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FOREIGN EXCHANGE INTERVENTION AND EXCHANGE RATE EXPOSURE: EVIDENCE FROM SOUTH AFRICA AND JAPAN

ABSTRACT

This paper investigates how central bank forex interventions impact exchange rate exposure in equity markets, comparing South Africa (an emerging market) and Japan (a developed economy). Using Kalman filter to estimate time-varying exchange rate exposure and quantile regression to assess the relationship, the findings show that interventions generally reduce the absolute level of exchange rate exposure. Specifically, in South Africa, negative interventions significantly lower exposure at the median level, while in Japan, similar interventions are associated with higher exposure at the upper quantiles. The paper also notes that the effect of these interventions does not depend on whether the exchange rate is depreciating or appreciating, and it highlights the critical role of clear, credible communication from policymakers in helping firms manage currency risks.

Keywords: Foreign Exchange Interventions; Exchange Rate Risk Exposure; Kalman Filter; Quantile Regression, Central Banks
JEL Classification: C46; C54; E5; F31

RIASSUNTO

Intervento sui tassi esteri e rischio di cambio: i casi del Sud Africa e del Giappone

Lo scopo di questo studio è esaminare come gli interventi della banca centrale sui tassi di cambio influiscano sul rischio di cambio in due diversi mercati: quello del Sud Africa (un paese emergente) e quello del Giappone (un'economia avanzata). Utilizzando il filtro di Kalman per stimare il rischio di cambio variabile nel tempo e la regressione dei quantili per valutare la relazione si sono ottenuti risultati secondo cui gli interventi generalmente riducono il livello assoluto di rischio di cambio. In particolare, in Sud Africa gli interventi negativi riducono significativamente il rischio a livello mediano, mentre in Giappone simili interventi sono

associati ad un rischio maggiore nei quantili più elevati. Dallo studio emerge, inoltre, che l'effetto di questi interventi non dipende dall'aumento o dalla diminuzione del tasso di cambio ed evidenzia il ruolo importante di un'informazione chiara e attendibile del governo ad aiutare le imprese a gestire i rischi valutari.

1. INTRODUCTION

The inherent risks associated with exchange rate fluctuations is underpinned by a plethora of economic and exchange rate theories. The theory of Purchasing Power Parity, originated by Cassel (1916), states that the exchange rates of two countries, is based on the relative purchasing power of their currencies (Dilger, 2022; Merza and Moosa, 2023). In addition, the Monetary Theory of Exchange Rates, originated by Friedman (1953), states that the exchange rates between two currencies are determined by the relative supply and demand of money in each country. These and other economic and exchange rate theories commonly postulate that changes that occur at foreign exchange rate levels, will yield significant downstream effects at a firm level. More specifically, firms characterised by large foreign-currency denominated assets and liabilities. The exposure to losses (or profits) arises from unexpected changes that occur in the foreign exchange rates of two currencies. That exposure can be characterised as either transactional exposure, which occurs when the future cash flows of the firm are affected by changes in the currency exchange rate such that the profits or losses arising when converting the currencies, or as an operational exposure, which is largely dependent on the extent to which the firm is exposed to fluctuations in exchange rates, impacting the value of certain assets of the firm and ultimately, impacting the firms overall profitability.

Therefore, central banks in emerging market economies often use targeted policy measures, such as foreign exchange intervention, to account for the challenges of exchange rate exposure (Mastromatteo and Rossi, 2023). Conceptually, when the currency value of one country decreases, relative to the currency value of another country, the currency is concluded to have depreciated in value. Subsequent to this prevailing change in economic conditions, the products or services in the country experiencing currency depreciation then become cheaper and more attractive to foreign buyers. The inverse holds true.

Exchange rate risk exposure continues to be a critical concern amongst firms that operate in a globalised economy, that influences the financial performance and strategic decisions of those firms. The existing pool of academic literature extensively explores the dynamics of exchange rate risks and their implications on the operations and finances of firms, with studies often highlighting the growing adoption of monetary policies to mitigating these risks (Gnagne and Bonga-Bonga, 2020; Thornton, 2025). In the Australian market, Loudon (1993) using a Two-Factor Asset Pricing model found a relationship between equity market returns and changes in foreign exchange rates. In the Asian emerging markets, Lin (2011) using an augmented market model, found a higher degree of statistically significant exchange rate risk exposure at a firm-level than at a market level – with South Korea and Indonesia yielding the highest levels of exchange rate exposure and both marred by financial crisis periods. This phenomenon may have been attributed to the offsetting effects that exist at a market level. In the African emerging markets however, Kodongo and Ojah (2011) adapting the Multi-Factor Asset Pricing model, found that exchange rate risk exposure was not unconditionally priced in any African equity markets, regardless of whether the returns are measured relative to the US Dollar or Euro.

Catalan-Herrera (2016) explored the effectiveness of central bank interventions on exchange rate risk exposure, in an inflation targeting regime and found that although monetary policy intervention had a reducing impact on daily exchange rate return's volatility, it had no real effect on the exchange rate. This notion is supported by Keefe and Shadmani (2018) studied the effects of exchange rate risk exposure at firm-level and assessed whether the central banks of those emerging markets yielded an asymmetric response to changes to exchange rates. Keefe and Shadmani concluded that asymmetric preferences became obsolete during periods of financial crises and that largely, the monetary policy interventions were ineffective when attempting to pressures of depreciation, during highly volatile periods.

Despite the valuable insights and contributions made in the pool of academic literature, notable gap persists in the literature regarding the long-term efficacy and strategic implications of central bank interventions, across various economic contexts. Much of the existing research tends to focus on immediate outcomes, leaving a void in understanding how these interventions impact exchange rate risk exposures over extended periods and in different market environments. For instance, Loudon (1993) in his study, did not price exchange rate risk. Doukas *et al.* (1999) did not explore whether the results held true to the pricing of exchange rate risk

exposure in stock markets. Kodongo and Ojah (2011) could have compared the effects of monetary policy interventions at firm-level versus aggregate market level, as it is plausible for critical information to be masked at aggregate market level. Alternatively, to extend the research, using firm-level data for each respective African country. Keefe and Shadmani's (2018) study only assessed the implications during a currency depreciation. It therefore remains unexplored whether the result also holds true for monetary policy interventions during currency appreciation (in contrast to currency depreciation).

The objective of this study is to empirically analyse the risks and exposures associated with the unpredictable changes that occur in foreign exchange rates. Furthermore, this study will assess the means through which the South African Reserve Bank (SARB) and the Bank of Japan (BoJ) employ their respective monetary policies, to intervene in the foreign exchange market, to manage and mitigate the degree of exchange rate risk exposure in the stock market. The choice of these countries is informed by their different monetary policy stance and the level of development. South Africa, as an emerging economy, pursues a monetary policy targeting framework. While Japan, a developed economy, applied very loose monetary policy, including quantitative easing and negative interest rates, in an effort to combat deflation. By analysing countries with different levels of development and monetary policy regimes, the paper aims to assess whether the link between monetary policy intervention and exchange rate exposure is dependent on specific environment and whether it is related to the type of monetary policy regime.

This paper will achieve the above mentioned objectives by examining the effects of exchange rate risk exposure at an aggregated level, rather than just at a firm level. Thus, the contribution of this paper is twofold. It uses Kalman filter technique to model the time-varying exchange rate exposure and analyses its dynamic. It makes use of quantile regression to account for the importance of different market conditions in the relationship between monetary policy intervention and exchange rate exposure. The remainder of the paper is structured as follows. Section 2 presents the literature review. Section 3 discusses the methodology. Section 4 presents the estimation and discusses the results obtained. Section 5 concludes the paper.

2. LITERATURE REVIEW

This literature review examines studies that are directly related to central bank interventions through respective monetary policies and the extent of their impact on exchange rate risk exposures. It is structured to highlight the methodologies employed across various research efforts and the findings derived from those methodologies. Several empirical studies have explored the relationship between central bank interventions and exchange rate risk exposure, utilising a diverse range of methodologies to produce their insights into this complex interaction. Notably, a significant number of researchers have employed the Jorion (1991) approach to price exchange rate risk exposure in stock markets.

Adjasi *et al.* (2007) utilised this approach to analyse the effect of exchange rate risk exposure on listed companies in Ghana. Adjasi *et al.* found a significant percentage of firms in their sample were exposed to US Dollar and British Sterling Pound fluctuations. Similarly, Asaolu (2011) also utilised this approach to analyse the effect of exchange rate risk exposure on Nigerian listed firms, ultimately concluding that the volatility in exchange rate risk is a critical burden to the financial performance of Nigerian listed firms.

In another approach, Aizenman and Sun (2012) employed a Quantile Regression approach during financial crisis periods to assess the response of exchange rate exposure to monetary policy interventions. Similarly, Viola *et al.* (2019) applied a Quantile Regression approach to assess the effect of interventions in Brazil on exchange rate exposure. Viola *et al.* found that the effectiveness of monetary policy interventions differed across various quantiles of exchange rate distributions. In the lower quantiles, the magnitude of the effect that monetary policy interventions have is low. This approach revealed that interventions were more effective during periods of extreme exchange rate movements, thus providing a nuanced understanding of their impact.

Other methodologies, such as Tail Dependence Networks have also been employed to assess the effects of exchange rate risk exposure. Van Cauwenberge *et al.* (2021) utilized this approach to establish that the timing of interventions significantly influenced their effectiveness, particularly in relation to market expectations. Van Cauwenberge *et al.* found that firms in the upper tail were significantly more susceptible to exchange rate risk exposure than those firms in the lower tail.

Among the plethora of studies evaluated, Sikarwar (2020) stands out as particularly relevant to our research. Sikarwar examined the real effects of central bank interventions on exchange rate risk exposure, analysing firms in emerging markets with floating exchange rate regimes. Using a Two-Factor Augmented Market model to estimate exchange rate exposure at a firm level, across countries, Sikarwar's research underscores the importance of understanding both immediate and long-term impacts of interventions. This aligns closely with the objectives of this study. By associating our study within this existing framework, we aim to build upon Sikarwar's contributions and further explore the nuanced, sector-specific effects of central bank strategies in managing exchange rate risks.

By assessing the effect of exchange rate risk exposure at an aggregate level, and not at a firm-level and concentrating on South Africa and Japan, we will first employ the Kalman Filter model to find exchange rate risk exposure and then run a Quantile Regression analyses by regressing the coefficients of exposure on variables that reflect exchange rate intervention.

3. METHODOLOGY

The primary aim of this study is to assess how foreign intervention by the central banks of South Africa and Japan affect the country's exchange rate exposure. This section outlines the methodology used to achieve the study's objectives, including a description of data sources, a rationale for the selected variables, and an empirical modelling strategy. Additionally, it details the econometric model employed, the estimation methods utilized, and a summary of the data involved.

3.1 Exchange Rate Exposure

3.1.1 Jorion Model

To assess the exchange rate exposure on country-level stock returns, it is essential to estimate how sensitive each country's returns are to changes in exchange rate factors. This study adopts the approach proposed by Jorion (1990), which builds on the empirical model by Adler and Dumas (1984). According to Adler and Dumas (1984), a firm's exchange rate exposure is determined by the regression coefficient from a regression of the firm's stock returns on the contemporaneous changes in the exchange rate. Jorion's (1990) two-factor model extends this

by estimating a firm's exposure through a regression of the firm's stock returns on both the exchange rate fluctuations and the returns on a broad market portfolio.

Specifically,

$$R_{it} = \beta_{0i} + \beta_{mi} \cdot R_{mt} + \beta_{st} \cdot R_{st} + \varepsilon_{it} \quad (1)$$

Where R_{it} is the return on the stock of firm i in period t

R_{mt} is the return on the market index in period t

R_{st} is the change in the relevant exchange rate in period t

β_{mi} is a measure of the firm's exposure to market risk

β_{si} measures the firm's exchange rate exposure

ε_{it} is the iid error term

This study uses a country specific local market index to proxy the firm's returns and the world index to proxy the market returns. For South Africa the All Share index (ALSI) is used and for Japan the Nikkei 225(N225). For the world index the Morgan Stanley Capital International (MSCI) is implemented. The value of β_{si} for a country indicates the effect of a 1 percent change in the exchange rate on the country's stock return after controlling for market-wide factors that affect the country's stock index. Given that the exchange rate is measured as units of local currency per United States (US) dollar, the estimated coefficient measures the exposure of a country to a depreciation of the local currency. Exporting nations are therefore anticipated to have positive exposures, whilst importing companies are anticipated to have negative exposures. Because they gauge how sensitive the return of the nation's stock index is to a local currency devaluation in comparison to the sensitivity of the global market portfolio, it should be noted that they are residual exposures. To estimate the Equation 1 β coefficients that are time varying the Kalman filter is used.

3.2 Kalman Filter

In order to maximize the accuracy of guessing unknown parameter values, Kalman (1960) created the Kalman filter, a Bayesian updating technique (Koch, 2006). This filter addresses the more general problem of predicting the state $[x \in \mathfrak{R}^*]$ of a time-controlled, discrete process that obeys the following linear stochastic difference equation:

$$x_t = Fx_{t-1} + Bu_{t-1} + w_{t-1} \quad (2)$$

With a measurement $[x \in \mathbb{R}^n]$:

$$z_t = Hx_t + v_t \quad (3)$$

The state transition matrix, denoted as F , governs the transitions between the different states of the system over time. It describes how the state variables evolve from one time step to the next. The control matrix, represented by B , maps the influence of any control variables onto the state variables. This allows the model to account for external inputs that may affect the system's behavior. The measurement matrix, H , establishes the relationship between the unobserved state variables and the available measurements. It provides a way to connect the underlying state of the system to the observed data. Process white noise and measurement white noise are indicated by the random variables w and v , respectively. These factors are thought to be independent, which means they are not correlated with one another. It is assumed that both w and v have normal probability distributions: $v(\cdot) \sim N(0, R)$ and $w(\cdot) \sim N(0, Q)$. The covariance matrices Q and R represent process noise and measurement noise, respectively. According to Koch (2006), they are evaluated using maximum likelihood techniques and are presumed to stay constant in this context. One of the key strengths of the Kalman filter is its ability to estimate time-varying coefficients. Unlike the Ordinary Least Squares, which assumes that the relationship between the dependent and independent variables remains constant over time, the Kalman filter is designed to handle dynamic systems where coefficients can change from one period to the next. This makes it ideal for modeling exchange rate exposure, where firms' exposure can vary over time due to evolving market conditions.

3.3 Effect of Foreign Exchange (Forex) Intervention on Exposure

Quantile Regression

To estimate the effect of foreign exchange intervention on exchange rate exposure. The study uses the quantile regression method developed by Koenker and Bassett (1978). This technique extends the classical least squares estimation of the conditional mean to a series of models for various conditional quantile functions. The fundamental quantile regression model expresses the conditional quantile as a linear function of the explanatory variables and is formulated as follows:

$$Y = X'\beta + \varepsilon \quad (4)$$

$$Q_\theta(Y|X = x) = x'\beta(\theta) \text{ and } 0 < \theta < 1 \quad (5)$$

Where Y is the dependent variable, X is a matrix of explanatory variables, ε is the error term and $Q_\theta(Y|X = x)$ denotes the θ th quantile of Y conditional on $X = x$. The θ th regression quantile estimate $\hat{\beta}(\theta)$, is the solution of the following minimization:

$$\text{Min}_{\beta \in \mathbb{R}} \sum_{Y \geq X'\beta} \theta |Y - X'\beta| + \sum_{Y < X'\beta} (1 - \theta) |Y - X'\beta| \quad (6)$$

We may trace the distribution of Y , conditional on X , and get a far more comprehensive picture of how explanatory variables affect the dependent variable by steadily raising the quantiles from 0 to 1. With this approach, the exchange rate exposure can change according to the quantiles of the intervention or control variables. The explanatory variables X and the nation's quantile conditional on X are the two variables that determine the q th quantile of reserve holdings. Consequently, the method will enable comparison of the effect of intervention on exchange rate exposure at various quantiles. Quantile Regression offers more nuanced insights by revealing how relationships vary across the distribution, especially in situations where the mean effect doesn't fully capture the heterogeneity of effects in the data.

Having estimated the exchange rate exposure using Kalman filter the study examines whether forex intervention by central banks affect South Africa and Japan exchange rate exposure. A quantile regression is performed to see how the exchange rate exposure is affected by the intervention and control variables.

The study first uses quantile regression on the following equation:

$$|\beta_{si}| = \gamma_{01} + \gamma_{int} INTERVENTION_i + \sum_{m=1}^n \gamma_m^F F_{mi} + \varepsilon_i \quad (7)$$

Where $|\beta_{si}|$ is the absolute magnitude of the country's exchange rate exposure estimated from Kalman filter. According to earlier studies (Aggarwal and Harper, 2010; Hutson and Laing, 2014), the absolute exposure coefficient should be used because country-level factors only influence the exposure's magnitude and not its direction. F_{mi} represents country-specific control variables for country i , respectively. $INTERVENTION_i$ is the variable capturing forex intervention by the

central bank. γ_{int} is the coefficient that captures the effect of intervention on exchange rate exposure.

In the further analysis, the positive effects of intervention on exposure are investigated. The study investigates whether the sale of foreign currency by the central bank has a different effect on country's exchange rate exposure. For this purpose, the following model for the countries is used:

$$|\beta_{si}| = \gamma_{01} + \gamma_{int}INTERVENTION_i + \gamma_d D_i \cdot INTERVENTION_i + \sum_{m=1}^n \gamma_m^F F_{mi} + \varepsilon_i \quad (8)$$

where D_i is a dummy variable that is equal to 1 if the central bank intervened negatively in the currency market during the sample period and 0 otherwise. In order to establish that exposure is influenced by negative interventions, the regression coefficient of interest, γ_d , must be significantly different from 0.

The study also seeks to determine whether the impact of the intervention on exposure is dependent on the depreciation of the currency rate, i.e., whether the exposure of the country is impacted by the interaction between interventions and depreciation periods.

$$\begin{aligned} |\beta_{si}| = & \gamma_{01} + \gamma_{int}INTERVENTION_i + \gamma_d D_i \cdot INTERVENTION_i \\ & + \gamma_{INTDEP} D_{DEP_i} \cdot INTERVENTION_i + \gamma_{saledep} D_{DEP_i} \cdot D_i \cdot INTERVENTION_i \\ & + \sum_{m=1}^n \gamma_m^F F_{mi} + \varepsilon_i \end{aligned} \quad (9)$$

where D_{DEP_i} is a dummy variable equal to 1 if the country experienced a depreciation of the local currency against the US dollar over the period, and 0 otherwise. The regression coefficients γ_{INTDEP} and $\gamma_{SALEDEP}$ indicate the effects of sale interventions during the depreciation periods.

3.4 Variables

3.4.1 Independent Variable – Foreign Intervention

Previous studies have highlighted several challenges in accurately measuring central bank interventions, as real forex intervention data is often not publicly available for most emerging economies. As a result, earlier research has typically used changes in foreign exchange reserves as a proxy for interventions. However, reserve accumulation can also occur for reasons unrelated to central bank actions. For example, reserves may increase when companies convert foreign currency receipts or earn accrued interest. Additionally, reserve fluctuations may arise due to prudential concerns rather than direct interventions.

To address this issue, a more precise proxy for central bank intervention is to use changes in the reserves-to-M2 ratio, as suggested by Levy-Yeyati *et al.* (2013) and Obstfeld *et al.* (2010). This approach helps exclude precautionary adjustments to reserves intended to accommodate broad money changes, ensuring that such movements do not artificially influence the variable. Consequently, the change in the reserves-to-M2 ratio captures the central bank's genuine forex intervention activities. In this context, foreign reserves are defined as the official reserves, and an increase in the ratio indicates a net purchase of foreign currency by the central bank. Using monthly data for 600 European firms for the period from 1999 to 2011, Parlapiano *et al.* (2017) showed that domestic firms are exposed to exchange rate changes. Empirical studies suggest that exchange rate exposure is higher in emerging economies than in developed markets.

The data for this measure is sourced from Thompson Reuters.

3.4.2 Control Variables

As in prior literature, the study also controls for country-specific variables (Chue and Cook, 2008). The study uses the following control variables:

Trade openness, defined as the ratio of trade to Gross Domestic Product (GDP), reflects the extent of a country's participation in international trade, which determines its exposure to global economic forces. Additionally, broad money, expressed as a percentage of GDP, serves as a measure of financial market development within a country. Well-developed financial markets offer a variety of hedging tools at lower costs, thereby minimizing a country's exposure to

exchange rate fluctuations. Moreover, GDP *per capita*, measured in US dollars, is often used as an indicator of a country's bond market development. A well-developed bond market can reduce a country's reliance on foreign debt, which, in turn, decreases its vulnerability to currency risk.

Prior research demonstrates that greater foreign sales are associated with higher exchange rate exposure, as foreign income increases the sensitivity of a firm's value to exchange rate volatility (Choi and Prasad, 1995; Doidge *et al.*, 2006; Hutson and Laing, 2014; Jorion, 1990). Furthermore, research results showed that macroeconomic variables such as inflation, monetary policy stance, and sector-specific factors influence exchange rate exposure. Consequently, this study also incorporates inflation, as measured by the consumer price index, interest rates (repo or lending rates), and foreign direct investment. The control variables year-end values are from the World Bank and Thompson Reuters.

4. DATA, ESTIMATION AND RESULTS

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics of the sample countries variables used. The sample period constitutes of quarterly data from 1996 to 2023. The data is sourced from the World bank development and Thompson Reuters.

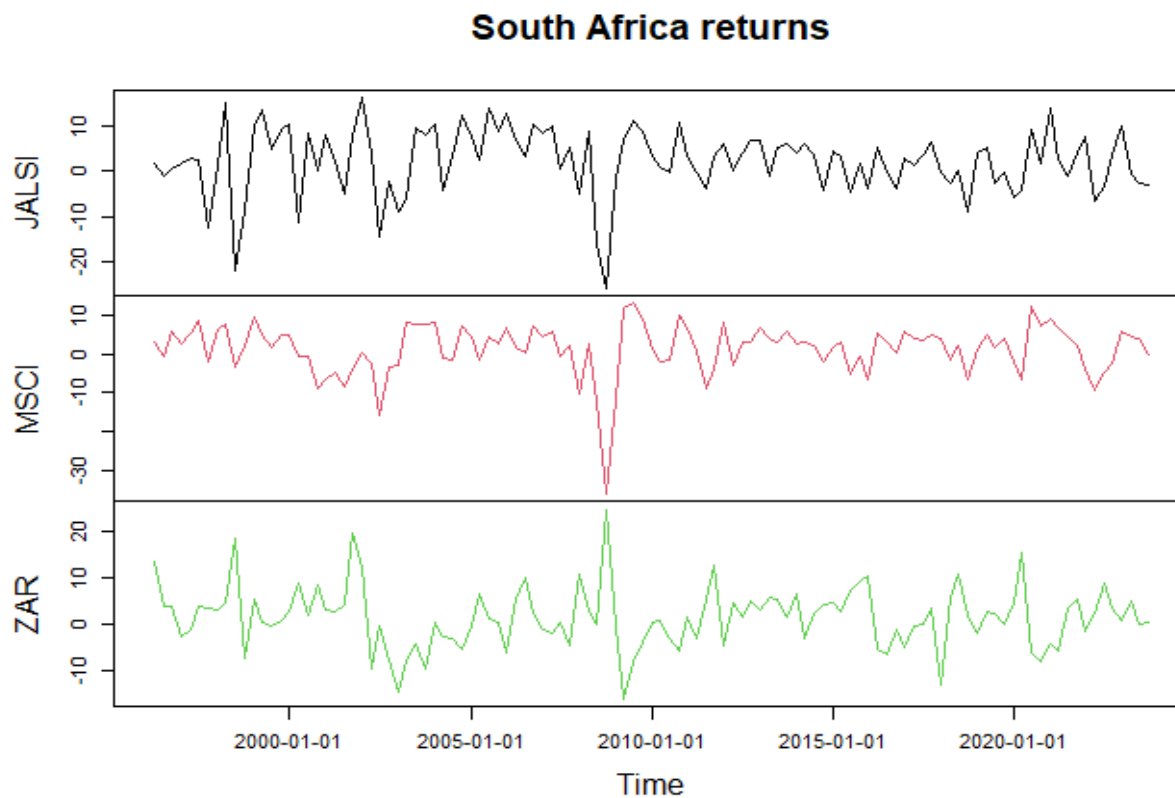
The summary of descriptive statistics for each South African variable used in this study is shown in Table below. 112 quarterly observations from 1996-2023 per data series were examined to estimate the mean, median, maximum, standard deviation, skewness and kurtosis descriptive statistics. The mean displays the series' average value and the standard deviation measures the distribution of the series. The maximum and minimum indicate the upper and lower values in the data series of each variable. The skewness quantifies the asymmetry of the distribution of a series around its mean.

TABLE 1 - *South Africa Descriptive Statistics*

	Mean	Maximum	Minimum	St. Deviation	Skewness	Kurtosis
JALSI returns	2.246	16.441	-26.01	7.3536	-0.9798	4.929291
MSCI returns	1.239	13.067	-36.161	6.5952	-1.9240	11.072248
ZAR return	1.445	24.636	-16.184	6.6082	0.3829	4.346891
Bsi	0.05174	0.41222	-0.44773	0.2200	-0.6110	2.783232
TR to M2	1.7958	5.1339	-3.1449	1.7300	-0.7120	2.993542
M2	62.84	73.97	45.33	8.6300	-6.6500	1.933628
GDP per capita	5821	8737	2708	166.00	-0.4990	2.159774
Interest R	11.995	21.792	7.042	3.6700	1.0700	3.286719
Trade	53.11	65.97	42.22	6.4300	0.1200	2.365029
FDI	1.698	9.6779	0.2051	1.5600	2.7100	11.695644
Inflation	5.516	10.075	-0.692	1.9300	-0.4710	3.978973

The data series reflects moderately skewed distribution for variables with values that lie between -0.5 and 1, whereas other show a highly skewed distribution with values greater than 1 or -1. All the data series show a leptokurtic distribution with kurtosis values greater than 1. Figure 1 shows the graph for the South African stock JALSI returns, MSCI world returns and ZAR/USD exchange rate changes.

The summary of descriptive statistics for each Japan variable used in this study is shown in Table 2. 112 quarterly observations from January 1996-December 2023 per data series were also examined.

FIGURE 1 - *South African Returns Plot*TABLE 2 - *Japan Descriptive Statistics*

	Mean	Maximum	Minimum	Sd	Skewness	Kurtosis
N225 returns	0.4025	20.5381	-28.277	10.367134	-0.4161	2.671035
MSCI returns	1.239	13.067	-36.161	6.59572	-1.9240	11.072248
JPY change	0.1793	13.88	-17.8052	5.52608	-0.4368	3.797474
Bsi	1.167	0.4888	-0.992	0.5760	-0.9450	3.547065
TR to M2	0.004848	0.0297	-0.01456	0.0083	0.8390	4.21354
M2	227.8	284.5	190.9	20.910	0.5720	2.281479
GDP per capita	38433	49145	32424	394.00	1.0300	3.833025
Interest R	2.45	1.576	0.95	0.4940	0.2850	1.651877
Trade	29.87	46.98	18.13	8.0400	0.2900	2.469942
FDI	0.36048	1.23793	-0.05209	0.3180	0.9760	2.964116
Inflation	3.172	0.3808	-1.3528	1.0200	1.0300	3.558227

The data series reflects moderately skewed distribution for variables with values that lie between -0.5 and 1, whereas other show a highly skewed distribution with values greater than 1 or -1. All the data series show a leptokurtic distribution with kurtosis values greater than 1. Figure 2 shows the graph for the Japan stock N225 returns, MSCI world returns and JPY/USD exchange rate changes.

FIGURE 2 - *Japan Returns Plot*

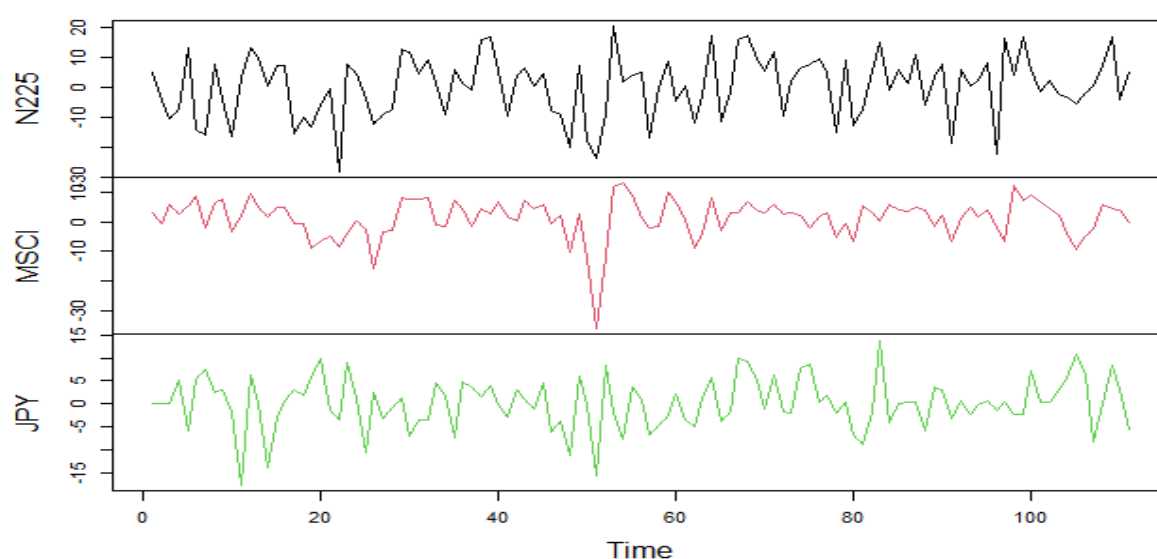


FIGURE 3 - *Time Varying Exposure for Japan using Kalman Filter*

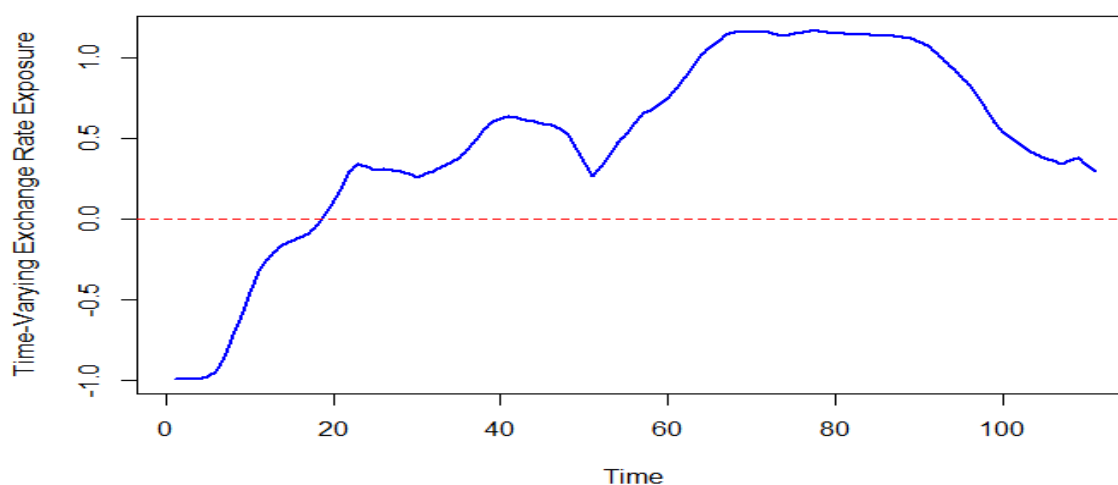
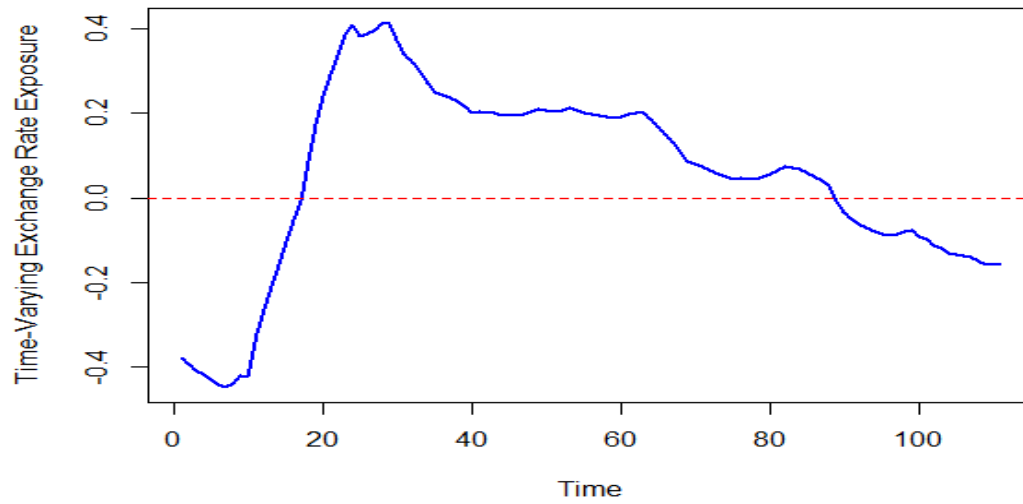


FIGURE 4 - *Time Varying Exchange Rate Exposure for South Africa using Kalman Filter*



From Figure 4 we can see also see that most of the time varying exchange rate exposures are also positive.

4.2 Quantile Regression

TABLE 3 - Summary results of the Quantile Regression Analysis

Dependent variable	$ \beta_{si} $							
	South Africa				Japan			
	q25	q50	q75	q90	q25	q50	q75	q90
Constant	-2.64430 ***	-0.72757	-0.38274	-0.64404 ***	-21.17373***	-17.86888***	-7.68252	-12.03466 ***
TR to M2	0.00410	-0.00849	-0.01446 ***	-0.01531 ***	-11.44605***	-19.28801***	-22.39628 ***	-19.89131 ***
Broad money	-0.00173	-0.00550	-0.00942 ***	-0.01012 ***	-0.00526***	-0.00783 ***	-0.00701***	-0.00917 ***
GDP per capita	0.33669 ***	0.11525	0.10329 ***	0.14506 ***	2.36640***	2.13882***	1.05343***	1.51218***
Trade openness	-0.00882	0.00098	0.00282***	0.00142	-0.04010***	-0.04209***	-0.00788	-0.00902
Inflation	0.00710	-0.00911	-0.00951***	-0.00529	0.32004***	0.32396 ***	0.24006***	0.33326***
FDI	0.01175 ***	0.00139	-0.00130	-0.00210	0.22452	0.31409	0.05797	0.18425
Interest rate	0.03230 ***	0.02562 ***	0.02177 ***	0.02299 ***	-0.67535***	-0.72176***	-0.46821***	-0.46179***

TABLE 4 - *Summary Results for the Quantile Regression Analysis for Positive Exposure*

Dependent variable	<i>Positive β_{si}</i>							
	South Africa				Japan			
	q25	q50	q75	q90	q25	q50	q75	q90
Constant	-2.67810 ***	-2.91738 ***	-1.80724 ***	-2.02035 ***	0.33253	-0.60937	-1.87602	-0.79693
TR to M2	0.01115 ***	0.01138 ***	0.01167 ***	0.01464 ***	-3.66183	-3.82871	-3.47809	-9.09656***
Broad money	-0.01494 ***	-0.01717 ***	-0.01719 ***	-0.01909 ***	-0.02541***	-0.02679 ***	-0.01566***	-0.00629
GDP per capita	0.44447 ***	0.48613 ***	0.36607 ***	0.40658 ***	0.53875	0.61941***	0.50684	0.23619
Trade openness	-0.01342 ***	-0.01359 ***	-0.01253 ***	-0.01387 ***	0.07762***	0.08413***	0.06760***	0.04551***
Inflation	0.02035 ***	0.02227 ***	0.02864 ***	0.03449 ***	-0.11698	-0.12388***	-0.10144 ***	-0.07257***
FDI	-0.00617	-0.01113	-0.03282 ***	-0.04066 ***	0.12045	0.26424***	0.15366	-0.01974

The quantile regression analysis of Equation (7) using the change in the reserves-to-M2 ratio as a forex intervention variable is shown in Table 3. For all quantiles in Japan and for q75 and q90 in South Africa, the intervention variable's coefficients are negative and significant. A unit increase in the intervention measure lowers the firms' absolute exchange rate exposure, as indicated by the negative sign. In other words, when the central bank sells foreign currency in the forex market, the amount of South Africa's and Japan's exchange rate exposure decreases.

When the central bank actively sells foreign currency in the forex market, it signals to the market that the local currency is under downward pressure. This can trigger heightened exchange rate volatility and uncertainty, leading countries to experience higher exposure to currency fluctuations.

- The study re-estimates Equation (7) for positive exchange rate exposure. Table 4 shows that the coefficient is positive and significant for South Africa in all quantiles, meaning a unit increase in the intervention causes a positive effective on the exchange rate exposure. The positive coefficient implies that when the central bank intervenes by purchasing foreign currency (positive intervention), it leads to an increase in the magnitude of the country's exchange rate exposure.
- For q90 Japan has negative significant values, meaning a unit increase in the intervention measure lowers the firms' absolute exchange rate exposure, as indicated by the negative sign.

TABLE 5 - *Summary Results for the Quantile Regression Analysis for Negative Exposure*

Dependent variable	<i>Negative β_{si}</i>							
	South Africa				Japan			
	q25	q50	q75	q90	q25	q50	q75	q90
Constant	0.15819	0.39541	0.55302	0.83727 ***	-279.33500	-122.30343	-53.18700	-53.18700
TR to M2	0.01764***	0.02055 ***	0.02110 ***	0.02109 ***	-426.41873	-176.44096	-62.63518	-62.63518
Broad money	-0.01708 ***	-0.01675 ***	-0.01671 ***	-0.01986 ***	0.03719	0.01787	0.00997	0.00997
GDP per capita	0.11275 ***	0.07732 ***	0.05408	0.03531	34.02670	15.12217	6.81490	6.81490
Trade openness	0.00956 ***	0.01066 ***	0.01152 ***	0.01447 ***	-2.67980	-1.21068	-0.57851	-0.57851
Inflation	-0.05534***	-0.06128 ***	-0.06584 ***	-0.07804 ***	0.78397	0.29866	0.11277	0.11277
FDI	-0.01380 ***	-0.01319 ***	-0.01094 ***	-0.01104 ***				
Interest rate	-0.03442***	-0.03270 ***	-0.03134 ***	-0.03133 ***	-14.99884	-7.61721	-4.37984	-4.37984

4.2.1 Effects of Negative Interventions on the Country's Currency Exposure

Table 6 reports the results of the analysis of Equation (8). For South Africa the statistically significant coefficient of sale intervention variable in q90 is negative and for Japan the coefficient is significant from q50-q90 and positive. The results show that sale interventions have a positive effect on Japan absolute currency exposure and a negative impact on South Africa. The results support the theoretical argument that central banks intervene differently in terms of the volume, frequency, or timing of sale or purchase transactions which asymmetrically affects the exchange rates (Berganza and Broto, 2012; Broto, 2013). As a result, countries prefer to take hedging positions where they take one-sided hedge based on their net asset liability transactions. For example, net importers would prefer to hedge against depreciation and may leave their exposure unhedged towards appreciation. In this case, their exposure would be more affected by sale interventions.

4.2.2 Interactions Effects of Interventions with Depreciation and Intervention

The study then looks into how negative interventions and currency rate depreciation interact to affect a country's exposure. Interventions in sales during depreciation periods are thought to affect the exchange rate and predict future increases in the value of the local currency. Importers leave their exposure partially hedged or unhedged because they view sale interventions as an implied government assurance against significant depreciations. Their exposure to exchange rates is so increased. Since Table 7 demonstrates that the impacts of sale interventions on absolute exposure during depreciation periods are negligible, this cannot be verified in our analysis.

TABLE 6 - *Summary Results of the Quantile Regression Analysis (Effects of Positive Intervention only on Exposure)*

Dependent variable	$ \beta_{si} $							
	South Africa				Japan			
	q25	q50	q75	q90	q25	q50	q75	q90
Constant	-3.19168 ***	-0.99327	-0.36385	-0.52800	-14.81731***	-11.76717 ***	-4.29894	-5.95387
TR to M2	0.00672	0.00633	-0.00459	-0.01225 ***	-18.22798***	-19.86145***	-24.80741***	-28.40762***
Broad money	-0.00365	-0.00325	-0.00857 ***	-0.00987 ***	-0.00555	-0.00490	-0.00801***	-0.00856***
GDP per capita	0.39564 ***	0.12708	0.09872 ***	0.13252 ***	1.77800***	1.43279***	0.76291	0.93939
Trade openness	-0.00606	-0.00044	0.00206	0.00103	-0.03867***	-0.02294	-0.00727	-0.00606
Inflation	-0.00536	-0.01830 ***	-0.00729	-0.00427	0.27530***	0.32636***	0.25414***	0.20482***
FDI	0.01436 ***	0.00767	-0.00231	-0.00247	0.33043	0.12879	0.08551	0.04875
Interest rate	0.03811 ***	0.03222 ***	0.01908 ***	0.02177 ***	-0.72760***	-0.55274***	-0.51970***	-0.52547***
D*Intervention	-0.02189	-0.08148 ***	-0.02742	-0.00342	27.91996	61.60992***	74.44875***	72.22487 ***

TABLE 7 - *Summary Results of the Cross-Sectional Analysis (Interaction Effects of Interventions with Depreciation Period on Exposure)*

Dependent variable	$ \beta_{si} $							
	South Africa				Japan			
	q25	q50	q75	q90	q25	q50	q75	q90
Broad money	-0.00385	-0.00334	-0.00825 ***	-0.01023 ***	-0.00552	-0.00471	-0.00737***	-0.00863***
GDP per capita	0.40795	0.12821	0.08554***	0.15224 ***	1.93796***	1.35908***	0.81952 ***	0.96521 ***
Trade openness	-0.00634	-0.00037	0.00217	0.00153	-0.04073***	-0.02131	-0.00755	-0.00859
Inflation	-0.00317	-0.01835	-0.00823	-0.00577	0.28885***	0.32560***	0.24883***	0.21059***
FDI	0.01482***	0.00765	-0.00236	-0.00175	0.37168	0.09846	0.10916	0.01754
Interest rate	0.03798 ***	0.03219 ***	0.01944 ***	0.02366***	-0.68697***	-0.56742***	-0.46409***	-0.56313***
D*Intervention	-0.01324	-0.08112***	-0.02256	0.01418	31.15317	108.48766	21.27171	64.78019
Dep*Intervention	0.00196	0.00015	-0.00089	0.00047	-2.78926	-2.94756	-3.06875	5.34252
Dep*D*Intervention	-0.00686	-0.00397	0.00015	-0.02132	-2.28211	-46.93639	55.19622	-2.17563

4.3 Discussion

The results demonstrate that foreign exchange intervention is a significant factor influencing exchange rate exposure for both emerging and developed countries. These findings carry important implications for firms, policymakers, and regulators. Central banks often intervene in the forex market with specific goals in mind, such as ensuring monetary stability, adjusting exchange rate levels, or limiting short-term fluctuations (Mohanty and Berger, 2013). However, central banks rarely disclose the precise reasons behind their interventions, and many interventions are neither officially confirmed nor reported. Research suggests that interventions are more effective when they are officially acknowledged.

In light of this, a key recommendation is that regulators should formally communicate interventions and clearly articulate their objectives. This would help firms avoid facing moral hazard and allow them to better assess potential risks. Foreign exchange interventions tend to lead firms to adopt asymmetrical hedging strategies, where firms hedge in one direction based on their net asset or liability positions (Koutmos and Martin, 2003; Bartov and Bodnar, 1994). This is especially true when interventions disproportionately affect exchange rates during periods of appreciation or depreciation. Official confirmation of interventions would support this effort.

Moreover, improving the transparency of firms' hedged and unhedged positions in their financial statements, along with stricter regulations regarding the reporting of hedging instruments, could benefit both investors and firms.

5. CONCLUSION

This study examines the impact of foreign exchange interventions on exchange rate exposure by analyzing data from an emerging economy, South Africa, and a developed economy, Japan, over the period from January 1996 to December 2023. The analysis estimates the exchange rate exposure coefficients using the Jorion model and applied the Kalman filter for more precise modelling. In the second stage, the study uses the exposure coefficients derived from the Kalman filter as the dependent variable and conducts quantile regression, with changes in the reserves-to-M2 ratio as the primary independent variable, while controlling for country-specific factors.

The findings indicate that interventions have a negative effect on exchange rate exposure at the 75th and 90th quantiles for South Africa, indicating increased sensitivity to exchange rate movements for firms that are heavily exposed. This finding is similar to previous studies by Koutmos and Martin (2003) and Bartov and Bodnar (1994). The research finds that foreign exchange interventions can result in negative effects on exchange rate exposure. Japan had negative effects across all quantiles. Both countries experience greater sensitivity to exchange rate fluctuations when their central banks sell foreign currency.

For Japan, foreign currency sales lead to a positive impact on exchange rate exposure across all quantiles, while South Africa experiences a negative impact at the 50th quantile. Additionally, the study reveals that the negative effects of interventions are more pronounced in developed countries, with Japan showing positive coefficients for all quantiles, whereas South Africa only exhibits a positive coefficient at the 90th quantile. This stands in somewhat contrast to previous research that typically suggests exposure is stabilized by interventions in developed markets (Mohanty and Berger, 2013), suggesting that the impact may vary greatly based on particular market conditions or intervention tactics.

These results offer important insights for policymakers and corporate managers. Poorly communicated interventions can lead to asymmetrical hedging practices by firms, where firms hedge only one-sided risks based on their asset or liability position. This poses a potential risk to the stability of financial markets. Regulatory bodies should consider formally communicating the objectives of foreign exchange interventions to enhance their credibility and improve awareness of potential exchange rate risks for firms and countries. For South Africa, where exchange rate fluctuations might be more frequent and impactful, interventions can reduce the volatility that contributes to inflation, allowing the central bank to avoid raising interest rates excessively and harming economic growth. In Japan, interventions that positively affect

Future research could build on these findings by utilizing high-frequency data on forex interventions and expanding the analysis to include a broader set of emerging and developed countries, which could provide more comprehensive insights. While this study did not find significant results concerning the effect of depreciation during periods of negative intervention, further research could explore this topic more deeply. Investigating the conditions under which

depreciation significantly influences exchange rate exposure would offer valuable insights into how firms and economies respond to different types of forex interventions.

We declare that there is no conflict of interest related to this paper.

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