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Efficacy of central bank intervention in the foreign exchange market of the BRICS countries

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Abstract

Central bank intervention plays a major role in managing exchange rate volatility. In comparison to advanced economies, emerging market economies are generally active in the forex market as excessive volatility of the local currency persists. The BRICS countries (Brazil, Russia, India, China and South Africa) are the major emerging economies influencing the international financial system. The paper empirically investigates the efficacy of central bank intervention in the case of the BRICS countries. It has been observed that intervention generally did not impact the exchange rate level; however, it reduced the volatility of the exchange rate. Furthermore, interventions in spot and derivatives markets are equally effective in containing exchange rate volatility, except in South Africa. It has been identified that sovereign yield spread impacts the exchange rate returns in China and South Africa and impacts the volatility in the returns in Brazil and Russia.

Keywords

Central bank, foreign exchange market, intervention, BRICS, GARCH.

JEL: C34, C58, E44, F3.

Introduction

The international monetary system has undergone a drastic change in the past decades, with the collapse of the Bretton Woods system[1] when the era of the fixed exchange rate system became history and flexible exchange rate policies were adopted by most of the central banks. The flexibility of the exchange rate has helped emerging economies (EMEs) to make it more market-driven and reduce intervention by policymakers. The flexible exchange also helped EMEs to (i) attract foreign investment, (ii) overcome their balance of payment crises. However, this also leads to infrequent interest rate wars and central bank intervention in achieving a competitive exchange rate, which has become a usual phenomenon.

Although it is a well-known fact that almost all central banks intervene in the foreign exchange market, there is no clear consensus on the efficacy of intervention. The question arises as to whether the interventional operation really matters? Finding the answer to this question is not easy. The area related to central bank interventions is traditionally considered secret, and the justification for this is that there might be a misuse of information by market participants (Neely, 2006). Particularly, this issue is more pertinent in the case of EMEs where market size is usually larger than the central bank's ability to intervene in the market (Humpage, 2011).

Due to the secrecy of the area related to the intervention, there are many issues. The main issue in this area is data availability. Barring very few EMEs (Latin American and Eurozone countries), there is a lack of publicly available daily data that would be the best choice to examine the efficacy of intervention. Most EMEs do not publish intervention data or if they do, then monthly, quarterly or yearly with a delay of one or two months. Due to global pressure to disclose exchange rate related activities, many countries publish data on interventions; further, the authenticity of the data is questionable. In the absence of a publicly available and credible dataset, alternative proxies are commonly used in the literature, such as a change in the official foreign exchange reserve as a proxy for intervention. It has been observed that the recent dataset on intervention published in the IMF working paper and compiled by Adler et al. (2021) captured more accurate intervention activities than any other proxies.

Why BRICS? In 2001, Jim O'Neill from Goldman Sachs first coined the acronym "BRIC," referring to the group of Brazil, Russia, India and China. In 2010, the fifth country, i.e., South Africa, joined the group and BRIC became BRICS. The emergence of new economic power blocks, such as BRICS, has witnessed a new role in international finance. China became a manufacturing hub and the world's largest foreign exchange reserves holder. The BRICS share in the world's GDP is around 23%. The five nations comprise 42.58% of the world's population, 17% of the global trade, and have 13.24% of voting power in the World Bank and 14.91% of the IMF quota (Rao & Padhi, 2020). Further, the global financial crisis (GFC) of 2008-2009 witnessed

[1] An international exchange rate arrangement appeared after World War II when countries' currencies were pegged to the US dollar and the dollar was convertible into gold.

an overall shift in financial market activities. After the GFC, an increase in capital flows to emerging economies resulted in appreciation pressure on their currencies. During this period, many economies actively intervened in the foreign exchange market.

The BRICS countries have differences in many fields. The five member countries are spread over four continents, with China having the largest population and Russia – the largest land area. The group members have different politics and economics. Nevertheless, there are many commonalities between them, for example, all emerging economies would like to influence the world by internationalizing currency and increasing foreign trade. All five economies formally admit that they intervene in the foreign exchange market to reduce the volatility of the domestic currency. The motives of the intervention are again a debatable area as there is no clear message from central banks. Furthermore, if there is a clear message, there is a difference between de facto and de jure. The issues with the availability of intervention data and the lack of clarity in the motives of intervention by central banks lead to estimation or methodological problems.

In this background, considering the importance from the central bank's point of view of examining the efficacy of intervention, the paper seeks to study the BRICS countries. Although there are some studies in the literature that discuss the BRICS foreign exchange markets (Kannaiah & Murty, 2017; Aroul & Swanson, 2018; Kannaiah & Murty, 2017), these studies are scant and address other issues besides the efficacy of central bank intervention. However, there are a large number of studies that analyse the effectiveness of intervention for Brazil (Eduardo et al., 2011; Oliveira, 2020; Viola et al., 2019) as Brazil publishes intervention data with daily frequency. In the case of other BRICS members, the studies are limited due to data inadequacy.

The present study attempts to assess the efficacy of forex intervention on the example of the BRICS countries. Further, when analysing the efficacy of intervention, the study also compares the differences and similarities of the BRICS countries. The study addresses the question: "Are interventions in the spot market and the derivatives market equally effective?" and examines the main driving forces or techniques involved in the intervention, as well as their intensity and direction of impact. Considering the volatility in the exchange rate variable, we use the GARCH (1,1) methodology to understand the efficacy of central bank intervention and other macroeconomic variables.

The results of the empirical estimates indicate that central bank intervention matters in both spot and derivatives markets as the intervention in both spot and derivatives markets reduces the volatility of the exchange rate returns. However, intervention plays a limited role in influencing the level of the exchange rate.

The rest of the study is divided into five sections. Section 1 provides background information on exchange rate volatility and central bank intervention in the BRICS countries. Section 2 presents currency markets and related policies adopted by the BRICS nations. Section 3 contains a report on the main studies available on the issue

of efficiency of forex intervention in the BRICS countries; section 4 explains the data used in the study and the empirical methodology; section 5 empirically estimates the efficacy of central bank intervention, while last section, on policy implications, concludes the study.

1. Exchange rate volatility and central bank intervention

Excessive exchange rate volatility adversely impacts the economy. Although excessive volatility results in different outcomes for corporations, from an investor's point of view, this creates uncertainty about future outcomes (Gulde & Wolf, 1992). Movements in the exchange rate of a particular currency depend on various macroeconomic factors and the exchange rate regime adopted by the country. Mainly there are two extreme regimes: fixed and floating. In between these two extreme regimes, various mixed regimes can be seen. However, the efficiency and suitability of exchange rate regimes have been the subject of research.

In its Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER) the IMF publishes exchange rate practices followed by various members. There are more than 10 exchange regimes, starting from free-floating, mostly adopted by advanced counties, to exchange rate arrangements with no separate legal tender (such as the European Currency Union), and currency board arrangements, such as the Hong Kong Monetary Authority's fixed exchange rate arrangement.

In the case of the BRICS countries, the IMF categorises Russia as a country with a free-floating exchange regime in which the central bank rarely intervenes in the foreign exchange market. Brazil, India and South Africa are grouped in a floating exchange rate regime under which the market forces largely determine the exchange rate. However, there is no predetermined path in which the central bank can intervene in the exchange rate in the market to prevent undue volatility. However, the IMF has kept it in the residual category (other managed arrangement regime) for China.

Table 1. Overview of exchange rate systems in BRICS

	Exchange Rate History	As per IMF classification	Foreign Exchange Market Size	Foreign Exchange Reserves (USD bn)*	Intervention data availability
Brazil	Soft page with USD (from 1995 to December 1998). From 1999 onwards, inflation targeting for 3.75% (with band +/- 1.5%)	Floating exchange rate	66	356.1	Daily data

Table 1. Continued

	Exchange Rate History	As per IMF classification	Foreign Exchange Market Size	Foreign Exchange Reserves (USD bn)*	Intervention data availability
Russia	From 1995 onwards, pegged exchange rate with crawling band against USD. 2015, inflation targeting regime was adopted with a target of 4%	Free Floating exchange rate	63	586.3	Monthly
India	Current account convertibility adopted in 1994. Adoption of flexible inflation targeting in August 2016, with a mandate of 4% (+/-2%)	Floating exchange rate	110	586.7	Monthly
China	Pegged with USD No inflation target	Other managed arrangement	270	3528.8	Do not publish
South Africa	From 2000 onwards, inflation targeting framework with a range of 3 to 6%.	Floating exchange rate	62	53.3	Do not publish

Note: Foreign exchange market size is a turnover of respective currency in USD billions per day. * – pertains to February 2021.

Source: Official websites of each country's central banks.

There is no clear consensus about which exchange regime is best for a particular country. However, early literature suggests that in smaller countries with open economies, a fixed exchange rate regime is suitable as it eliminates unwanted volatility of the exchange rate and helps the country keep inflation under control. On the other hand, a flexible exchange regime tends to allocate resources efficiently as the market forces determine it. In reality, an optimal exchange rate system is not an option but rather a decision determined by the failure of previous systems to deliver stability and sustainable growth (Dua & Ranjan, 2012).

The performance of the BRICS countries after the exchange rate changes also varies, and there is an interdependence of spillover effect as identified in the correlation matrix of Table 2 below. The sample period is from January 2000 to July 2021 at a non-nominal exchange rate per USD. All currency returns are positively correlated. Returns from the South African rand are positively correlated with the Brazilian real, the Russian ruble and the Indian rupee returns. It can be observed that, except the Chinese yuan, other three currencies indicate interdependency. The Chinese renminbi is the least correlated currency with other BRICS currencies. A possible reason behind this may be the fact that, in comparison to their currencies, the Chinese currency is tightly regulated by the PBOC (Dube, 2019).

Table 2. Correlation matrix of currency returns

	Brazilian Real	Russian Ruble	Indian Rupee	Chinese Yuan	South African Rand
Brazilian Real	1.000				
Russian Ruble	**0.394**	1.000			
Indian Rupee	**0.485**	**0.359**	1.000		
Chinese Yuan	0.212	0.204	0.170	1.000	
South African Rand	**0.405**	**0.336**	**0.485**	0.209	1.000

Source: Compiled by the authors.

Exchange rate volatility has always been a major concern for any central bank. Apart from various other macroeconomic variables, such as money supply, current account balance, external trade, inflation, etc., uneven movements in the exchange rate can play the role of a leading indicator (Rao & Padhi, 2020). Excessive volatility leads to a currency crisis if it cannot be contained on time. It has been observed that large capital flows and heightened volatility in the exchange rate were closely related (Chutasripanich & Yetman, 2015).

In the case of the BRICS currencies, Brazil experienced a currency crisis in 1999, with hyperinflation exceeding 900% in 1994 (Gruben & Kiser, 1999). However, recently, due to continuous monitoring, the Brazilian real has been comparatively stable against the Russian ruble and the Indian rupee.

Russia experienced a currency crisis in 1997-1998 and recently, in 2014-2015 (Rodionov et al., 2015). In the following Figure 1, we can see that the Russian ruble sharply devaluated in 2014-2015. South Africa also experienced episodes of currency crises between 1998 and 2001 (Bhundia & Ricci, 2005). However, the rand could not swing largely as compared to what other currencies usually experience during a currency crisis. India also faced a currency crisis in 1991. China and India also faced currency pressure during the East Asian crisis of 1997 (Peng & Bajona, 2008).

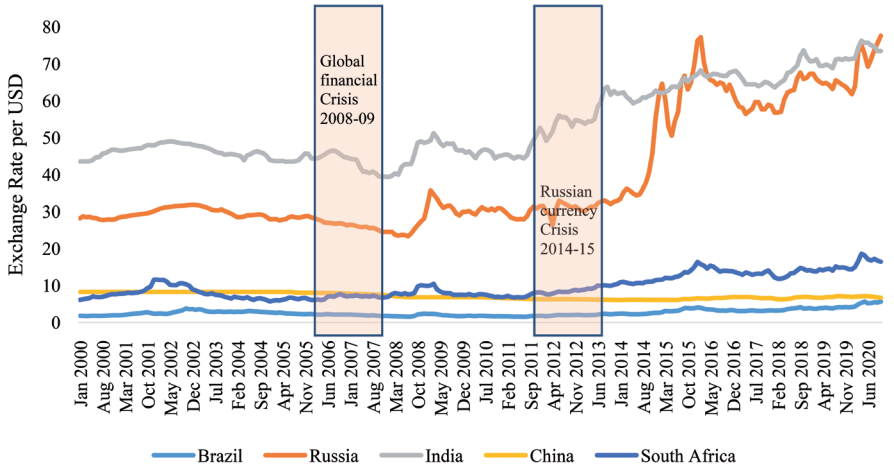

Figure 1. Exchange rate per USD. *Source:* Official websites of each country's central banks.

The BRICS countries need to be more vigilant considering the past experiences of currency crises. Apart from fiscal prudence, the countries need to ensure financial stability.

1.1. Factors determining the effectiveness of intervention

Various theories have been propounded to explain how the exchange rate was determined. However, all these theories can not be considered as a whole due to their specific assumptions and limited scope. Notwithstanding the extensive literature on theories and modelling of the exchange rate, unexpected exchange fluctuations continue to pose concern to governments and policymakers. Possible factors determining the effectiveness of intervention are the size of the market, the duration and the amount of intervention.

Foreign exchange markets are mainly divided into segments – spot and derivatives. A spot market is also called a cash market, where transactions are carried out immediately. Whereas a derivative market is a market for financial instruments such as forwards, futures, swaps and options. Though central bank intervention operations predominate in spot markets, foreign currency derivatives market interventions are more frequent (Adler et al., 2021a).

According to the latest triennial survey report of 2019 by the BIS (Bank for International Settlements), the overall foreign exchange market turnover per day in the world was USD 6,595 billion. As for the BRICS countries, the Brazilian real turnover was USD 66 billion, the Russian ruble turnover – USD 63 billion, the Indian rupee – USD 110 billion, the Chinese yuan – USD 270 billion, and the turnover of the African rand was USD 62 billion. Together, the BRICS currency share is 8.7% of the total foreign exchange turnover in the world.

Table 3. Foreign exchange market turnover – BRICS currencies

Currency	2010		2013		2016		2019	
	Amount	Percent	Amount	Percent	Amount	Percent	Amount	Percent
USD / Brazilian real	25	0.6	48	0.9	45	0.9	66	1.0
USD / Russian ruble	...	...	79	1.5	53	1.1	63	1.0
USD / Indian rupee	36	0.9	50	0.9	56	1.1	110	1.7
USD / Chinese yuan	31	0.8	113	2.1	192	3.8	270	4.1
USD / African rand	24	0.6	51	1.0	40	0.8	62	0.9
All currency pairs	**3,973**	**100.0**	**5,357**	**100.0**	**5,066**	**100.0**	**6,595**	**100.0**

Source: BIS Annual Survey; authors' calculation. Amount is in USD billion.

1.2. NDF vs domestic exchange rate market

NDF (non-deliverable forward) is an over-the-counter currency market in the offshore market. It's a derivative contract providing an avenue for investors to trade in non-

convertible currencies. The contract is usually settled in any convertible currency. An NDF market is usually located beyond the borders of domestic currency's jurisdiction. Being outside the ambit of regulatory jurisdiction, the price discovery depends on the demand and supply forces in the market. Various studies have discovered that there were interlinkages between onshore and offshore markets. Behera et al. (2021) discovered a stable and long-run relationship between onshore and NDF markets. The interaction between the NDF and the onshore foreign exchange market limits the effectiveness of intervention in the exchange rate (Lau et al., 2020).

Although global turnover in offshore non-delivery forward (NDF) continues to rise in aggregate, the paths of NDF markets have diverged across currencies: the Chinese yuan shows a sharp drop in turnover, while other emerging market currencies are gaining importance (BIS Triennial Central Bank Survey, 2016). As per the latest report by the Bank of England (January 29, 2019) on the percentage shares of average daily turnover by currency reported at the United Kingdom foreign exchange market, the Indian rupee turnover rose from 0.9% in April 2018 to 1.2% in October 2018, which is equal to the share of the South African rand, Mexican peso and higher than the Brazilian and Russian currencies turnover in the UK market.

Table 4. BRIC currency turnover in the NDF market (in USD bn)

Currency	2013		2016		2019	
	Amount	Percent	Amount	Percent	Amount	Percent
Brazilian real	15.9	12.5	18.7	14.0	35.7	13.8
Russian ruble	4.1	3.2	2.9	2.2	5.5	2.1
Indian rupee	17.2	13.5	16.4	12.2	50	19.3
Chinese yuan	17	13.4	10.4	7.8	11.8	4.6
All currencies	**127.3**		**134**		**258.8**	

Source: BIS triannual survey on the central banks; author's calculation.

Since foreign banks and institutional investors are present in both onshore and offshore NDF markets, they profit from arbitrage opportunities. Such entities buy dollar-rupee forwards in the onshore market and sell forwards in the offshore NDF market. Primarily, major foreign banks (namely HSBC, UBS, JP Morgan, Citibank, Standard Chartered and Deutsche Bank), several international subsidiaries of big Indian corporations and some diamond merchants are the main players in the arbitrage activities between the NDF market and domestic markets. There are two major offshore markets for the Indian rupee: Singapore and London. Probably owing to the difference in trading hours, there is a possibility that the impact of/on these markets on/of the Indian market may vary.

2. Central bank intervention in the BRICS forex market

Central bank intervention in the foreign exchange market is not a very recent phenomenon, the first kind of intervention policy was used in the US during the Great Depression. Exchange rate regimes are the main determinants of interventions.

China's exchange rate policy is perhaps the most popular example of intervention. Being an export-oriented economy, China's central bank always ensured that yuan did not appreciate against the US dollar, as the USA is the main importer of its goods. The Bank of Japan is also a classic case of intervention. As Japan was suffering from chronic depression and other shocks, like a massive earthquake and nuclear disaster in 2011, therefore, to overcome these situations, the Bank of Japan undertook massive intervention activities in collaboration with the US Federal Reserve and the European Central Bank, which is an example of coordinated intervention. For the most part, Japan succeeded in achieving its intervention objectives.

Table 5. Intervention stance of the BRICS countries

Country	Central Bank	Official stance on intervention
Brazil	Central Bank of Brazil (BCB)	The BCB may occasionally intervene "to ensure the smooth functioning of the foreign exchange market"
Russia	Bank of Russia (BoR)	"Currency interventions implemented by the BoR above the determined target amounts are aimed to decrease ruble exchange rate fluctuations that are not caused by the fundamental economic factors"
India	Reserve Bank of India	"…our forex interventions to maintain the stability of the rupee." RBI Governor speech on Aug 25, 2021
China	Peoples Bank of China (PBOC)	No official statement available on intervention
South Africa	South African Reserve Bank (SARB)	"The Bank may get involved in the foreign exchange market to smooth out abrupt and severe adjustments of the exchange rate, to facilitate an orderly functioning of the foreign exchange market, as well as for financial stability reasons"

Source: Official websites of the respective central banks.

But, as stated earlier, intervention can pursue different targets: either to change level or to contain volatility, or both (Disyatat & Galati, 2005). As emphasised by the Plaza Accord[2] and the Louvre Accord,[3] in the 1980s, intervention by major central

[2] ThePlaza Accord aimed to depreciate the US dollar in relation to the yen and German Deutsche Mark, which was agreed upon at the G7 meeting in 1985, as at that time the US had a trade deficit while Japan and some European countries were experiencing a trade surplus along with negative GDP growth.

[3] The Louvre Accord was an agreement signed in 1987 and aimed at stabilizing the international currency markets and ending the continued decline of the US Dollar caused by the Plaza Accord."

banks was mainly directed at the exchange rate level. While after the 1990s, the main objective behind the intervention was to curtail the unwarranted volatility, as declared by various central banks on various occasions.

3. Literature review

Literature on the effectiveness of intervention related to BRICS is very limited. However, some studies examine the BRICS foreign exchange market and their comparison, exchange rate pass-through and relationship between exchange rate equity prices.

Maradiaga et al. (2012) evaluated the exchange rate volatility in the case of BRICS currencies. The authors used the vector autoregressive model (VAR) and the Granger Causality test for a coefficient of variation in the real exchange rates. Apart from the exchange rate, other variables used in the paper were GDP, agriculture export, agriculture GDP of monthly frequency for the period from January 1961 to December 2008. The authors observed that exchange rate volatility had a statistically significant impact on agricultural exports in China and Brazil. However, the authors could not find any effect for other countries – India, Russia, and South Africa. Furthermore, the authors advocated that BRICS should have had their own currency for the purposes of trade or the issuance of credits or grants to each other.

It is important to understand how exchange rates impact inflation. In this direction, Balcilar et al. (2021) examined exchange rate pass-through (ERPT) in the BRICS countries. The authors used monthly frequency data from January 1999 to December 2019 on consumer price index, nominal exchange rate, short-term nominal interest rate and output growth. Using non-linear STVAR (smooth transition vector autoregressive model) methodology, the authors observed that the pass-through of the exchange rate was higher when the economy was in a high growth phase, indicating that economic activities impacted ERPT. Another study on exchange rate volatility and the ERPT by Vieiraa and da Silva (2020) found a long-run cointegration relationship between the exchange rate and other macroeconomic variables. The authors used the ARDL bound test on the exchange rate, money supply, inflation, index of industrial production, international reserves, and oil prices from January 2005 to December 2019. Further, the authors claimed that there was a sluggish speed of the exchange rate and inflation towards adjustment in long-run equilibrium.

Das and Roy (2021) investigated the turning points in volatility of the BRICS currencies using the Markov switching autoregressive methodology. Based on daily exchange rate data from April 2006 and March 2018, the authors identified that the Chinese yuan had the least volatility among the BRICS currencies; on the other hand, the authors found the highest volatility in the South African rand. Other variables used in the paper were interest rates, money supply, index of industrial production, foreign exchange reserves and inflation. Furthermore, the authors suggested that lower volatility in the Chinese yuan was the result of China's more active intervention in the foreign exchange market.

Regarding monetary policies towards exchange rate in the BRICS countries, Mallick and Sousa (2013) stated that contractionary monetary policies in the BRICS countries reduced output and increased appreciation pressure on their domestic currency. Using quarterly data for the period from 1990 Q1 to 2008 Q4, as well as the policy rate and other macroeconomic variables, such as GDP and inflation, the authors observed that commodity price shock played a crucial role in returns in the BRICS currencies.

While estimating vulnerability to global crises, Caporale et al. (2017) observed an asymmetric impact on the BRICS currencies. The authors used newspaper headlines about the exchange rates of the BRICS currencies based on daily data for the period from January 3, 2000 to December 5, 2013. Based on the VAR-GARCH (1,1) model for mean and variance estimation, the authors found that the BRICS foreign exchange markets responded quickly to any foreign news reports.

Rao and Padhi (2020) examined common determining factors for currency crises in the BRICS countries and observed that the Russian ruble was in more stressful conditions than other BRICS currencies. The authors used a panel data approach based on quarterly data related to the BRICS counties for the period from 1996 Q1 to 2015. Q4 The authors evaluated various macroeconomic variables that could impact currency crises and found that the ratio of base money to broad money, growth in broad money, inflation, interest rates trade balance and current account balance provided information on future crises along with respective countries external vulnerability towards the currency crisis.

Jiang (2019) analyses the BRICS exchange rate regimes and provides a comparative analysis of these regimes. The author observes that, apart from China, other BRICS exchange rate systems are more flexible, hence, there is a scope for China to make its exchange rate system more liberalized, which will reflect price discovery by the market forces.

Efficacy of financial markets in the case of the BRICS countries was examined by Bhandari and Kamaiah (2016). The authors applied various non-linear tests to monthly frequency data on NEER (Nominal Effective Exchange Rate) of the BRICS countries from April 1994 to September 2014. The authors observed that the BRICS markets represented a weak form of market efficiency, indicating a chaotic structure of financial markets.

Chkili and Nguyen (2014) evaluated the relationship between volatility in exchange rate and stock market returns using a regime-switching autoregressive methodology for the BRICS countries. The authors discovered that stock market returns influenced exchange rate movements during the whole sample period (from March 1997 to February 2003). A similar study by Raja (2018) on the BRIC (with the exception of South Africa) countries finds that stock market returns and exchange rate returns are correlated. Using correlation estimation on daily data from 2013 to 2018 on the returns of indices of the BRIC countries and returns on the exchange rate, the author finds a short-run and long-run correlation of the variables. However, the paper concludes that there might be other factors impacting the reruns on the exchange rate.

3.1. Country-specific studies

In the case of Brazil, Nedeljkovic and Saborowski (2017) examined the effectiveness of intervention in spot and forward markets. The authors used daily data for the period from 2008 to 2013 on the real-dollar exchange rate, purchase and sell off dollar by monetary authority (Banco Central do Brazil), the volatility index (VIX), daily returns on 5-year credit default swaps and interest rate differential. Using two-stage least squares and implied volatility, the authors found a significant relationship between intervention and the exchange rate level and volatility. The findings suggest that intervention in the spot market is more effective in containing volatility than intervention in the forward market.

Souza and Carvalho (2011) examined the Brazilian real's movement in different regimes, from pegged to freely floating exchange rate. The authors discussed high exchange rate volatility and high-interest rates appreciated the real, which adversely impacted the Brazilian economy.

Chamon et al. (2017) examined the effectiveness of the intervention policies implemented by the Central Bank of Brazil during the taper tantrum period of 2013-2014, when the US monetary authority began to abandon the easy money policy (quantitative easing), which was started to tackle the global financial crisis of 2008-2009. During this period, the Central Bank of Brazil implemented two programmes through which it intervened in the foreign exchange market to tackle excessive volatility in the market. The authors used an event study approach on weekly frequency data of exchange rate capital flows for the period from May 29, 2013 to March 19, 2014. Findings of the paper indicate that the intervention program did not successfully mitigate volatility in the real against the dollar.

Viola et al. (2019), using the quantile regression approach, examined the effectiveness of interventions in the Brazilian real level and volatility. The authors used daily data for the period from January 2, 2003, to December 31, 2014. The findings of the paper suggest that the government in the inflation targeting regime has a target for the exchange rate level and the intervention, if announced in advance, provides better results in containing volatility.

A recent study by Oliveira (2020) evaluated the efficacy of spot and derivatives interventions in the foreign exchange market. The author used generalised method of moments (GMM) on daily data on the exchange rate, intervention in spot and forward markets for the period from January 2006 to April 2016. The author's findings suggest that both interventions (spot and forward) are effective in containing the exchange rate level of the real.

Rodionov et al. (2015) analysed Russian currency crises and exchange rate policies adopted by the government. The authors advocated free market for price discovery, but proposed certain restrictions for portfolio flows. The paper suggests that foreign exchange reserves can shield exchange rate volatility.

Frankel (2007) explored the determinants of the South African rand for the period from 1984 to 2007. The author used regression on monthly frequency variables

of exchange rate factored on consumer price index, mineral price index, interest rate differential, and dummy for revival of capital controls. The paper's findings suggest that the lagged values of the exchange rate are major components of the exchange rate momentum. The author claims that appreciation in the rand during the study period leads to the "Dutch disease"[4] – causal relationship between the mineral prices and the exchange rate. The rand depreciates when mineral exports decline and appreciates when there is a price boom in natural resources. Further, the findings show that interest differential in South Africa and the US has a positive impact on currency demand. The findings evidence that country specific variables determine the exchange rate.

Mpofu (2016) also investigated the determinants of the exchange rate volatility in the rand for the period from February 1986 to November 2013. The paper used monthly data on GDP, money supply, and foreign exchange reserves. The author applied the GARCH (1,1) model and observed that the change of the exchange regime to a floating exchange rate and trade openness positively impacted the exchange volatility, while changes in output, natural resource prices, money supply and foreign exchange reserves increased the volatility in the rand.

The effect of intervention depends on various factors. For example, Humpage (2003) argues that a flexible exchange rate with a higher degree of monetary policy independence provides more power to influence the forex market. A large body of literature suggests an asymmetric impact of sales (negative intervention) and purchase (positive intervention). Broto (2012) studied four Latin American countries[5] using daily data and found that there was no homogeneous pattern impact of intervention on the exchange rate across these countries. The paper showed that the size of intervention was rather irrelevant, and rule-based intervention was more helpful to curb volatility.

3.2. Is intervention in EMEs different from that in advanced economies?

Broto (2012) states that intervention in EMEs has a different nature than in developed countries and the effects may be different. He adds that EMEs tend to intervene frequently, irrespective of their monetary policy regime. Disyatat and Galati (2007) argue that intervention in EMEs is more effective than in developed countries due to factors such as large forex intervention relative to market turnover, capital controls and informational advantage. Further, the authors observe that intervention in emerging markets is more effective than in developed countries. Sarno (2001) conducted a survey on microstructure of foreign exchange market and shed light on major issues in the foreign exchange market, such as the transmission of information among market participants,

[4] A causal relationship between an increase/ improvement in one sector, such as natural resources in the case of South Africa, and a decline in other sectors, such as manufacturing and/or agriculture sector.

[5] Mexico, Peru, Colombia and Chile.

heterogeneity of agent expectations and implications of agent heterogeneity for trading volume and exchange rate volatility.

The literature shows that intervention impacts the exchange rate through three main channels: 1) monetary policy channel – according to (Disyatat & Galati, 2005), in managed floating regimes the usefulness of intervention depends on whether or not exchange rates can be influenced independently of the monetary policy stance; 2) portfolio-balance channel – sterilised intervention influences the relative distribution of domestic and foreign assets in the portfolio of the private sector. The resulting changes in demand for assets denominated in foreign currency affect the exchange rate; 3) "signalling effect" channel – when a central bank intervenes in the market, it gives a signal to the market players about the future monetary policy stance and the long-run equilibrium of the market (Mussa, 1981). Thus, market participants factor in this intervention signal and adjust their expectations about the future spot rate accordingly. Chen et al. (2014) argue that intervention conveys a signal to the market about the exchange rate objective of the central bank.

Apart from the above three intervention channels, the international coordination channel and the noise trading channel were studied in the literature. A combination of various channels works simultaneously, and the most important channel is referred to as a signal channel.

Although there are various studies of the relationship between central bank intervention and exchange rate volatility, however, in the case of EMEs, there are very few studies on the efficacy of central bank intervention on the forex market due to the lack of transparency of intervention, motive and clear operational guidelines. Adler and Tover (2011) examined foreign exchange intervention practices and their effectiveness using qualitative and quantitative aspects for 15 countries, including India (for which the authors used the change in forex reserve as a proxy for intervention) for a period of 7 years (from 2004 to 2010), using a two-stage Instrumental Variable approach. The results show that interventions moderate the pace of appreciation, but the effects decrease rapidly with the degree of capital account openness, for which Chinn and Ito's index of capital account openness was used.

Fatum (2003) focused on daily Bundesbank (Germany) and the US official intervention operations, using an event study approach. He found that intervention affected the exchange rate in the short run. The findings were consistent with the literature interpreting intervention as a means to "signal" future policy and the central bank's views on the fundamental/equilibrium value of the exchange rate.

Neely (2011) examined the effect of coordinated interventions by the G7 countries to prevent volatility in the Japanese yen due to the massive earthquake of March 11, 2011. Due to the high volatility and disorder in the financial markets, the G7 countries decided to jointly intervene in the forex market. Exchange rates reacted strongly and quickly to the interventions, moving 3 to 4% in the desired direction within 30 minutes of the announcement and also exhibited lower volatility in the following days. Thus, he found that coordinated intervention could be a very effective tool in managing volatility in the forex market.

Cicek (2014) examined the effects of Turkey's central bank's interventions via auctions on the level and volatility of the Turkish lira/US dollar exchange rate between February 2, 2009 and January 31, 2014 using daily data. The study used the exponential GARCH (1,1) framework and suggested that interventions had no significant effect on the exchange rate level. Regarding volatility, the presence of the Central Bank in the market itself was not statistically significant, however, the size of intervention volume had a minor significant impact on the exchange rate volatility.

At the same time, interventions are more effective in the context of already "overvalued" (appreciated) exchange rates. Mbarek (2011), using GMM technique, observed that interventions of the Central Bank of Tunisia were efficient at the level of exchange returns, yet they were inefficient at the level of volatility. In the case of India, Behera, Narasimhan, & Murty (2008), using monthly data and GARCH (1,1), found that RBI's intervention effectively reduced volatility in the forex market. Bhumik and Mukhopadhyay (2000) studied the effectiveness of RBI's intervention on rupee/dollar exchange rate and found no clear result. Inoue (2015) examined the causal relationship between intervention and the exchange rate in India using monthly data for the period from 1997 to 2011 and found that there was causality in variance from exchange rate to central bank intervention but not the other way round. The absence of causality from intervention to exchange rate implied that RBI's intervention had not influenced the exchange rate volatility. Ghosh (2002) used the Tobit model and daily data collected from the press views. The author observed a lack of transparency in RBI's day-to-day operations and concluded that RBI intervened to minimise deviation from the exchange rate target and contain volatility.

In the following table, we present a synoptic view of the criteria for classifying the studies on BRICS intervention.

Table 6. BRICS foreign exchange rate markets

Effectiveness of intervention	Efficiency of the foreign exchange rate market	Relationship between exchange rate and stock market	Exchange rate pass-through
Chinese yuan has the least volatility, while South African rand is more volatile. Lower volatility in yuan is due to intervention (Das & Sinha Roy, 2021)	BRICS markets are a weak form of market efficiency, indicating a chaotic structure of financial markets (Bhandari & Kamaiah, 2016); BRICS foreign exchange markets give a quick reaction to any foreign news reports. (Caporale et al., 2017)	Stock market returns influence exchange rates movements (Chkili & Nguyen, 2014)	Pass-through of the exchange rate is higher when the economy is in a high growth phase (Balcilar et al., 2021); long-run cointegration relationship between the exchange rate and other macroeconomic variables (Vieiraa & da Silva, 2020)

Source: Compiled by the authors.

4. Data and methodology

4.1. Data

The primary motive behind the study is to analyse the efficacy of intervention in the forex market; thus, daily data is more appropriate. However, due to secrecy in motives (BIS, 2005), data on such operations, mostly in the case of EMEs, are not publicly available, or if available, it is of low frequency, i.e. monthly in the case of India. In the case of Russia, monthly intervention in the US dollar and euro is publicly available from August 2008 onwards. However, in the case of China, which does not publish foreign exchange intervention data (US Department of the Treasury, 2019), researchers have to rely on alternative proxies only.

Actual intervention data related to the BRICS countries are provided with varying frequency. For Brazil, its a daily frequency, for Russia and India its a monthly frequency, while South Africa and China intervention data are not publicly available. In this background, we used a database recently published in an IMF working paper (Adler et al., 2021a). These data are a proxy for central bank intervention and the change in official reserves of the respective country. Although, change in reserves may differ from intervention, because reserves change not only due to intervention but also due to other factors, such as valuation changes, income flows (like accrual of interest), debt operations on behalf of other agents, etc. However, change in reserve is still considered as a good proxy (Neely, 2005) as the comparison of the two series showed a high correlation.

We also checked the correlation of the proxy data with the actual available intervention data and found that the correlation was about 0.82 in the case of Brazil and 0.91 for India. The central bank's general motive for intervention in the forex market is to reduce the volatility component of the exchange rate.

Our dependent variable, as well as the residuals using the ordinary least square, shows volatility clustering. Here, "large changes tend to be followed by large changes, of either sign, and small changes tend to be followed by small changes," meaning there are periods of low volatility and periods when volatility is high. From the simple plot of our dependent variable, i.e., *lnrt*, it can be observed that the variable has a volatility clustering (Figure 2). A similar pattern was observed in the case of the residuals of the ordinary least square.

The yield spread on sovereign government bonds against similar US bonds is used as an indicator of country risk in the literature (Chamon et al., 2013; Ishii et al., 2006). The yield spread is a measure of country risk and foreign investor sentiment, which are potential key determinants of demand for local currency. The variable also captures a possible monetary policy spillover on local currency as a higher spread attracts foreign investment, leading to appreciation in the domestic currency (Ishii et al., 2006). The study took the 10-year yield on government securities of all BRICS countries and subtracted from it the 10-year yield on US government bonds. Figure 2 shows

that after the global financial crisis of 2008-2009, the spread is declining barring a few exceptions (Russia for 2014 and 2015 due to the country crisis).

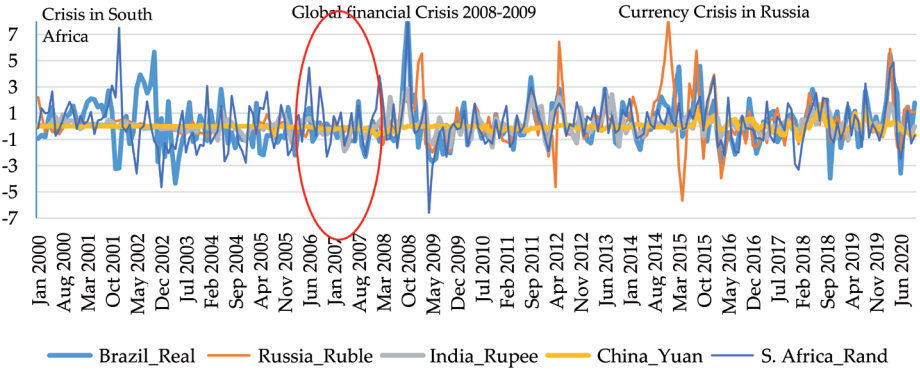

Figure 2. BRICS exchange rate returns. *Source:* Official websites of each country's central banks.

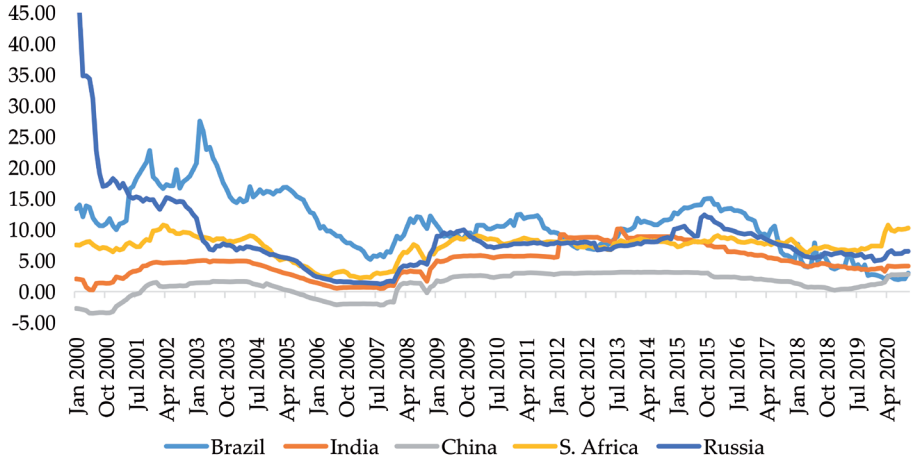

Figure 3. Yield spread of the BRICS countries' 10-Year government securities vs 10-Year US government bonds. *Source:* Compiled by the authors.

The entire dataset is publicly available on a monthly basis. The sources and notations used in the estimation are explained in the table 7. The empirical exercise aims to examine how central bank intervention impacts exchange rate volatility. As per the standard literature approach, we used returns as a volatility measure of the exchange rate. The return was calculated using the following formula:

$$lnr_t = 100 \times (\ln S_t - \ln S_{t-1}). \quad (1)$$

Where, lnr_t is the return on the exchange rate; S is the spot exchange rate of the rupee per US dollar. The positive (negative) lnr_t shows that local currency depreciates

(appreciates) against the US dollar. Intervention variables are in million USD, Sale (negative), Purchase (positive) both in the spot market and the derivatives market. Both markets – spot and derivatives – operate around the clock. However, settlements are done immediately in the spot market, while settlements or product delivery are done on a predetermined future date in the derivatives market. Capturing the efficacy of intervention in the derivatives market is vital as many central banks use foreign

Table 7. Description of the variables

Variable	Notation used	Source
Return on nominal exchange rate (local currency per USD)	*lnrt*	IMF exchange rate archives https://www.imf.org
Intervention in spot market	*Spot_intv*	(Adler et al., 2021b)
Intervention in derivatives market	*Deriv_intv*	(Adler et al., 2021b)
Sovereign government bond yield spread between a BRICS country and the US	*Yield_spread*	IMF's International Financial Statistics (IFS) dataset https://data.imf.org

Note: All monthly data from January 2000 to July 2021 259 observations in total.

Source: Compiled by the authors.

exchange swaps[6] to manage liquidity in the market. The variable – intervention in derivatives market – includes both forwards and futures markets.

Following the previous literature on determining the exchange rate return, we tried to estimate the following equation for the study:

$$lnr_t = \beta_0 + \beta_1 lnr_{t-1} + \beta_2 Spot\_intv_t + \beta_3 Deriv\_intv_t + \beta_4 Yield\_spread_t + \varepsilon_t. \quad (2)$$

4.2. Methodology

In the empirical estimation of central bank intervention, a major problem is endogeneity. As intervention impacts exchange rate, exchange rate movements also simultaneously influence central bank behaviour related to intervention (Boer, 2019). The simultaneous relationship between exchange rate and intervention and omitted variables, such as any macroeconomic activities, are referred to as endogeneity issues. The use of intraday/high-frequency data along with instrumental variables or an event study methodology could be more appropriate for assessing the impact of intervention on exchange and avoiding endogeneity. However, an intervention analysis of 35 advanced and emerging economies by Blanchard et al. (2015) with the use of the vector autoregression method

[6] Foreign exchange swaps are simultaneous operations for sale and purchase of foreign currency in spot and forward markets and they do not necessarily impact the central bank's foreign exchange position if spot and forward legs are taken into account.

found that the impact of the intervention was significant in the long run. Roundup (2019) suggested using low-frequency data such as weekly, monthly or quarterly, as the effects of intervention can be established over longer horizons which may provide valuable advice to central banks.

To check the endogeneity of our data, we estimated the pairwise Granger causality test. The Granger causality test is based on the VAR model, which alternatively places each variable as a dependent variable. Further, the causality test is used to understand the variables' short-run dynamics. As intervention is a short-run tool used by central banks to reduce volatility, the use of the test is more appropriate.

$$\Delta y_t = c_0 + \sum_{j=1}^{p} a_j \Delta y_{t-j} + \sum_{j=1}^{q} b_j \Delta x_{x-j} + \Delta u_t, \tag{3}$$

$$\Delta x_t = d_0 + \sum_{j=1}^{m} c_j \Delta y_{t-j} + \sum_{j=1}^{n} d_j \Delta x_{x-j} + \Delta v_t. \tag{4}$$

As our dependent variable, i.e. the change in log of the exchange rate returns, regressed with its own lag, we get a series of residuals that are heteroskedastic (changing variance). Hence, considering the heteroskedastic nature of the data, the most appropriate mode is GARCH type models that treat heteroskedasticity as a variance to be modeled. As per the GARCH (1,1) framework developed by Baillie and Bollerslev (1989), we estimate the following equation to model returns on exchange rates of the BRICS countries.

$$lnr_t = \beta_0 + \beta_1 lnr_{t-1} + \beta_2 Spot\_intv_t + \beta_3 Deriv\_intv_t + \beta_4 Yield\_spread_t + \varepsilon_t. \tag{5}$$

The above equation is a mean equation, it indicates that the average returns on the exchange rate at time "t" (lnr_t) depend on their own lag, intervention in the spot and derivatives market, as well as the intervention differential and yield spread and the error term (ε_t). Further, ε_t depends on some lagged information (Ω_{-1}) and ε_t is assumed normally distributed with zero mean and its variance (h_t).

$$\varepsilon_t \left| \Omega_{-1} \sim N(0, h_t). \right. \tag{6}$$

Here, the variance equation can be written as:

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + |\alpha_3 Spot\_int_t + \alpha_4 Deriv\_intv_t + \alpha_5 Yield\_spread_t|. \tag{7}$$

4.3. Descriptive statistics

The following table presents descriptive statistics of the selected variables. Descriptive statistics of all variables are also given in the table below. Here it can be observed that the exchange return series for China and South Africa are positively skewed, while for Brazil, Russia and India they are negatively skewed.

Table 8. Descriptive statistics of variables

	Variable	Mean	Maximum	Minimum	SD	Skewness	Kurtosis	JB	Prob
Brazil	rt	-0.00003	0.38	-0.32	0.07	-0.15	8.05	266.66	0.000
	Spot_Intervn	800.856	15202.01	-20224.73	3535.31	-0.34	9.20	408.86	0.000
	Deriv_Intervn	-220.253	34897.29	-37116.00	4983.58	-0.53	27.55	6339.07	0.000
	Yield_Spread	10.968	27.51	1.92	4.77	0.41	3.28	7.84	0.019
Russia	rt	-0.00012	0.15	-0.32	0.05	-1.70	12.73	1107.54	0.000
	Spot_Intervn	1861.617	35551.73	-52429.84	9567.79	-1.50	11.11	784.13	0.000
	Deriv_Intervn	-29.973	9449.06	-11952.73	1682.38	-0.75	24.02	4664.98	0.000
	Yield_Spread	8.572	52.62	1.22	6.18	3.45	20.43	3660.76	0.000
India	rt	-0.00004	0.08	-0.14	0.03	-0.49	5.67	84.31	0.000
	Spot_Intervn	1632.208	15594.43	-22199.45	4470.23	0.02	6.83	153.94	0.000
	Deriv_Intervn	171.393	20599.00	-9449.00	2933.32	2.06	15.79	1895.34	0.000
	Yield_Spread	4.798	10.13	0.27	2.43	0.11	2.39	4.48	0.106
China	rt	-0.00003	0.04	-0.04	0.01	0.21	7.20	186.02	0.000
	Spot_Intervn	7634.590	95478.45	-125944.00	28262.97	-0.74	8.06	291.41	0.000
	Deriv_Intervn	No Data							
	Yield_Spread	1.171	3.14	-3.49	1.82	-0.96	2.96	38.04	0.000
South Africa	rt	0.00337	0.20	-0.11	0.05	0.62	3.95	25.29	0.000
	Spot_Intervn	85.438	2103.02	-4777.38	549.25	-2.44	27.20	6398.76	0.000
	Deriv_Intervn	72.877	2232.00	-1257.00	457.48	1.55	8.28	394.03	0.000
	Yield_Spread	7.265	10.73	2.19	1.89	-1.21	4.00	71.40	0.000

Note: rt – return on nominal exchange rate in log form; Spot-Intervn and Deri_Intervn are interventions in spot market and derivatives markets; Yield_Spread is difference between10-year sovereign government securities and US 10-year government securities yield; SD – Standard Deviation; JB – Jarque-Bera; Prob – Probability.

Source: Compiled by the authors.

However, all five countries show leptokurtic returns, indicating the presence of volatility. In the case of China, due to the non-availability of data, intervention in the derivatives market was not reported. If we compare the returns of the exchange rates for all BRICS currencies, the renminbi exhibits the lowest volatility (measured by SD-standard deviation), while the Brazilian real, the Russian ruble, the South African rand, and the Indian rupee all exhibit high volatility.

4.4. Unit root test

For any empirical estimation that involves time series, it is customary to check the stationarity of data. We checked the unit root test for all variables used in the study and found that all of them are stationary at the 1% significance level, except the yield spread. So, we took the first difference of these variables to transform them into stationary variables. The results of the Augmented Dickey-Fuller test (ADF) for all variables are given in table 9.

Table 9. Unit root test results

Variable	Brazil	Russia	India	China	South Africa
lnr_t	-11.565	-10.276	-13.648	-10.259	-15.902
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Spot_Intervn	-4.437	-7.841	-9.128	-4.107	-15.647
	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)
Deriv_Intervn	-11.711	-12.744	-9.301	na	-12.995
	(0.000)	(0.000)	(0.000)	na	(0.000)
Yield_Spread	-1.443	-6.866	-1.400	-2.149	-1.937
	(0.561)	(0.000)	(0.581)	(0.515	(0.632
Yield_Spread (1st difference)	-16.749		-13.237	-10.410	-11.861
	(0.000)		(0.00)	(0.000)	(0.000)

Note: As the yield spread is non-stationary at level, however, the variables are stationary at level. Hence, we used the variables at the 1st difference. Figures in paranthesis indicate the probability value.

Source: Compiled by the authors.

5. Empirical estimation

To check the endogeneity issue, we performed a pairwise Granger causality test on the selected variables. The time period of the data is from January 2000 to July 2021. The results of the pairwise Granger causality test are given in Table 10. It shows that it is the intervention that causes the exchange rate returns and not the other way round,

except in Russia where the exchange rate returns cause intervention in the derivatives market.

Table 10. Pair-wise Granger causality test results

Country	Null Hypothesis	F-Statistic	*P-value*
Brazil	Spot intervention does not granger cause exchange rate returns	2.147*	0.094
	Exchange rate returns do not granger cause spot intervention	0.599	0.616
	Derivatives intervention does not granger cause exchange rate returns	7.2885*	0.007
	Exchange rate returns do not granger cause derivatives intervention.	1.262	0.262
Russia	Spot intervnetion does not granger cause exchange rate returns	6.178*	0.001
	Exchange rate returns do not granger cause spot intervention	1.363	0.247
	Derivatives intervention does not granger cause exchange rate returns	0.572	0.599
	Exchange rate returns do not granger cause derivatives intervention.	2.901*	0.056
India	Spot intervention does not granger cause exchange rate returns	6.708*	0.015
	Exchange rate returns do not granger cause spot intervention	1.522	0.220
	Derivatives intervention does not granger cause exchange rate returns	9.336*	0.002
	Exchange rate returns do not granger cause derivatives intervention.	0.333	0.563
China	Spot intervention does not granger cause exchange rate returns	3.520*	0.061
	Exchange rate returns do not granger cause spot intervention	2.685	0.102
South Africa	Spot intervention does not granger cause exchange rate returns	0.319	0.727
	Exchange rate returns do not granger cause spot intervention	0.143	0.866
	Derivatives intervention does not granger cause exchange rate returns	0.175	0.839
	Exchange rate returns do not granger cause derivatives intervention.	0.899	0.408

*Note: * – pertains to ???*

Source: Compiled by the authors.

The motive of the empirical exercise is to determine the factors contributing to the volatility in the exchange rate return. Hence, based on the past literature on determining the exchange rate return, we tried to estimate equations 5 and 7. Table 11, based on these equations, provides a summary of the GARCH estimation. In the mean equation, intervention variables have no statistically significant coefficients, except Brazil in derivatives intervention, which indicates that interventions have

a limited impact on the exchange rate level. However, in the variance equation, both variables are significant with a negative sign (except Russia for derivatives intervention and South Africa for spot intervention), which indicates that central banks are successful in reducing volatility through intervention.

Further, the yield spread variable showed mixed results. In the case of China and South Africa, the significant coefficient with negative and positive signs indicates that the yield spread appreciates the Chinese yuan, while it depreciates the South African rand. Further in the variance equation, the yield spread impacts volatility in Brazil and Russia. A positive sign for Brazil indicates that the yield spread increases volatility in the returns, while a negative sign for Russia suggests that the yield spread reduces volatility in the returns. We observed that the results were similar to the standard literature (Berganza & Broto, 2012; Broto, 2012).

Table 11. GARCH model estimates

Variable	Brazil	Russia	India	China	South Africa
Dependent Variable: Return on Exchange Rate: lnr_t					
Mean equation: $lnr_t = \beta_0 + \beta_1 lnr_{t-1} + \beta_2 Spot\_intv_t + \beta_3 Deriv\_intv_t + \beta_4 Yield\_spread_t + \varepsilon_t$					
β_0	-0.0012	0.006	0.002	-0.0000005	0.14
	(0.58)	(0.58)	(0.92)	(0.98)	(0.66)
$\beta_1(lnr_{t-1})$	-0.577*	-0.382*	0.42*	-0.35*	-0.55*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\beta_2(Spot\_intv_t)$	0.00000008	0.000000006	-0.00000003	0.000000000007	0.0005
	(0.11)	(0.87)	(0.71)	(0.99)	(0.55)
$\beta_3(Deriv\_intv_t)$	0.00000011*	0.00000029	0.000000018		0.0005
	(0.00)	(0.87)	(0.71)		(0.47)
$\beta_5(Yield\_spread_t)$	-0.006	-0.00068	0.0018	-0.0017*	2.47*
	(0.27)	(0.37)	(0.77)	((0.04)	(0.00)
Variance equation: $h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \lvert \alpha_3 Spot\_int_t + \alpha_4 Deriv\_intv_t + \alpha_5 Yield\_spread_t \rvert$					
α_0	0.0004*	0.0019*	0.0002*	0.000004*	9.8
	(0.00)	(0.00)	(0.00)	(0.00)	(0.10)
$\alpha_1(\varepsilon_{t-1}^2)$	0.149*	0.15*	0.15*	0.15*	0.28*
	(0.00)	(0.09)	(0.08)	(0.00)	(0.04)
$\alpha_2(h_{t-1})$	0.599*	0.60*	0.59*	0.60*	0.42*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.08)

Table 11. Continued

Variable	Brazil	Russia	India	China	South Africa
$\alpha_3(Spot\_int_t)$	-0.0000000019*	-0.0000006*	-0.00000003*	-0.000000000008*	0.006*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\alpha_4(Deriv\_intv_t)$	-0.0000000022*	0.000000025*	-0.000000001*		-0.0019
	(0.02)	(0.00)	(0.01)		(0.57)
$\alpha_6(Yield\_spread_t)$	0.000077*	-0.000106*	0.000008	0.0000002	4.29
	(0.00)	(0.00)	(0.57)	(0.04)	(0.60)
Diagnostics					
R^2	0.35	0.14	0.17	0.13	0.28
DW	2.36	2.11	2.21	2.22	2.20
Log Likelihood	363.02	430.82	549.13	908.95	-774.02
Q(20)	43.47 (0.00)	57.88 (0.00)	87.80 (0.00)	29.36 (0.08)	34.77 (0.02)
$Q(20)^2$	17.26 (0.69)	47.08 (0.00)	48.20 (0.00)	0.74 (1.00)	15.66 (0.73)
ARCH-LM	0.28(0.59)	2.09 (0.14)	0.081 (0.77)	0.009 (0.92)	0.193 (0.66)

Note: DW – Durbin Watson Statistic; LM – Lagrange Multiplier.

Source: Compiled by the authors.

Regarding the residual diagnostics, the DW statistics for all five currencies are close to 2, implying no autocorrelation of residuals, while adjusted R-squares range from 0.13% to 0.35% indicating the variation in the returns is explained by 13 to 35% in the model. Further ARCH LM test rejects.

Summary and conclusion

It is a recognised fact that most central banks intervene in the foreign exchange market to anchor exchange rates or tame volatility as per the country's macroecnomic situation and the monetary policy stance. However, there is no consensus in the literature on the effectiveness of the intervention in the exchange rate. In our empirical analysis, we find that central bank intervention matters, whether in the spot market or the derivatives market. Intervention can reduce the volatility in the exchange rate returns. However, intervention is not impacting the exchange rate level, which indicates that intervention can only be used to reduce undue volatility and not to change the exchange rate level. Central banks may use other policy tools to change the exchange rate level, such as the interest rate differential or the yield spread. Although intervention helps in achieving the desired aim of reducing undue exchange rate volatility, intervention

is not an effective tool for managing the exchange rate level. The results confirm that the BRICS central banks generally do not impact the exchange rate level; however, they reduce the exchange rate volatility. Furthermore, intervention in the spot and derivatives markets is equally effective in containing exchange rate volatility. It is found that the yield spread also impacts the exchange rate volatility in Brazil and Russia.

These results are important for central banks when assessing the efficacy of forex interventions. However, the analysis still lacks other relevant elements, namely generalization of the model to include other characteristics of forex interventions, such as persistence, or further control variables in the level equation, i. e. the degree of exchange rate misalignment.

Foreign exchange market intervention requires constant assessment of market conditions, such as global and domestic liquidity conditions, government securities market conditions and forward market projections. Raj et al. (2018) observed that many EMEs had successfully managed the "impossible trinity"22 by using country-specific mix of sterilised intervention, exchange rate flexibility and capital flow management. Therefore, to ensure effective intervention in the desired direction, not only intervention is required, but a combination of various market analysis measures, such as forex swaps (sell-buy or buy-sell), intervention in onshore and offshore (NDF) markets and integration of financial markets.

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Appendix 1

Appendix. Major studies on the BRICS forex market

Study	Country	Methodology and variables	Key findings
(Kamaiah, 2016)	BRICS	Monthly data from April 1994 to Sept 2014; variance tests	The authors found the presence of non-linearity in the five BRICS currencies. The findings also confirmed the presence of the underlying chaotic structure of the markets
(Chkili & Nguyen, 2014)	BRICS	Weekly data from March 1997 to Feb 2013 on stock prices and USD exchange rates linkages.	The US dollar movements impact the BRICS currencies. However, the impact of exchange rates on stock market returns is not significant. Stock markets influence exchange rates in all business cycles of economic activities
(Basu, 2009)	Theoretical; India	Micro-market structure industrial organisation theory	Intervention operations are effective in devaluing the currency. However, this leads to a build-up of excess reserves
(Caporale et al., 2017)	BRICS	Daily data form January 3, 2000 to May 12, 2013 are used to understand how negative news impact the exchange rate in the BRICS currencies. VAR-GARCH (1,1)	The authors examine the effects of newspaper headlines on the exchange rates. The paper uses the US dollar and the euro in the BRICS currencies. The findings reconfirm the role of the BRICS currencies in the international market. Furthermore, the foreign exchange markets have become more responsive to foreign news
(Adrian et al., 2020)	Theoretical	DSGE simulation approach attempts to understand how multiple policy tools potentially improve monetary policy	Central bank intervention and capital flow management tools may improve policy efficiency, especially in inflation-targeting economies
(Zhou et al., 2019)	BRICS	Daily data for the period from May 10, 2007 to May 16, 2017. The authors use VOX as a measure for oil market volatility. Cross-quantilogram model proposed	The authors examine the direction and volatility predictability from oil price to the stock return of the BRICS countries. In overall, oil price volatility has directional predictability for the stock returns in the BRICS countries

Appendix. Continued

Study	Country	Methodology and variables	Key findings
(Baghestani et al., 2019)	BRIC (4 countries)	Data on oil prices and exchange rate related to the BRICS from 1994 to 2007	Movements in oil prices accurately predict the direction of change in the exchange rates in the case of Brazil and Russia. However, for China, oil prices failed to display any directional predictive power
(Raja, 2018)	BRICS	Daily data from 2013 to 2018	Returns from the BRICS stock market indices and exchange rates returns are correlated
(Dube, 2019)	BRICS	Daily data from January 2008 to December 30, 2011 on returns on exchange rate using DCC-GARCH model	It was observed that, except the Chinese yuan, other 4 currencies indicate interdependency. The Chinese renminbi is the least correlated currency with other BRICS currencies
(Adler & Mano, 2021)	73 countries	Monthly data from 2002 to 2013 on the exchange rate, net foreign assets position	This paper provides the conceptual basis of the intervention cost. The paper finds that annual costs of intervention are 0.2 to 0.7% of GDP per year in countries with limited intervention. At the same time, the cost reaches 0.3 to 1.2% of GDP per year in heavy-intervening economies
(Menkhoff, 2010)	Summary of the studies	Review of the studies	The paper identified that central bank interventions in the foreign exchange markets moved the exchange rate level in the desired direction. However, interventions increased volatility in the short run, but in the long run, interventions reduced volatility. Intervention operations can be more successful if they are coordinated by central banks

Source: Compiled by the authors.