# Foreign exchange intervention and exchange rate exposure: evidence from South Africa and Japan

Bonga-Bonga, Lumengo and Nyambayo, Kudznai and Mpofu, Delani

24 February 2025

# Foreign exchange intervention and exchange rate exposure: Evidence from South Africa and Japan

By

Lumengo Bonga-Bonga

Delani Mpofu

Kudzanai Nyambayo

Abstract

Foreign exchange (forex) interventions by central banks have become increasingly frequent in emerging markets. While the effects of these interventions on exchange rate volatility are well-documented, their implications for broader country-level outcomes remain underexplored. This study posits that forex interventions should affect a country's sensitivity to currency movements, particularly influencing its cash flows. It examines this hypothesis by analysing the impact of forex interventions on exchange rate exposure in South Africa, an emerging market, and Japan, a developed economy, using quarterly data from January 1996 to December 2023.The study utilizes the Kalman filter to estimate time-varying exchange rate exposure and applies quantile regression to explore the relationship between forex interventions and exchange rate exposure. The findings reveal that interventions generally have a negative effect on the absolute values of exchange rate exposure. Specifically, in South Africa, negative central bank interventions show a significant negative effect at the 50th quantile. In Japan, however, these interventions exhibit a positive effect from the 50th to the 90th quantile. Additionally, the study examines the effect of currency depreciation during periods of negative intervention but does not find statistically significant results. The research underscores the importance of credible communication from policymakers regarding the objectives of central bank interventions, as this could help firms better manage potential currency risks.

Keywords: Foreign exchange interventions, Exchange rate risk exposure ,Kalman filter, Quantile regression ,Central banks

## 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. In addition, the Monetary Theory of Exchange Rates, originated by Friedman (1953), states that the exchange rates between two currencies is 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. 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 the 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 performances 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. 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 high 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 et al. (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.

In the case of Japan, Doukas et al. (1999) using an Intertemporal Multi-Factor Asset Pricing model, found that foreign exchange rate risk exposure was indeed priced into the Japanese equity market. Notably, the exchange rate risk exposure was greater in firms characterised by high exports. While in the case of South Africa, Ho and Iyke (2021), using a Multi-Factor Arbitrage Pricing model, found that exchange rate risk exposure had an adverse effect on the sectors and industries, but argued that the exposure was driven largely by industrial exposures, as opposed to exchange rate exposure in the respective sectors.

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 et al. (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 hold 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 are informed by their different monetary policy stance and the level of development. South Africa, an emerging economy, applies a monetary policy targeting. 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 level 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 ofmonetary 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 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, Olufem (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, Klotzle et al. (2019) applied a Quantile Regression approach to assess the effect of interventions in Brazil on exchange rate exposure. Klotzle 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 has 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. Braekers et al. (2021) utilized this approach to establish that the timing of interventions significantly influenced their effectiveness, particularly in relation to market expectations. Braekers 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 a firm- level. 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 countrys' 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,

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

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

$\beta_{mi}$ is a measure of the firm's exposure to market risk

$\beta_{si}$ measures the firm's exchange rate exposure

$\varepsilon_{it}$ 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 βsi 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 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 $\beta$ 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:

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

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

$$z_t = Hx_t + v_t \tag{3}$$

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, may change at every time step in real-world applications. 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. Since its introduction, numerous studies have utilized this approach to assess the impact of explanatory variables on the dependent variable across different points in the distribution. The fundamental quantile regression model expresses the conditional quantile as a linear function of the explanatory variables and is formulated as follows:

$$Y = X'\beta + \varepsilon \tag{4}$$

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

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 $\theta$th quantile of Y conditional on X = x. The θth regression quantile estimate $\hat{\beta}(\theta)$, is the solution of the following minimization:

$$Min_{\beta\epsilon\mathfrak{R}} \sum_{Y\geq X'\beta} \theta|Y - X'\beta| + \sum_{Y<X'\beta} (1-\theta)|Y - X'\beta| \qquad (6)$$

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 qth 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:

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

Where $|\beta_{si}|$ 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. $\gamma_{int}$ 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 has a different effect on country's exchange rate exposure. For this purpose, the following model for the countries is used :

$$|\beta_{si}| = \gamma_{01} + \gamma_{int} INTERVENTION_I + \gamma_d D_i . INTERVENTION_{\ i} + \sum_{m=1}^{n} \gamma_m^F F_{mi} + \varepsilon_i \qquad (8)$$

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, $\gamma_d$, 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.

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

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 $\gamma_{\mathrm{INTDEP}}$ and $\gamma_{\mathrm{SALEDEP}}$ 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 Eduardo 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 (Burger & Warnock, 2007). 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 & Prasad, 1995; Doidge et al., 2006; Hutson & Laing, 2014; Jorion, 1990). Furthermore, Chaieb and Mazzotta (2013) found 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

The following table 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.

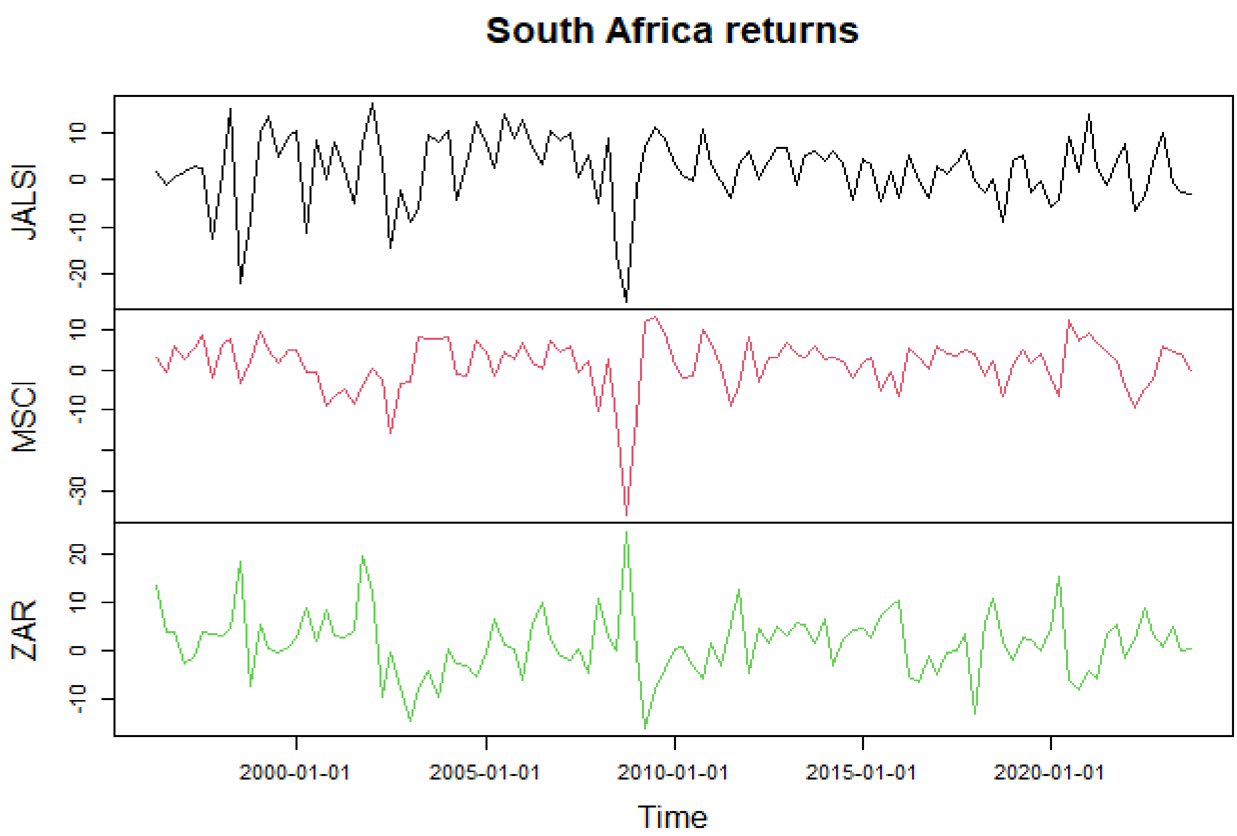
Table 1. South Africa Descriptive Statistics

| | Mean | Maximum | Minimum | Sd | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| JALSI returns | 2.246 | 16.441 | -26.010 | 7.353685 | -0.9798297 | 4.929291 |
| MSCI returns | 1.239 | 13.067 | -36.161 | 6.595720 | -1.9240050 | 11.072248 |
| ZAR return | 1.445 | 24.636 | -16.184 | 6.608224 | 0.3829200 | 4.346891 |
| Bsi | 0.05174 | 0.41222 | -0.44773 | 2.198584e-01 | -6.113637e-01 | 2.783232 |
| TR to M2 | 1.7958 | 5.1339 | -3.1449 | 1.726451e+00 | -7.121128e-01 | 2.993542 |
| M2 | 62.84 | 73.97 | 45.33 | 8.633689e+00 | -6.646542e-0 | 1.933628 |
| GDP per capita | 5821 | 8737 | 2708 | 1.659718e+03 | -4.992338e-01 | 2.159774 |
| Interest R | 11.995 | 21.792 | 7.042 | 3.670449e+00 | 1.071383e+00 | 3.286719 |
| Trade | 53.11 | 65.97 | 42.22 | 6.430067e+00 | 1.196721e-01 | 2.365029 |
| FDI | 1.6980 | 9.6779 | 0.2051 | 1.557682e+00 | 2.713250e+00 | 11.695644 |
| Inflation | 5.516 | 10.075 | -0.692 | 1.934235e+00 | -4.707779e-01 | 3.978973 |

The summary of descriptive statistics for each South African variable used in this study is shown in Table above. 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 (Brooks, 2014). 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 (Brooks, 2014).

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. The figure below shows the graph for the South African stock ALSI returns, MSCI world returns and ZAR/USD exchange rate changes.

Figure 1 South African returns plot




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

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. The figure below shows the graph for the Japan stock  N225 returns, MSCI world returns and JPY/USD exchange rate changes.

**Table 2. Japan Descriptive statistics**

| | Mean | Maximum | Minimum | Sd | Skewness | Kurtosis |
|---|---|---|---|---|---|---|
| N225 returns | 0.4025 | 20.5381 | -28.2770 | 10.367134 | -0.4161225 | 2.671035 |
| MSCI returns | 1.239 | 13.067 | -36.161 | 6.595720 | -1.9240050 | 11.072248 |
| JPY change | 0.1793 | 13.8800 | -17.8052 | 5.526086 | -0.4368169 | 3.797474 |
| Bsi | 1.1670 | 0.4888 | -0.9920 | 5.760162e-01 | -9.451712e-01 | 3.547065 |
| TR to M2 | 0.0048480 | 0.0297361 | -0.0145688 | 8.350810e-03 | 8.387825e-01 | 4.213540 |
| M2 | 227.8 | 284.5 | 190.9 | 2.907382e+01 | 5.715532e-01 | 2.281479 |
| GDP per capita | 38433 | 49145 | 32424 | 3.938688e+03 | 1.027455e+00 | 3.833025 |
| Interest R | 2.450 | 1.576 | 0.950 | 4.935571e-01 | 2.851420e-01 | 1.651877 |
| Trade | 29.87 | 46.98 | 18.13 | 8.037722e+00 | 2.900243e-01 | 2.469942 |
| FDI | 0.36048 | 1.23793 | -0.05209 | 3.178398e-01 | 9.761817e-01 | 2.964116 |
| Inflation | 3.1720 | 0.3808 | -1.3528 | 1.024822e+00 | 1.027303e+00 | 3.558227 |

**Figure 2 Japan returns plot**

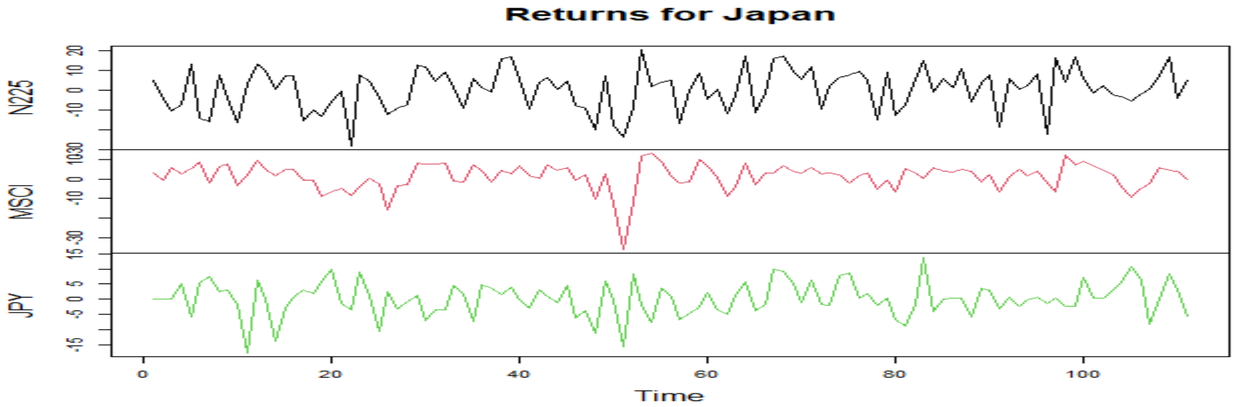



**Figure 3 Time varying exposure for Japan using Kalman filter**

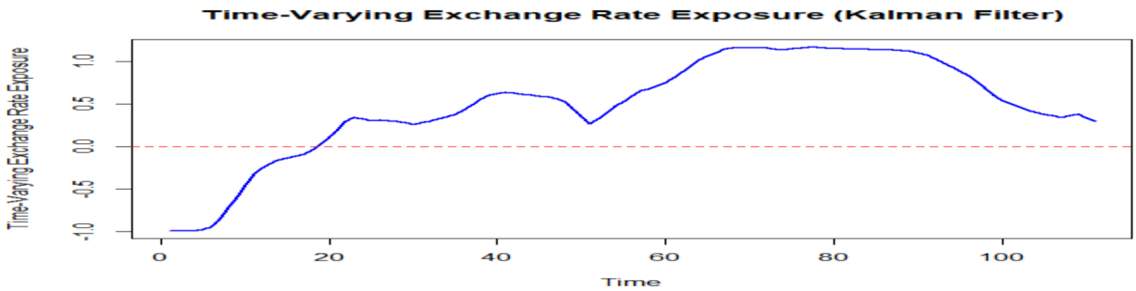
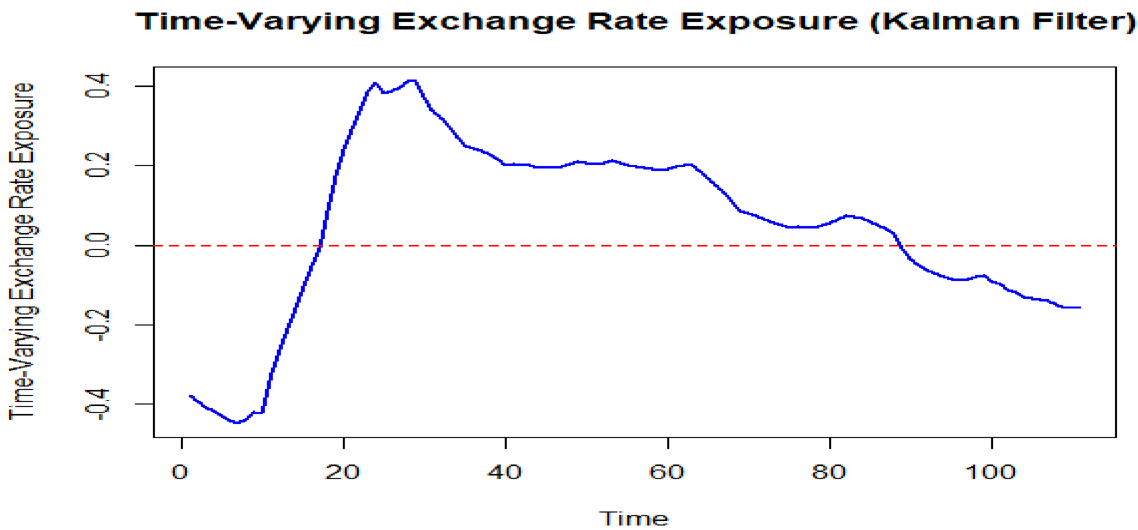



**Figure 4 Time varying Exchange rate exposure for South Africa using Kalman Filter**



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 | $\lvert\beta_{si}\rvert$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 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 *** |

The quantile regression analysis of Equation (7) using the change in the reserves-to-M2 ratio as a forex intervention variable is shown in the above table For all quantiles in Japan and for q75 and q90 in South Africa, the intervention variable's coefficient 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.

**Table 4 Summary results for the quantile regression analysis for positive exposure**

| Dependent variable | $Positive\ \beta_{si}$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 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 |
| Interest rate | 0.04889 *** | 0.05217 *** | 0.04387 *** | 0.04692 *** | -1.41817 *** | -1.26738 *** | -0.86642 *** | -0.50764 *** |

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 the table above 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 | $Negative\ \beta_{si}$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 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 |

For all quantiles the coefficients are positive and significant for intervention meaning a unit increase in intervention causes a positive impact on the negative exposure.

4.2.1 Effects of negative interventions 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 of 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, countrys' 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 | $\lvert\beta_{si}\rvert$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 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 | $\lvert\beta_{si}\rvert$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | South Africa | | | | Japan | | | |
| | q25 | q50 | q75 | q90 | q25 | q50 | q75 | q90 |
| Constant | -3.27897 | -1.00021 | -0.27059 | -0.70726 *** | -16.52858 *** | -11.06208 *** | -5.14338 | -6.08061 |
| TR to M2 | 0.00480 | 0.00611 | -0.00595 | -0.01735 *** | -18.25678 *** | -16.04180 *** | -23.79015 *** | -28.54076 *** |
| 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 & 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 (Menkhoff & Stöhr, 2017).

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 & Martin, 2003; Bartov & 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 Koutmos & Martin (2003) and Bartov & 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 & 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.

**References**

Adjasi, C.K., Salifu, Z., and Osei, K.A., 2007. Foreign exchange risk exposure of listed companies in Ghana. *The Journal of Risk Finance*, *8*(4), pp.380-393.

Adler, M. and B. Dumas, 1984. Exposure to currency risk: Definition and measurement. Financial Management, vol. 13, pp. 41-50.

Aggarwal, R., Harper, J.T., 2010. Foreign exchange exposure of " domestic " corporations. J. Int. Money Finance 29 (8), 1619–1636.

Aizenman, J. and Sun, Y., 2012. The financial crisis and sizable international reserves depletion: From 'fear of floating 'to the 'fear of losing international reserves'?. *International Review of Economics & Finance*, *24*, pp.250-269.

Bartov, E. & Bodnar, G.M., 1994. Firm valuation, earnings expectations, and the exchange-rate exposure effect. The Journal of Finance, 49(5), pp.1755-1785.

Bartov, E., & Bodnar, G. M. (1994). *Firm valuation, earnings expectations, and the exchange-rate exposure effect*. Journal of Finance, 49(5), 1755-1785.

Braekers, R., Van Cauwenberge, A., Vancauteren, M., and Vandemaele, S., 2021. Measuring and explaining firm-level exchange rate exposure: The role of foreign market destinations and international trade. *Economic Modelling*, *105*, p.105667.

Burger, J. D., & Warnock, F. E. (2007). *The influence of financial markets on currency exposure*. Journal of Financial Economics, 5(2), 150-167.

Cassel, G., 1916. The present situation of the foreign exchanges. *The Economic Journal*, *26*(103), pp.319-323.

Catalán-Herrera, J., 2016. Foreign exchange market interventions under inflation targeting: the case of Guatemala. *Journal of International Financial Markets, Institutions and Money*, *42*, pp.101-114.

Chaieb, I., & Mazzotta, S. (2013). *Macroeconomic factors and exchange rate exposure*. Journal of Financial and Quantitative Analysis, 48(1), 175-200.

Choi, J. J., & Prasad, A. M. (1995). *Exchange risk sensitivity and its determinants: A firm and industry analysis of US multinationals*. Financial Management, 24(3), 77-88.

Chue, T.K., Cook, D., 2008. Emerging market exchange rate exposure. J. Bank. Finance 32 (7), 1349–1362.

Doidge, C., Griffin, J., & Williamson, R. (2006). *Measuring the economic importance of exchange rate exposure*. Journal of Financial Economics, 82(1), 199-231.

Doukas, J., Hall, P.H. and Lang, L.H., 1999. The pricing of currency risk in Japan. *Journal of Banking & Finance*, *23*(1), pp.1-20.

Eduardo, L.Y., Sturzenegger, F., Gluzmann, P., 2013. Fear of appreciation. J. Dev. Econ. 101 (C), 233–247.

F. Parlapiano, V. Alexeev, M. Dungey Exchange rate risk exposure and the value of European firms Eur. J. Financ., 23 (2) (2017), pp. 111-129

Friedman, M., 1953. *The Case for Flexible Exchange Rates*. Essays in Positive Economics/University of Chicago Press.

Hutson, E., & Laing, E. (2014). *Foreign exchange exposure and multinationality*. Journal of Corporate Finance, 25, 18-34.

Iyke, B.N. and Ho, S.Y., 2021. Exchange rate exposure in the South African stock market before and during the COVID-19 pandemic. *Finance Research Letters*, *43*, p.102000.

Jorion, P. (1990). *The exchange-rate exposure of US multinationals*. Journal of Business, 63(3), 331-345.

Jorion, P., 1990. The exchange rate exposure of U.S. multinationals. Journal of Business, vol. 63, no. 3, pp. 331-345.

Jorion, P., 1991. The pricing of exchange rate risk in the stock market. *Journal of financial and quantitative analysis*, *26*(3), pp.363-376.

Kalman, R.E. (1960), A new approach to linear filtering and prediction problems. ASME Journal of Basic Engineering, 82(1), 35-45.

Keefe, H.G. and Shadmani, H., 2018. Foreign exchange market intervention and asymmetric preferences. *Emerging Markets Review*, *37*, pp.148-163.

Klotzle, M.C., Pinto, A.C.F. and da Silveira Barbedo, C.H., and Viola, A.P., 2019. Foreign exchange interventions in Brazil and their impact on volatility: A quantile regression approach. *Research in International Business and Finance*, *47*, pp.251-263.

Koch, W. (2006), Advanced target tracking techniques. Advanced Radar Signal and Data Processing, 2(1), 2-34.

Kodongo, O. and Ojah, K., 2011. Foreign exchange risk pricing and equity market segmentation in Africa. *Journal of Banking & Finance*, *35*(9), pp.2295-2310.

Koenker, R., Bassett, G., 1978. Regression quantiles. Econometrica 46, 33–50.

Koenker, R., Hallock, K., 2001. Quantile regression. J. Econ. Perspect. 15, 143–156

Koutmos, G. & Martin, A.D., 2003. Asymmetric exchange rate exposure: Theory and evidence. Journal of International Money and Finance, 22(3), pp.365-383.

Koutmos, G., & Martin, A. D. (2003). *Asymmetric exchange rate exposure: Theory and evidence*. Journal of International Money and Finance, 22(3), 365-383.

Lin, C.H., 2011. Exchange rate exposure in the Asian emerging markets. *Journal of Multinational Financial Management*, *21*(4), pp.224-238.

Loudon, G.F., 1993. Foreign exchange exposure and the pricing of currency risk in equity returns: Some Australian evidence. *Pacific-Basin Finance Journal*, *1*(4), pp.335-354.

Menkhoff, L. & Stöhr, T., 2017. Foreign exchange intervention and the effectiveness of central banks in emerging markets. Journal of International Economics, 104, pp.189-202.

Menkhoff, L., & Stöhr, T. (2017). *Foreign exchange intervention: A foreign exchange textbook review*. Journal of Economic Surveys, 31(3), 654-686.

Mohanty, M. S., & Berger, B. (2013). *Central bank forex interventions and their effectiveness*. BIS Papers No. 73.

Mohanty, M.S. & Berger, B., 2013. Central bank foreign exchange market intervention and the volatility of exchange rates: Evidence from the G-10 countries. BIS Working Papers, No. 73. Bank for International Settlements.

Mouradian, F., 2017. *Exchange Rate Exposure and Firms' Strategies* (Doctoral dissertation, Université Paris sciences et lettres).

Obstfeld, M., Shambaugh, J.C., Taylor, A.M., 2010. Financial stability, the trilemma, and international reserves. Am. Econ. J. Macroecon. 2 (2), 57–94.

Olufem, A.T., 2011. Exchange rate risk exposure of Nigerian listed firms: an empirical examination. *International Business Research*, *4*(2), pp.219-225.

Sikarwar, E., 2020. Forex interventions and exchange rate exposure: Evidence from emerging market firms. *Economic Modelling*, *93*, pp.69-81.

Streit, D., 2016. Firm-level effects of asymmetric intervention in foreign exchange markets: Evidence from the Swiss currency floor. *Journal of International Money and Finance*, *60*, pp.289-312.