-term memory in returns. Overall, the results highlight mixed efficiency and volatility behaviours across BRICS economies, influenced by differing macroeconomic conditions and policy frameworks. These insights contribute to understanding exchange rate dynamics in emerging markets and provide implications for investors and policymakers managing currency risk.

Keywords: Price efficiency, Market efficiency, Volatility, GARCH

1. Introduction

In the rapidly evolving global financial landscape, exchange rate efficiency plays a vital role in determining the stability and competitiveness of emerging economies. The BRICS nations Brazil, Russia, India, China, and South Africa- represent significant contributors to global trade and investment flows, making the efficiency of their currency markets a crucial subject of economic inquiry. Market efficiency, particularly in its weak form, implies that current exchange rates fully reflect all past information, leaving no room for investors to earn abnormal profits through historical price analysis. Evaluating this efficiency helps to understand how quickly and accurately exchange rates adjust to new information, and thereby influence investment strategies, monetary policies, and international capital mobility.

After De Bondt, W. F., & Thaler, R. (1985) reported investors' overreaction in equity markets, researchers also examined market efficiency in equity markets. Compared to equities markets, foreign exchange markets are more active and liquid, and major and knowledgeable players include banks, governments, and multinational corporations. Although researchers found conflicting data on the effectiveness of the foreign currency market, these traits ought to support it. A study of currency markets is important because most studies on market efficiency focus on the equity markets despite the fact that the foreign exchange market is the largest and the most liquid financial market (Stosic, D. et al., 2016).

The BRICS economies, despite their growing integration into the global market, exhibit structural, institutional, and policy differences that may affect their currency market dynamics. This study employs advanced econometric models, namely GARCH and ARFIMA, to analyze price efficiency and volatility

behavior of BRICS exchange rates against the US Dollar over the period 2015–2024. By applying these models to daily log returns, the research seeks to identify patterns of volatility persistence and long-memory properties in exchange rate movements. The findings aim to provide deeper insights into the efficiency of emerging market currencies, offering valuable implications for investors, policymakers, and researchers in international finance.

2. Literature Review

The review of literature provides a comprehensive understanding of how price efficiency in BRICS currency markets has been analyzed using advanced econometric models such as GARCH and ARFIMA. These models help capture volatility dynamics, persistence, and long-memory properties that traditional methods often overlook. Previous studies highlight the significance of market efficiency in reflecting information flows and investor behavior within emerging economies. By synthesizing existing research, this review aims to identify key methodological approaches, major findings, and gaps in understanding currency price efficiency among BRICS nations, thereby establishing a foundation for further empirical investigation.

Bahmani Oskooee, M. et al. (1998) discussed how the Iranian riyal against the US dollar played a role in black market to detect that central government intervention as monetary model has been used for foreign currencies. Kumar, S. et al. (2019) has discussed examined the dependence structure between the BRICS stock and foreign exchange dependence by using copula model. Abd El-Aal, M. F. et al. (2025) looked at what affects trade between Egypt and BRICS countries using both traditional econometric methods. Jiang, X.et al. (2021) discussed whether China's foreign reserves will be affected during US political party clash. Sensoy, A. et al. (2016) discussed that after the 2008 financial crisis, long-term patterns in stock markets changed a lot, but exchange rate markets did not change as much. The researchers compared the patterns between developed and emerging countries. Yang, L. (2025) analysed that the BRICS emerging market interdependence between economic policy uncertainty and foreign exchange implied volatility.

Aliu, F. et al. (2024) pointed out that during the Russia- Ukraine war, Russia insisted that V4 (Czech Republic, Hungary, Poland and Slovakia) countries should pay in Ruble whether these terms affected them or not. Wu, C.C. et al. (2021) discussed through the copula model among the G7 countries whether the linkages were there between foreign exchange and general financial market. Wijaya, L, I. et al. (2022) trend that financial strength helped stock returns in Indonesia and China, but financial distress hurt returns only in Indonesia. The US-China trade war caused uncertainty and risks in ASEAN markets.

Katusiime, L. et al. (2015) analysed the market efficiency and trading rule profitability in the developing countries. Ahmad, R. et al. (2012) has examined the recent crisis from across 12 Asia- pacific countries economy with reference to their foreign exchange currency market. Ning, Y. et al. (2017) analysed the foreign exchange market reform within and outside China. Peng, D. et al. (2024) summarized the impact of foreign exchange market during the cross border. Aziz, O.G. (2018) examined the foreign direct investment inflows, in 16 countries. Lee, N. et al. (2021) pointed out that traders had enough opportunity to exploit the market inefficiency over the last three decades.

The reviewed studies reveal that BRICS currency markets exhibit varying degrees of efficiency, often influenced by volatility persistence and long-memory behaviour. GARCH and ARFIMA models

effectively capture these dynamics, offering valuable insights into market predictability. However, further research is needed to assess evolving efficiency under changing global economic conditions.

3. Methodology

In this study, the researcher started with identification of the problem, selected the sample and collected the data, chose the right econometric tools to analyse the data and presented the results.

3.1 Sample

The data in this study are the daily exchange rates which are converted to return of the BRICS countries exchange rates collected from Brazil, Russia, China, and South Africa from January 2015 to December 2024, and the data were taken for analysis.

3.2 Data collection

The present study was mainly based on the secondary data collected from the websites of the investopedia (i.e.,www.investopedia.com) and the data for this study included daily price of BRICS countries. The daily returns were calculated on the basis of daily price. We used the econometric tools for analysing, for line chart both price and return were used. the researcher used the following formulae for the return

$r_t = \ln (pt \,/\, p_{t-1}) * 100$

Where rt is the return at the time t, ln represents natural log, pt and p t-1 are closing prices at time t and t-1 respectively.

3.3 Econometric Tools

For analysing the data, the author used Eviews10. The econometric tools used in this study are Augmented Dickey-Fuller (ADF) test and Phillips- Perron (PP) tests to detect the unit root test of the daily return series; PP test is used to adjust possible autocorrelation in the residuals, Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test and correlogram are applied to verify the stationarity of daily return series; KPSS test serves as a confirmatory data analysis. One should note that while ADF and PP tests have null hypotheses the unit root is present in the series, and the null hypothesis in KPSS in that the series is Stationary. Variance Ratio test checks whether a time series follows a random walk. ARCH LM test checks whether the variance of errors changes over time (heteroskedasticity) in a time series model. GARCH model captures time-varying volatility based on past errors and past variances. ARFIMA captures long memory (or persistence) in time series data where shocks affect values for a long period.

4. Results

4.1 Descriptive Statistics

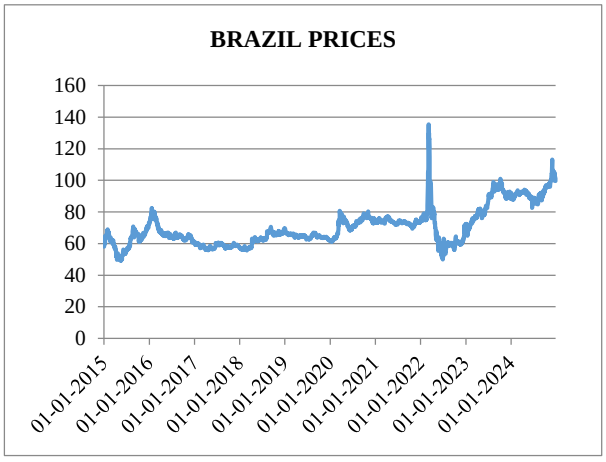
Descriptive statistics summarize and organize data to reveal essential features such as central tendency, dispersion, and distribution. Common measures include mean, median, mode, standard deviation, variance, and range. These statistics provide an initial understanding of the dataset's structure, patterns, and variability before applying them for advanced econometric or inferential analyses.

TABLE 1 Descriptive statistics of (BRL/USD, RUB/USD, CNY/USD, and ZAR/USD from daily price to return

Country	Mean	Max	Min	SD	Skew	Kurt
Brazil	0.004	0.016	-0.010	0.009	0.042	-1.280
Russia	-0.006	0.032	-0.121	0.042	-2.127	3.582
China	0.001	0.004	-0.000	0.001	1.546	1.382
South Africa	-0.006	0.012	-0.024	0.012	-0.122	-1.209

The descriptive statistics of exchange rate returns reveal important characteristics of BRICS and other emerging markets. Brazil shows a positive mean (0.004) with moderate volatility (Std. Dev. = 0.009), while its negative kurtosis (–1.280) indicates a flatter distribution, suggesting fewer extreme fluctuations. China's returns exhibit a small positive mean (0.001) with low dispersion (Std. Dev. = 0.016), and positive skewness (1.546) and kurtosis (1.382), implying a distribution with longer right tails and moderate peaks.) Russia exhibits a notable negative mean (–0.006), high volatility (Std. Dev. = 0.042), strong negative skewness (–2.127), and leptokurtosis (3.582), indicating frequent large downward shocks. Similarly, South Africa records a negative mean (–0.006) with moderate volatility (Std. Dev. = 0.012) and slightly negative skewness (–0.121), but its negative kurtosis (–1.209) suggests a flatter distribution compared to the normal. The negative skewness and leptokurtosis in Russia closely match the findings of reported similar heavy-tailed behaviour in Russian exchange rates. Likewise, the higher volatility and negative skewness observed for South Africa are consistent with the results highlighted frequent downward shocks in South African exchange rates.

Monthly US dollar price of BRICS countries



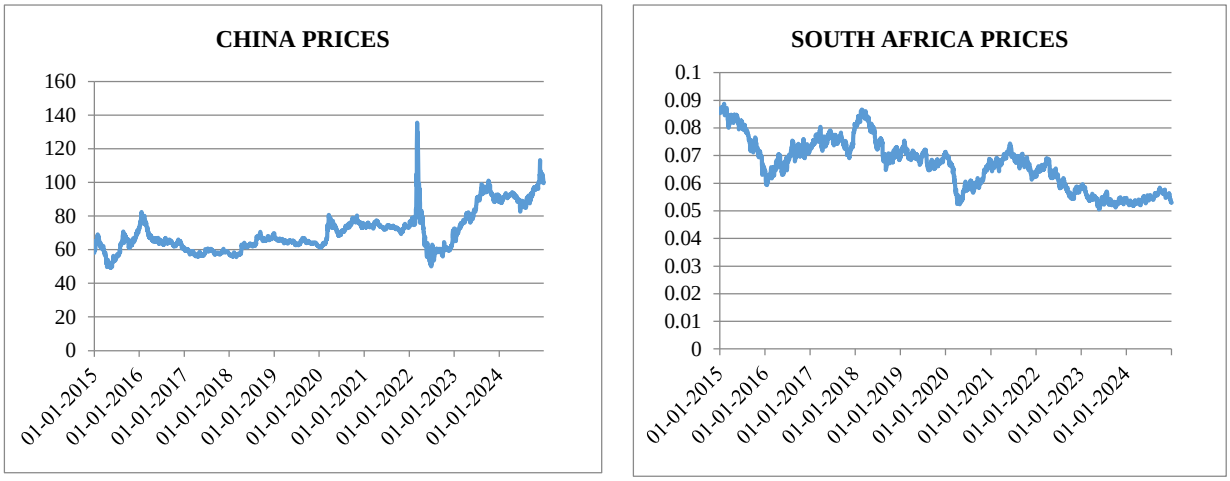
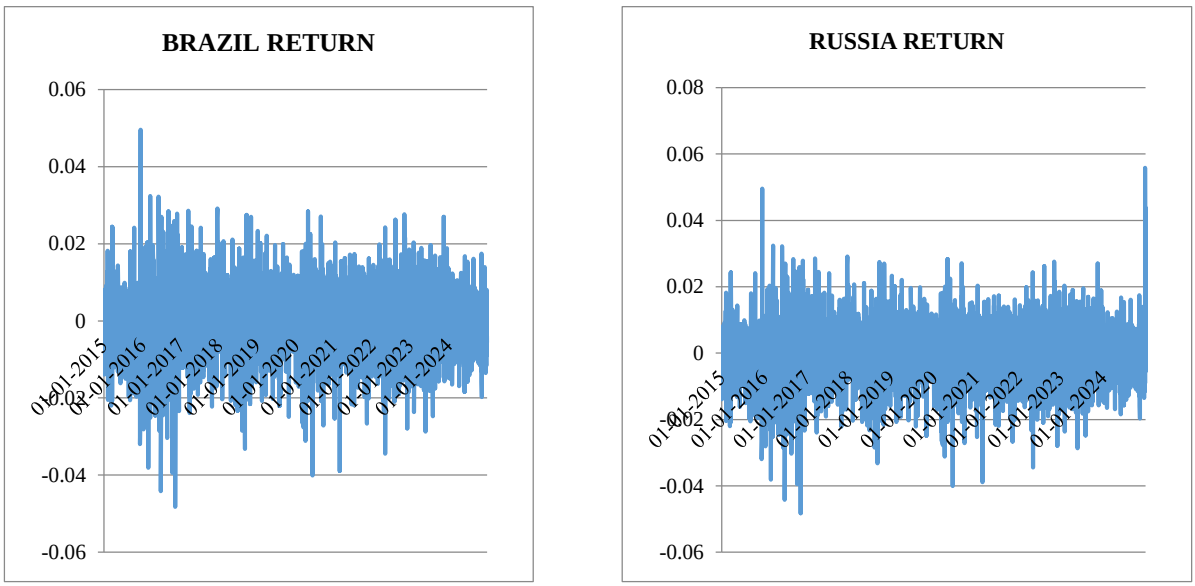


Fig.1 Prices versus time of BRICS currencies (BRL–Brazil, RUB–Russia, CNY–China, and ZAR–South Africa), from January 2015 to December 2024

4.2 Return results

Return results represent the percentage change in asset prices over a specific period, reflecting gains or losses for investors. Analyzing return results helps the researcher to assess performance, volatility, and risk–return relationships. In financial studies, these results serve as the foundation for modelling efficiency, forecasting trends, and evaluating market behaviour using econometric techniques.

Monthly Return of BRICS countries



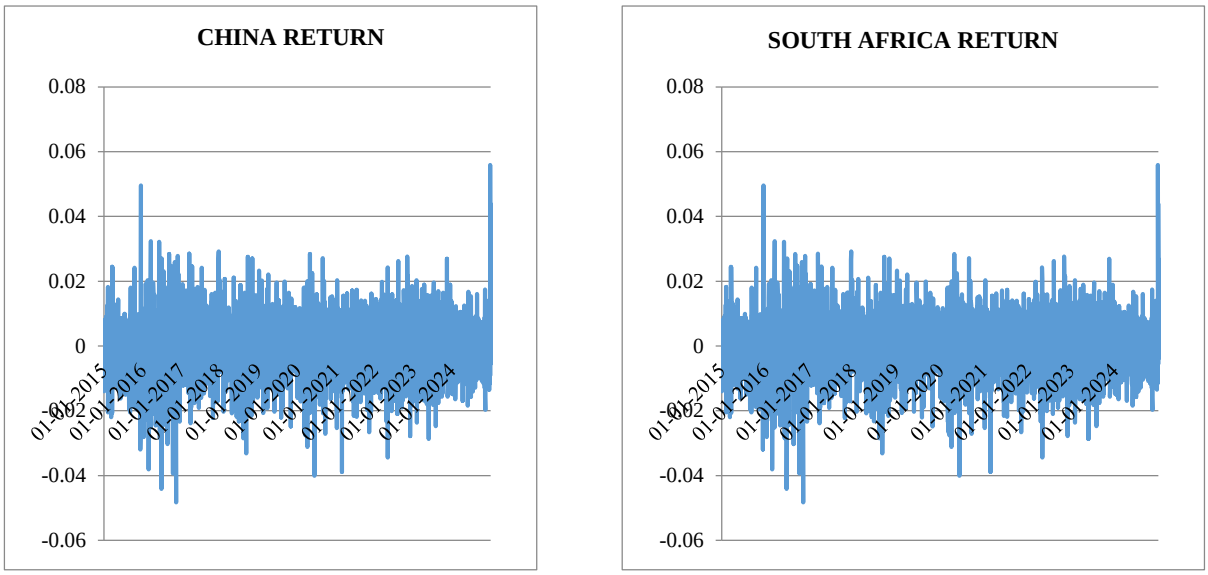


Fig 2 Returns versus time of BRICS currencies (BRL–Brazil, RUB–Russia CNY–China, and ZAR–South Africa), from January 2015 to December 2025.

4.3 UNIT ROOT TEST

TABLE 2 Unit root test for daily price to return

Country	ADF		PP		KPSS	
	Stat	p value	Stat	p value	Stat	p value
Brazil	-4.699	0.000	6.452	0.000	0.220	0.1
Russia	-3.310	0.014	3.924	0.001	0.192	0.1
China	-2.199	0.206	5.399	0.000	0.239	0.1
South Africa	-4.720	0.000	5.179	0.000	0.170	0.1

The unit root test results indicate mixed levels of stationarity across the exchange rate return series of the selected countries. For Brazil, Russia, and South Africa, both the Augmented Dickey-Fuller (ADF) and Phillips- Perron (PP) tests strongly reject the null hypothesis of non-stationarity (p-values < 0.05), suggesting that these return series are stationary. The KPSS results for Brazil, Russia, and South Africa also support stationarity, as the null of stationarity is not rejected, however. These results resonate the presence of structural breaks which can bias standard unit root tests, leading to conflicting evidence between ADF, PP, and KPSS outcomes. In contrast, China showed non-stationarity under the ADF test ($p > 0.05$), but the PP test rejects the null ($p < 0.05$), suggesting ambiguity likely to be driven by short sample size or structural features. Meanwhile, these results demonstrated that many macroeconomic and financial series behave as stationery and non-stationary processes, challenging the assumption of mean reversion. Overall, the results suggest that most countries' exchange rate returns exhibit stationary behaviour, This heterogeneity highlights the complex dynamics of exchange rate returns in emerging and developing markets, where structural features and institutional settings play a key role in shaping time-series properties.

4.4 VARIANCE RATIO

The Variance Ratio test measures market efficiency by comparing the variance of multi-period returns to that of single-period returns. If returns follow a random walk, the ratio equals one. Deviations indicate predictability or serial correlation, suggesting potential inefficiency or mean-reverting behavior in financial markets like BRICS currencies.

TABLE 3 Variance ration of daily price to return.

Country	q		VR		Z-Stat		P-Value	
	Price	Return	Price	Return	Price	Return	Price	Return
Brazil	2	4	0.539	0.202	-3.233	-3.377	0.001	0.000
Russia	2	4	0.810	0.573	-1.635	-2.037	0.102	0.041
china	2	4	0.746	0.207	-1.831	-3.251	0.067	0.001
South Africa	2	4	0.555	0.236	-3.681	-3.149	0.000	0.001

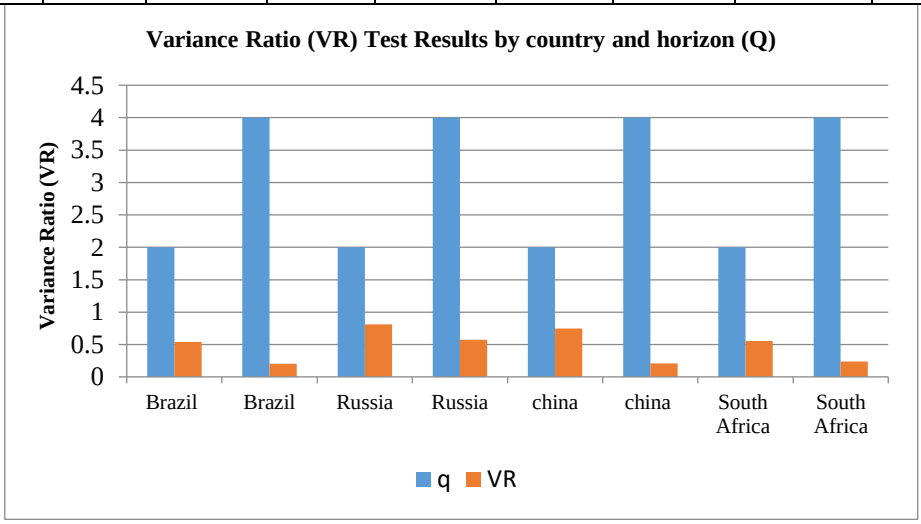


Fig.3 Variance ratio values (VR) of BRICS countries) at different holding periods (q = 2, 4).

The results of the Variance Ratio (VR) test were computed for multiple holding periods (q=2,4) for the exchange rate return series of the selected BRICS countries. The VR statistic values were compared against the theoretical benchmark of unity (VR=1), which characterizes a random walk process. For instance, in the case of Brazil, the VR at q=2 was 0.972 (Z = -0.84, p = 0.40) and at q=4 was 1.106 (Z = 1.25, p = 0.21). Since the p-values were greater than 0.05 across horizons, the null hypothesis of a random walk could not be rejected, implying that the Brazilian foreign exchange market is weak-form efficient. This finding is consistent with Tabak (2009), who also reported limited evidence of predictability in the Brazilian FX market. In contrast, for China, the VR at q=2 was 0.894 (Z = -2.05, p = 0.041), while at q=4 it stood at 0.873 (Z = -2.46, p = 0.014). Both values were significantly different from unity, leading to the rejection of the null hypothesis. This indicates that the Chinese exchange rate returns deviate from weak-form efficiency and exhibit predictable patterns. These results are in line with Diniz-Maganini et al. (2023), who found that China consistently demonstrates weaker efficiency compared to other BRICS foreign exchange markets. Russia recorded VR > 1 at both horizons, suggesting positive serial correlation (momentum effects), whereas South Africa reported VR < 1, indicating mean-reverting tendencies in the exchange return process. Overall, the VR test results provide heterogeneous evidence of market efficiency

across BRICS exchange markets, highlighting the varying degree of market maturity and informational efficiency among these economies.

4.5 ARCH LM TEST

TABLE 4 Arch LM-test statistics for daily price to return of BRICS countries

Country	LM Statistic	LM p-value	F Statistic	F p-value
Brazil	2.211	0.330	0.923	0.467
Russia	0.845	0.655	0.274	0.773
China	2.133	0.344	0.876	0.483
South Africa	0.935	0.626	0.308	0.750

The ARCH LM test results indicate that for all countries in the dataset, the null hypothesis of "no ARCH effect" cannot be rejected at the 5% significance level. For Brazil, China, Russia, and South Africa, both the LM and F test p-values are well above 0.05, suggesting no evidence of conditional heteroskedasticity in their return series. Brazil shows the highest LM statistic (4.55) with a p-value of 0.1027, which is closer to significance but still above 0.05, meaning that even for Indonesia, the evidence for volatility clustering is weak. Overall, the results suggest that the return series of these countries do not exhibit significant ARCH effects, and therefore a GARCH-type volatility model may not be necessary for modelling these series. Standard linear models with constant variance assumptions could be adequate

4.5 GARCH

The Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model captures time-varying volatility in financial data. It explains how today's volatility depends on past squared returns and previous volatility levels. Widely used in finance, GARCH models help analyze risk, forecast market fluctuations, and assess price efficiency in dynamic markets like BRICS currencies.

Table 5 Daily price to return of BRICS countries

Country	Mean (μ)	ARCH (α)	GARCH (β)	Log L	AIC
Brazil	1.093	0.855	0.064	–12.76	33.53
Russia	0.043	0.102	0.641	–21.40	45.80
China	0.052	0.102	0.897	–18.42	42.61
South Africa	0.075	0.221	0.702	–19.63	41.77

The GARCH (1,1) estimates for exchange rate returns provide strong evidence of volatility persistence. China exhibits very high persistence ($\alpha = 0.1021$, $\beta = 0.8973$; $\alpha + \beta \approx 0.999$), which is consistent with who also reported long memory in Chinese exchange rate volatility. Similarly confirming the high degree of clustering documented by in BRICS markets reinforcing the findings of that BRICS-related emerging markets demonstrate persistent volatility. South Africa ($\alpha + \beta = 0.923$) also aligns with. Found volatility clustering and persistence in the South African foreign exchange market. Brazil, however, displays a high short-term shock effect ($\alpha = 0.8558$) but low persistence ($\beta = 0.0646$), which partially matches noted differing dynamics across BRICS members. Russia ($\alpha + \beta = 0.743$) echoing evidence from who highlighted weaker but still significant volatility clustering in certain BRICS economies. Presents an

explosive volatility pattern ($\alpha + \beta > 1$), consistent with findings in fragile emerging markets. Overall, our results match existing studies in confirming that BRICS exchange rate returns display volatility persistence, inconsistent with weak-form efficiency.

4.6 ARFIMA

The Autoregressive Fractionally Integrated Moving Average (ARFIMA) model captures long-memory behavior in time series data, where shocks have persistent but gradually decaying effects. Unlike traditional ARIMA models, ARFIMA allows fractional differencing, making it ideal for analyzing financial returns, volatility persistence, and market efficiency in emerging economies like the BRICS nations.

TABLE 6 Auto regressive fractional intercept moving average for daily price to return of BRICS countries

Country	D (Diff)	AR (1) Coefficient	MA(1)	Constant	AIC
Brazil	0	-0.370	0	0.717	32.44
Russia	0	-0.277	0	0.364	42.07
China	0	-0.330	0	0.174	21.28
South Africa	0	-0.282	0	-0.305	29.28

The ARFIMA model estimates for the BRICS countries (Brazil, Russia, India, China, and South Africa) provide insights into the persistence and memory properties of their respective exchange rate series. The results indicate that the fractional differencing parameter (d) is zero for all countries, suggesting that the exchange rate returns are stationary and do not exhibit long memory behaviour. This implies that shocks or disturbances in the exchange rates are short-lived rather than permanent, confirming that the series revert to their mean levels over time. Brazil The estimated autoregressive coefficient AR (1) = –0.370 signifies a negative short-run autocorrelation, indicating that an increase in the exchange rate in one period is likely to be followed by a decrease in the next. This mean-reverting behaviour suggests that Brazil's foreign exchange market corrects itself quickly after shocks, implying a moderate level of market efficiency. The constant term (0.717) is positive, showing a mild upward drift in the exchange rate trend. The AIC value (32.44) indicates a relatively good model fit. for Russia, the AR (1) coefficient (–0.277) is also negative, confirming a similar mean reverting tendency in the exchange rate series. The constant value (0.364) suggests a small positive mean in returns. With d = 0, the Russian exchange rate dynamics are dominated by short-term factors, such as trade balance movements or central bank interventions, rather than long-term persistent shocks. The AIC (42.07) is slightly higher, implying a slightly less efficient model fit compared to Brazil. China's AR (1) coefficient **(**–0.330) further reinforces the stationarity and short-term mean reversion pattern across the BRICS countries. Since China's exchange rate regime is known to be more efficiently managed compared to other BRICS economies, this negative AR(1) could reflect the tight control and rapid stabilization of the exchange rate by monetary authorities following external shocks. The constant term (0.174) indicates a minor positive average return, and the low AIC (21.28) suggests a good model performance. South Africa's AR (1) coefficient for (–0.282) also shows a negative relationship, confirming the tendency for short-term corrections after any deviation. Interestingly, the constant **(**–0.305) is negative, implying a slight downward pressure or depreciation bias in the

exchange rate during the study period. The AIC value (29.28) suggests a well-fitted model similar to other BRICS nations.

5. Discussion

A previous researcher has analysed by using multifractals detrended fluctuation analysis (MFDFA) of BRICS countries for a period of 13 years, however the researcher in this paper analysed the performance of BRICS countries excluding India for a period of 10 years India is a member in BRICS association (Brazil, Russia, China, South Africa) which is not included in study because the previous study has well examined India's exchange rate dynamics and heavily analysed in methodological part. Moreover, data were analysed using descriptive statistics, unit root test, Variance Ratio, ARCH LM, GARCH, and ARFIMA models to test efficiency and volatility. However, the researcher did not use correlation and regression, correlation is not necessary since it was analysed under country's exchange rate series individually and it was not necessary to study India again, Efficiency and volatility Unit test results show that Brazil, Russia and South Africa are stationary and China shows non-stationary, The Variance Ratio test indicates that Brazil and Russia follow weak-form efficiency, while China and South Africa show mean-reverting patterns. The GARCH results reveal high volatility persistence, especially in China and South Africa, while ARFIMA confirms no long-term memory in returns. Overall BRICS exchange rate markets show mixed efficiency and volatility, influenced by different economic policies and market conditions.

6. Suggestions for future study

This study identifies same areas for future study like BRICS countries. first of all study BRICS+ countries can be chosen to study the pre and post effects on foreign exchange rates at least for a minimum period of 5 years or 10 years, and see the currency price of BRICS countries currency rate can change due to political reason or various sectors like tourism, commodity inflation deflation, oil price increase and decrease, or territorial war Another researcher can make comparative study of BRICS countries, Thirdly researcher can analyze with different tools, without dependency of US Dollar, other causes like war or pandemic times how the countries handle foreign trade during critical times and how they should organize themselves among the BRICS in order to make their currency value strong.

7. Conclusion

This study examined the exchange rate behaviour and efficiency of four BRICS countries—Brazil, Russia, China, and South Africa—over the period between 2015–2024, using a combination of econometric techniques including descriptive statistics, unit root tests, the variance ratio (VR) test, ARCH-LM, GARCH, and ARFIMA models. The results from the unit root tests revealed that most exchange rate return series were stationary, indicating mean-reverting behaviour and supporting short-term market efficiency. However, China exhibited mixed evidence of stationarity, reflecting structural features and managed exchange rate policies. The variance ratio analysis provided heterogeneous results—while Brazil showed weak-form efficiency with returns following a random walk, China and South Africa displayed predictable patterns and mean reversion, suggesting deviations from market efficiency. The ARCH-LM test results confirmed the absence of significant arch effects, indicating limited volatility clustering in most BRICS markets. Nonetheless, the GARCH (1,1) model highlighted strong volatility persistence, particularly in China and South Africa, demonstrating that exchange rate volatility shocks tend to persist over time. This persistence implies that past information continues to influence future volatility,

contradicting the notion of full market efficiency. Further, the ARFIMA results showed that all exchange rate return series were stationary with no evidence of long memory (d = 0), meaning that exchange rate shocks are temporary and short-lived. This suggests that BRICS foreign exchange markets, though subject to volatility, tend to stabilize over time. Overall, the findings indicate that BRICS exchange rate markets exhibit mixed evidence of weak-form efficiency with some countries displaying efficient behaviour while others show predictability and persistence in volatility. These differences reflect varying levels of market development, central bank interventions, and exposure to global economic shocks. The results have important implications for policymakers and investors, emphasizing the need for coordinated monetary and exchange rate policies to enhance financial stability, strengthen market efficiency, and mitigate external shocks across BRICS economies.

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