The Effect of Exchange Rate Volatility on Trade between South Africa and her Top Trading Partners: Fresh Insights from ARDL and Quantile ARDL Models

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We investigate the impact of exchange rate volatility on exports and imports between South Africa and its main trading partners, namely the United States and China, across 22 import and export industries. The study employs the quantile autoregressive distributive lag (QARDL) model using quarterly data from the period spanning from 1994Q1 to 2022Q4. Our initial ARDL estimates establish that currency volatility does not significantly harm most trade sectors with both countries. In fact, many industries exhibit an insignificant or positive correlation with currency volatility. Nevertheless, upon re-estimating the regressions using the QARDL model, we uncover 'hidden cointegration' relationships existing at quantiles beyond the mean and median estimates, which are undetectable by traditional ARDL models. By considering these location-based asymmetries, we conclude that trade activities with China benefit more from exchange rate volatility compared to those with the United States. Overall, our findings imply that monetary authorities may not need to intervene in currency markets to stimulate trade with the top trading partners, as firms appear to be willing to bear the currency risks associated with the volatile Rand exchange rate.

Keywords: exchange rate volatility, exports, imports, trade, ARDL, QARDL, South Africa, United States, China
JEL Classification: F31, F10

Received 2023/10/01 · Revised 2023/12/04 · Accepted 2023/12/26
Published online 2024/09/30 https://doi.org/10.26493/1854-6935.22.253-277

Introduction

Following the demise of the Bretton Woods exchange rate system in 1971, the South African Rand has been one of the most volatile currencies worldwide, raising concerns for domestic multinational firms and foreign trading partners who rely on the exchange rate for international trade as well as for government agencies that use tariffs and subsidies to intervene in markets to mitigate such risks (Nyahokwe and Ncwadi 2013). However, the existing theoretical and empirical literature presents conflicting evidence on the effects of exchange rate volatility on trade, and three main reasons contribute to the lack of consensus. Firstly, most studies focus on the effects of exchange rate volatility on aggregated trade activity, while in reality, exchange rates have varying effects on different trade sectors and partners (Bahmani-Oskooee and Gelan 2020). Secondly, studies often fail to differentiate between export and import items, even though importers and exporters may have different risk attitudes towards currency fluctuations and are hence affected differently by exchange rate movements (Bahmani-Oskooee and Harvey 2018). Lastly, many studies do not adequately account for the asymmetric effects of different levels of currency volatility on trade performance, thus failing to distinguish the effects between 'extreme', 'normal', and 'very low' volatility.

Against this backdrop, this study examines the asymmetric effect of exchange rate volatility on disaggregated export and import items across 22 South African trade industries with her top trading partners, China and the US, utilizing quarterly data from 1994Q1 to 2022Q4. The choice of these two trading partners is significant as they represent South Africa's main trading partners in the 'West' and the 'East' parts of the world. Initially, the US was South Africa's primary global trading partner through the Africa Growth and Opportunity Act (AGOA) trade agreement until 2009/2010 when China became South Africa's main trading partner after joining the BRICS forum (Amusa and Fadiran 2019). We focus on the post-1994 period as it coincides with the democratic era in which the country experienced structural shifts in politics, trade, and central banking, including the lifting of international sanctions and the South African Reserve Bank's transition to inflation targeting. Despite South Africa's position as the trading hub of Africa, the Rand has remained one of the most volatile currencies among emerging markets, experiencing varying levels of currency volatility, particularly during events such as the

2001 emerging markets currency crash, 2007 global financial crisis, 2016 emerging markets sell-off, and the 2020 COVID-induced financial market crash (Qabhobho, Wait, and Roux 2020; Zerihun, Breitenbach, and Iyke 2020; Iyke and Ho 2021; Mpofu 2021). Our study hypothesizes that the observed varying levels of currency volatility could have different effects on bilateral trade volumes. Additionally, we distinguish between short-run and long-run effects of exchange rate volatility on trade, recognizing that firms and traders can hedge against short-term currency risk in a less costly manner than long-term risk (Peree and Steinherr 1989). To this end, we use the quantile autoregressive distributive (QARDL) model developed by Cho, Kim, and Shin (2015) to capture the impact of varying levels of currency volatility on industrial export and import activity between South Africa and her two top trading partners.

To the best of our knowledge, our study is the first of its kind and makes three specific contributions to the empirical literature. Firstly, while previous South African studies have not focused on disaggregated markets beyond the sectoral level, we follow the research of Bahamani-Oskooee, Harvey, and Hegerty (2014), Bahamani-Oskooee and Hegerty (2015), Bahamani-Oskooee and Aftab (2017), and Bahamani-Oskooee and Huseyin (2019; 2022), who conducted similar analyses at the industry level for bilateral partners such as the US and UK in separate studies. By adopting a similar disaggregated approach for South Africa, our study enables the identification of specific export and import items from different industries that are adversely, positively, or insignificantly affected by exchange rate volatility. Secondly, we focus on bilateral trade relations between South Africa and two of its trading partners. This diverges from previous studies that tend to concentrate on one trading partner at the bilateral level when conducting industry-level analyses. Consequently, our study provides more informative insights by demonstrating that exchange rate volatility can have different effects on trade within the same industry for different bilateral partners. Identifying such discrepancies can have implications for strategic trade positions against currency risk. Lastly, no prior studies have utilized the QARDL model to capture asymmetries in the relationship between exchange rate volatility and trade. Our study demonstrates the usefulness of this method in capturing location asymmetries or hidden cointegration relationships among variables, which the conventional ARDL model failed to capture.

Contrary to the findings of previous South African-based studies (see the next section for a detailed literature review), our findings reveal that extreme volatility does not hinder trade volumes in the country's key trade industries. While the ARDL estimates indicate that most South African industries are insignificantly affected by currency volatility in their trade with both the US and China, the QARDL estimates further reveal positive hidden cointegration effects for exports and imports in several Chinese manufacturing industries. Thus, in differing from the ARDL results, the QARDL estimates suggest that high exchange rate volatility has a more positive impact on both export and import trade with China compared to the US. This insight would have been difficult to discern by relying solely on ARDL estimators. Overall, we interpret these results as evidence of both importing and exporting firms being willing to undertake currency risk in trade with China, which may be attributed to the presence of currency swap agreements between the two countries that are absent in the case of South Africa-US relations.

The rest of the study is structured as follows. The second section provides a brief review of theory and empirical studies. The third outlines the empirical framework of the study. The fourth section presents the data and empirical results. The fifth presents the analysis of the results and finally, the sixth section concludes the study.

Literature Review

In this section we present the literature. We start by discussing the theoretical foundations of the paper and then provide a review of associated empirical literature.

THEORETICAL REVIEW

During the 1970s, as the world shifted from fixed to flexible exchange rates, the theory surrounding exchange rate risk on trade balance emerged (Cushman 1983). This transition fostered the liberalization of financial markets and trade, giving rise to two schools of thought on the subject. The first school expressed concerns that greater variability and uncertainty in exchange rates would negatively impact investment and trade. In contrast, the second school argued that the removal of restrictions on capital flows and trade would result in a net increase in the volume of international trade transactions.

One of the earliest theoretical models was presented by Clark (1973), who contended that covering foreign exchange risk in forward exchange rate markets is more costly under a flexible exchange rate regime. Ethier (1973) argued that floating exchange rate regimes lead to currency uncertainty, which makes trading firms' revenue sensitive to fluctuations and increases the trade-off between expected profit and risk reduction, ultimately reducing trade volumes. Baron (1976) found that under floating exchange rate regimes, the choice of invoice strategy is crucial. If exports are invoiced in the importers' currency, the exporter faces transaction costs and exposes revenue to currency risk. Conversely, if exports are invoiced in the exporters' currency, there is uncertainty in quantity demanded, as exporters cannot adjust the price of the product for every change in the exchange rate, leading to greater risk aversion. Without appropriate government intervention through tariffs and subsidies, these factors have an adverse effect on international trade. Peree and Steinherr (1989) expanded the analysis to medium-term uncertainty, showing that the adverse effects of medium-term currency risk on competitiveness and trade are more severe than those of short-term risk.

Conversely, other researchers argue that exchange rate volatility can have a positive impact on trade activity. For example, Frankel (1991) posited that an increase in exchange rate volatility creates differences in domestic and foreign prices, generating commodity arbitrage opportunities that can increase trade volume. Viaene and Vries (1992) further argued that if a certain proportion of exports and imports are denominated in foreign currency while the rest is denominated in the local currency (partial currency invoicing), exchange rate volatility could positively affect trade volumes when the aggregate net foreign position is positive. Sercu and Vanhuhulle (1992) found that exchange rate risk compels exporters to exploit their comparative advantages, making export-based strategies more valuable than foreign direct investment (FDI) strategies and resulting in an increase in trade activity. Broll and Eckwert (1999) discovered that large currency fluctuations make the real option to trade more profitable, increasing production volume and international trade when investors are more willing to take risks.

EMPIRICAL REVIEW

Empirical studies have extensively examined the impact of exchange rate volatility on international trade, employing various estimation techniques and synthetic measures of exchange rate volatility (see McKenzie 1999; Bahmani-Oskooee and Hegerty 2007) for a comprehensive review of previous international literature). In this section we review studies which have focused on South Africa or included it within a panel of other countries. A total of 27 related articles were identified through an extensive search on Google Scholar using keywords such as 'Exchange rate volatility and trade/exports/imports Africa', 'Exchange rate volatility and trade/exports/imports South Africa', and 'Exchange rate volatility and exports Sub-Saharan Africa' (see table 1). Among these studies, a majority of previous South African-related studies (16 out of 27) found a negative effect of exchange rate volatility on trade volume, while fewer studies reported a positive relationship (7 out of 27) or insignificant effects (4 out of 27).

Studies that examined the trade balance at the export and import levels also displayed limited consistency in their results. For example, Bahmani-Oskooee (1996), Kargbo (2006), Omojimite and Akpokodje (2010), Musila and Al-Zyoud (2012), and Meniago and Eita (2017) found a negative relationship between exchange rate volatility and both export and import items. In contrast, Bahmani-Oskooee and Payesteh (1993) and Ekanayake, Thaver, and Plante (2012) reported insignificant and positive effects on both exports and imports, respectively. Studies conducted at the sectoral level also exhibited discrepancies in their findings. Todani and Munyama (2005) found a positive effect on total trade but insignificant effects for other trade classifications (goods, services, and gold), while Olayungbo, Yinusa, and Akinlo (2011) found a positive effect on total and manufacturing trade but insignificant effects on primary products.

Methodologically, the empirical techniques used in these studies mirrored those employed in international research, including linear estimation techniques such as OLS, GMM, FMOLS, DOLS, Engle-Granger, VECM, and ARDL models. More recently, some studies have considered the use of the nonlinear ARDL (NARDL) model, which distinguishes the effects of increasing and decreasing levels of exchange rate volatility. For instance, Bahmani-Oskooee and Arize (2020) and Dada (2021) applied the NARDL model and found negative effects on different partitions of the trade balance. Anyikwa and Domela (2022) also used the NARDL model and reported negative and positive effects on different partitions of the trade balance.

In recent years, the Quantile Autoregressive Distributed Lag (QARDL) methodology has gained popularity as a more flexible variant of the conventional ARDL, compared to the NARDL, model. Baek (2021) highlighted the superiority of the QARDL model over the NARDL model in capturing location asymmetries at different quantiles of distribution. Uche and Effiom (2021) demonstrated the usefulness of the QARDL model in capturing locational asymmetries in exchange rate volatility as a determinant of capital flight in Nigeria.

Our study aims to address the gaps observed in the literature by applying the QARDL model to investigate the impact of exchange rate volatility on trade between South Africa and the US across 22 industries. Previous studies in South Africa have primarily focused on aggregate or sectoral levels, while this study delves into industry-level trade, reducing product aggregation bias. Additionally, while some international literature has examined the impact of currency risk on bilateral industry trade items, previous studies have only focused on one trading partner, introducing country aggregation bias. Lastly, the study utilizes the advanced QARDL model to explore short-run and long-run cointegration effects of exchange rate volatility on trade at different quantile distributions, incorporating the quantile regression model to capture location asymmetries.

Methodology

BASELINE FUNCTIONAL REGRESSIONS

To investigate the industry-level relationship between exchange rate volatility and export/import trade, we use the following Marshall-Lerner type export and import functions augmented with exchange rate volatility variable, i.e.

$$X = f(Y^d_{i,j}, Y^f_{i,j}, ERV_{i,j}) \tag{1}$$

$$M = f(Y^d_{i,j}, Y^f_{i,j}, ERV_{i,j}) \tag{2}$$

where X(M) is the value of exports (imports) of industry i to the trading partner j, Y^d is real domestic income, and Y^f is the foreign income, whereas ERV is the exchange rate volatility which is unobservable and extracted as the conditional volatility of following the GARCH (1,1) model fitted to the real exchange rate (RER):

$$RER_{it} = \mu + \theta RER_{it-1} + \varepsilon_t \tag{3}$$

$$h^2_{it} = \omega + \alpha\varepsilon^2_{it-1} + \rho h^2_{it-1}, \tag{4}$$

where α and ρ are the ARCH and GARCH parameters which are non-negative shocks and persistent parameters, and the conditional variance, h^2_{it} measures the volatility of each equity return.

TABLE 1 Summary of Related Literature

Author	Country	Period	Method	Results
Bahmani-Oskooee and Ltaifa (1992)	86 countries	1973-1980	POLS	-ve effect on exports
Bahmani-Oskooee and Payesteh (1993)	G7 and 6 emerging countries	1973:q1 – 1990:q4	E-G cointegration	Insig. for imports and exports
Bahmani-Oskooee (1996)	6 emerging economies	1973:q1 – 10090:q2	VECM	-ve for imports and exports
Sauer and Bohara (2001)	91 countries	1973 – 1979	FE and RE models	-ve effect for full and African samples
Arize, Malindretos, and Kasibhatla (2003)	10 LDC	1973:q2 – 1998:q1	VECM	+ve effect on exports
Bah and Amusa (2003)	South Africa	1990:q1 – 2000:q4	ARCH and GARCH	-ve effect
Todani and Munyama (2005)	South Africa	1980:q1 – 2004:q4	ARDL and GARCH	+ve impact for total and insignificant for goods, services, gold exports.
Kargbo (2006)	South Africa	1960-2004	VECM	-ve impact of South Africa agriculture imports and exports
Takaendesa, Tsheole, and Aziakpono (2006)	South Africa	1992:q1 – 2004:q4	VECM	-ve effect on exports
Mukherjee and Pozo (2009)	214 countries	1948-2000	Parametric and Semiparametric gravity model	-ve impact of volatility on trade balance
Ozturk and Kalyoncu (2009)	6 countries	1980-2005	E-G technique	-ve for South Africa
Omojimite and Akpokodje (2010)	8 CFA and 8 non-CFA countries	1986-2006	FE and GMM	-ve impact on imports and exports for all samples
Olayungbo, Yinusa, and Akinlo (2011)	40 African countries	1986-2005	POLS and GMM	+ve effect on total, primary and manufacturing trade for non-ECOWAS countries
Sekantsi (2011)	South Africa	Jan 1995 – Feb 2007	ARDL and GARCH	-ve
Ekanayake, Thaver, and Plante (2012)	South Africa	1980:q1 -2009:q4	DOLS and ARDL	+ve effect on both imports and exports

Musila and Al-Zyoud (2012)	42 African countries	1998 – 2007	Gravity model	-ve effect on imports and exports
Nyahokwe and Ncwadi (2013)	South Africa	2000-2010	VECM and GARCH	Insig.
Serenis and Tsounis (2014)	3 African countries	1973q1 – 1990q1	Sd moving average log of exchange rate and VECM	+ve relationship on exports
Aye et al. (2015)	South Africa	1986q4-2013q2	SVAR and GARCH-M	-ve impact on exports
Ishimwe and Ngalawa (2015)	South Africa manufacturing exports	2009q1 – 2014q4	ARDL	+ve effect on manufacturing exports
Vieira and MacDonald (2016)	106 countries	2000-2011	GMM	-ve (+ve) effect on exports (imports)
Meniago and Eita (2017)	39 SSA countries	1995-2012	FE and RE	-ve effect on both imports and exports
Senadza and Diaba (2017)	40 African countries	1993-2014	PMG	Insig. effect on exports
Bahmani-Oskooee and Gelan (2018)	12 African counties	1971q1 – 2015q4	ARDL	+ve for imports and insig. for exports
Bahmani-Oskooee and Arize (2020)	13 African countries	1973:q1 – 2015:q4	NARDL and GARCH	-ve effect for positive (negative) partition in exports (imports)
Dada (2021)	17 African countries	2005-2017	NARDL	-ve effect at both positive and negative partitions
Anyikwa and Domela (2022)	South Africa	2009:m01 – 2019:m12	NARDL	-ve (+ve) effect on positive (negative) partition
Ekanayake and Dissanayake (2022)	BRICS	1993:q1 – 2021:q2	FMOLS, DOLS, ARDL	Insig. for South Africa

BASELINE ARDL MODEL

We employ the autoregressive distributed lag (ARDL) model proposed by Pesaran, Shin, and Smith (2001) to estimate the empirical regressions (1) and (2), which capture both short- and long-run cointegration relationships between the time series. The ARDL model offers several empirical advantages, including flexibility in accommodating a mix of I(0) and I(1) variables, suitability for small sample sizes, and unbiased estimates of long-run coefficients even when some regressors are endogenous (Pesaran, Shin, and Smith 2001). Our baseline ARDL model is concisely defined as follows:

$$Y_t = \alpha_0 + \sum_{i=0}^{p} \beta_1 Y_{t-i} + \sum_{i=0}^{q} \beta_2 X_{t-i} + \gamma_1 Y_{t-1} + \gamma_2 X_{t-1} + \quad + \varepsilon_i \tag{5}$$

where Δ represents the differences operator, α denotes the intercept, β's and γ's are the short-run and long-run model coefficients, respectively, and ε represents the error term. We begin the modelling process by conducting a bounds test for cointegration, which involves testing the following null hypothesis:

$$\gamma_1 = \gamma_2 = 0 \tag{6}$$

against the alternative hypothesis:

$$\gamma_1 \neq \gamma_2 \neq 0 \tag{7}$$

To test these hypotheses, we employ F-statistics and compare them to lower-bound and upper-bound critical values provided by Pesaran, Shin, and Smith (2001). If the estimated F-statistics exceed the upper-bound critical value, we conclude the presence of cointegration effects. Conversely, if the F-statistics fall below the lower-bound critical value, we reject the existence of cointegration. In cases where the F-statistics lie between the lower and upper bounds, the test results are inconclusive.

Once cointegration effects are confirmed, we proceed to estimate the long-run regression. The long-run coefficients, computed as $\psi_1 = \gamma_2/\gamma_1$ and $\psi_2 = \gamma_3/\gamma_1$, are derived from this estimation. Finally, we derive the short-run and error correction form by extracting the error term from the long-run regression equation, resulting in the following error correction model:

$$Y_t = \alpha_0 + \sum_{i=0}^{p} \beta_1 Y_{t-i} + \sum_{i=0}^{q} \beta_2 X_{t-i} ECT_{t-1} + \varepsilon_i, \tag{8}$$

where ECT represents the error correction term, which measures the speed of reversion back to equilibrium following a system shock. It is assumed to be negative and statistically significant. Additionally, Pesaran, Shin, and Smith (2001) consider the t-statistics of the ECT as an additional test for cointegration in the ARDL model.

QARDL MODEL

While the ARDL model is recognized for its versatility in capturing long-run and short-run cointegration relationships among time series, it lacks the ability to incorporate location asymmetries. To overcome this drawback, we employ the QARDL model introduced by Cho, Kim, and Shin (2015), which expands upon the conventional ARDL model by integrating the quantile regression approach proposed by Koenker and Bassett (1978). Our baseline QARDL model can be represented as follows:

$$Y_t = \alpha_0(\tau) + \sum_{i=0}^{p} \phi_i(\tau) Y_{t-i} + \sum_{i=0}^{p} {}^{*}\phi_i(\tau) X_{t-i} + \varepsilon_{i_t}(\tau), \tag{9}$$

where Y_{it} is the dependent variable, trade, and X_{it} is the compact set of distributive lag covariates. We further re-specify equation (8) as the following compact regression:

$$Y_t = \alpha_0(\tau) + \sum_{i=0}^{q-1} W'_{t-i}\delta_j(\tau) + X'_t\gamma(\tau) + \sum_{i=0}^{q} \phi_i(\tau) Y_{t-i} + \varepsilon_{i_t}(\tau), \tag{10}$$

where

$$\gamma(\tau) = \sum_{i=0}^{q-1} W'_{t-j}\theta_j(\tau), W_t = \Delta X_t, \text{and } \delta_j(\tau) = -\sum_{i=0}^{p} {}^{*}\phi_i(\tau) X_{t-i}.$$

Following Koenker and Bassett (1978), the conditional mean function of Y on X is given as:

$$\min_{\beta} [\theta \sum |Y_t - X_t\beta| + (1+\theta) \sum |Y_t - X_t\beta|]$$
$$\{t{:}\, FS_t \geq X_t\beta\}\{t{:}\ FS_t < X_t\beta\}, \tag{11}$$

where $\{Y, t = 1, 2\ldots, T\}$ represents a random sample of the regression process. $Y = {}_t + X_t\beta$, with a conditional distribution function of $F_{Y/X}(y) = F(Y_t \leq trade) = F(Y_t - X_t\beta)$, and $\{X_{t,} t = 1, 2\ldots, T\}$ is a sequence of known design matrices. The θ^{th} regression quantile, Q_(Y/X)(θ), where 0 < θ < 1, denotes any solution to the minimizing problem, and β_θ represents the solution from which the θ^{th} conditional quantile

$Q_{Y/X}(\theta) = x\beta_\theta$. After deriving the estimates from the baseline QARDL regression, we can compute the long-run estimator as:

$$\beta(\tau) = \gamma(\tau)(1 - \sum_{i=0}^{p} {}^{*}\phi_i(\tau) - 1. \tag{12}$$

Furthermore, the short-run and error correction models are estimated as

$$\Delta Y_t = \alpha_0(\tau) + \zeta_*(\tau)(Y_{t-i} - \beta(\tau)'X_{t-i}) + \sum_{i=0}^{p-1} \phi_i(\tau)\Delta Y_{t-i} + \sum_{i=0}^{p} {}^{*}\phi_i(\tau)\Delta X_{t-i} + U_t(\tau), \tag{13}$$

where $(Y_{t-i} - \beta(\tau)'X_{t-i})$ is the quantile error correction term.

Empirical Data

The study utilizes a dataset spanning from 1994:q1 to 2022:q4 on a quarterly frequency. Data for the exports (X) and imports (M) for 22 industries were collected from Quantec (https://www.quantec.co.za/). The GDP growth rate for China and the US (Y^f) were obtained from the Federal Reserve Economic Data (FRED) database (https://fred.stlouisfed.org/). The South African GDP growth rate (Yd) and the real exchange rate (RER) were collected from the South African Reserve Bank (SARB) online dataset (https://www.resbank.co.za/en/home/what-we-do/statistics/releases/online-statistical-query). To measure exchange rate volatility, the conditional volatility of a GARCH model fitted on the RER was used as a proxy, following the conventional literature. All data were logged for empirical analysis.

Tables 2 and 3 present the summary statistics and unit root tests for the time series of Chinese and American trade, respectively. These tables report the average volume, standard deviation, and unit root test results. The statistics help identify South Africa's main export and import industries based on trade volume. For China, the top exports include mineral products, iron and steel, chemicals, wood pulp and paper, and textiles, while the top imports consist of machinery, textiles, iron and steel, chemicals, footwear, plastics and rubber, stone and glass, vehicles, aircraft, and vessels, as well as photographic and medical equipment. For the US, the main export items are precious metals, iron and steel, chemicals, vehicles, machinery, and mineral products, while the main imports include machinery, vehicles, aircraft, and vessels, photographic and medical equipment, mineral products, chemicals, plastics and rubber, iron and steel, and wood pulp and paper. These top trade products

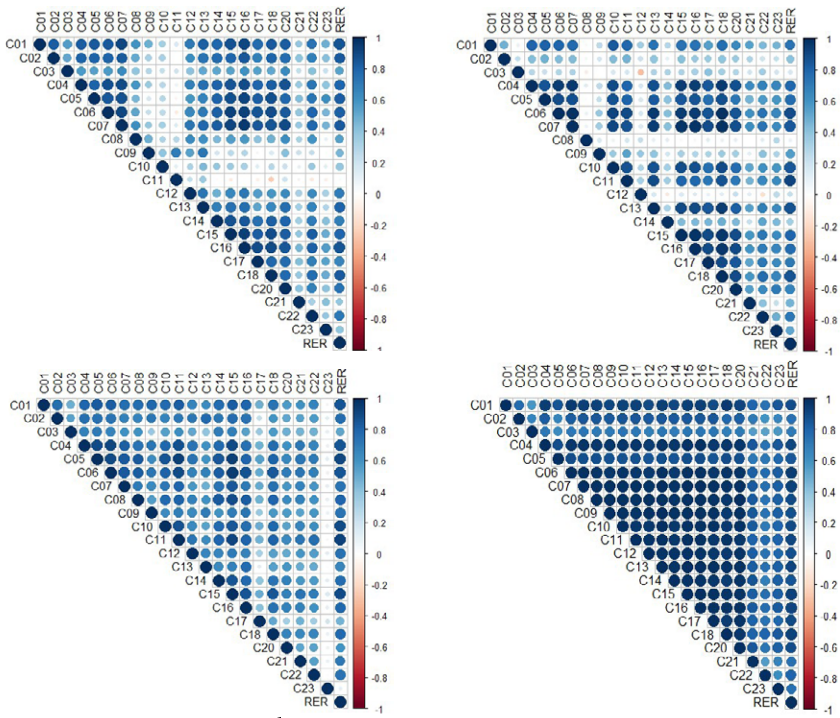

FIGURE 1 Heatmap Correlation Matrix

NOTES top right: correlation between ERV and US exports, top left: correlation between ERV and US imports, bottom left: correlation between ERV and China exports, bottom right: correlation between ERV and China imports.

align with findings from previous studies by Amusa and Fadiran (2019) and Bahmani-Oskooee and Gelan (2020), which examined the disaggregated J-curve for South Africa and the US at the industry level. Lastly, the ADF unit root tests, conducted on the first differences of the series, indicate that none of the variables exhibit an integration order higher than I(1), which is a requirement for using the ARDL and QARDL models.

Figure 1 presents a heatmap-coloured correlation matrix between exchange rate volatility and exports to China, imports from China, exports to the US, and imports from the US. The observed colour contours, predominantly blue, suggest a positive correlation between exchange rate volatility and most trade items, except for C11 (textiles) in exports to the US, C08 (raw hides & leather) in imports from the US, and C23 (equipment components) in exports to China, which exhibit a lack of correlation. However, these results are considered preliminary, and a more formal analysis is presented in the subsequent section of the paper.

TABLE 2 Descriptive Statistics (China)

Code	Industries	Exports Mean	Std. Dev	JB (p-value)	ADF	Imports Mean	Std. Dev	JB (p-value)	ADF
01	Live animals	16.680	1.8720	0.000	9.15***	17.896	1.543	0.000	−14.04***
02	Vegetables	16.285	2.825	0.000	10.18***	18.31	1.185	0.033	−11.73***
03	Animal or vegetable fats	13.513	2.392	0.000	9.27***	13.831	1.931	0.000	−11.78***
04	Prepared foodstuffs	16.891	2.4827	0.000	10 33***	17.946	2.161	0.000	−10.13***
05	Mineral products	21.543	2.192	0.001	8.52***	18.925	1.154	0.223	−12.40***
06	Chemicals	18.608	1.476	0.000	4.52***	20.224	1.671	0.024	−13.68***
07	Plastics & rubber	16.807	2.616	0.000	5.22***	19.620	1.980	0.005	−13.16***
08	Raw hides & leather	16.504	2.486	0.000	8.66***	18.786	1.363	0.005	−27.75***
09	Wood products	14.861	2.898	0.000	8.79***	17.526	1.632	0.001	−15.50***
10	Wood pulp & paper	18.208	2.296	0.000	3.26***	17.969	2.036	0.003	−12.61***
11	Textiles	18.420	1.176	0.024	3.92***	20.780	1.594	0.001	−9.82***
12	Footwear	12.183	3.181	0.000	9.16***	20.148	1.285	0.001	−11.27***
13	Stone & glass	15.968	1.783	0.000	9.36***	19.213	1.579	0.003	−13.61***
14	Precious metal	17.049	3.859	0.000	6.96***	16.837	1.981	0.000	−13.30***
15	Iron & steel	20.459	2.027	0.000	9.96***	20.319	1.833	0.005	−11.17***
16	Machinery	17.837	1.724	0.000	8.28***	21.936	1.948	0.002	−10.51***
17	Vehicles, aircraft & vessels	17.023	1.627	0.000	12.57***	19.237	2.076	0.002	−14.08***
18	Photographic & medical equipment	14.274	2.411	0.000	7.76***	19.362	1.463	0.003	−15.64***
20	Toys & sports apparel	13.010	1.990	0.000	4.13***	20.097	1.557	0.002	−33.07***
21	Works of art	12.662	2.299	0.000	9.29***	14.081	1.517	0.000	−11.41***
22	Other unclassified goods	13.842	2.987	0.001	4.94***	15.383	3.832	0.023	−6.91***
23	Equipment components	11.138	2.732	0.000	6.03***	17.961	2.638	0.000	−9.76***
	Real GDP (South Africa)	13.694	0.219	0.003	−12.4***	13.694	0.219	0.003	−12.46***
	Real GDP (United States)	29.537	0.996	0.012	−3.311*	29.537	0.996	0.012	−3.311*
	ERV	102.355	59.43	0.056	−8.75***	122.355	59.43	0.056	−8.751***

NOTES ***, **, * represent 1%, 5%, and 10%, significance levels, respectively. Critical values for ADF unit root test are −3.51 (1%), −2.89 (5%) and −1.94 (10%).

TABLE 3 Descriptive Statistics (USA)

		Exports				Imports			
Code	Industries	Mean	Std.Dev	JB(p-value)	ADF	Mean	Std.Dev	JB(p-value)	ADF
01	Live animals	17.839	0.729	0.000	-11.5^{***}	17.783	1.214	0.000	-9.41^{***}
02	Vegetables	18.602	1.308	0.000	-19.1^{***}	18.946	0.65	0.000	-11.21^{***}
03	Animal or vegetable fats	13.382	1.907	0.000	-10.0^{***}	15.912	0.906	0.000	-11.05^{***}
04	Prepared foodstuffs	18.951	0.987	0.000	-13.7^{***}	18.792	0.775	0.000	-10.674^{***}
05	Mineral products	20.27	1.092	0.001	-10.7^{***}	19.675	0.946	0.001	-11.36^{***}
06	Chemicals	20.703	0.783	0.000	-9.10^{***}	21.028	0.734	0.000	-10.74^{***}
07	Plastics & rubber	18.073	0.852	0.000	-9.5^{***}	19.823	0.709	0.000	-9.27^{***}
08	Raw hides & leather	17.395	0.348	0.000	-10.3^{***}	15.681	0.625	0.000	-10.20^{***}
09	Wood products	16.524	1.045	0.000	-9.59^{***}	17.497	0.328	0.000	-10.12^{***}
10	Wood pulp & paper	17.962	0.497	0.000	-10.2^{***}	19.246	0.422	0.000	-11.50^{***}
11	Textiles	18.49	0.687	0.000	-10.6^{***}	18.285	0.417	0.024	-12.92^{***}
12	Footwear	15.666	0.612	0.000	-11.2^{***}	15.827	0.495	0.000	-12.50^{***}
13	Stone & glass	17.383	0.713	0.000	-10.3^{***}	18.513	0.963	0.000	-11.073^{***}
14	Precious metal	21.411	1.555	0.000	-8.2^{***}	17.642	1.153	0.000	-9.52^{***}
15	Iron & steel	21.215	0.795	0.001	-8.8^{***}	19.375	0.632	0.000	-10.93^{***}
16	Machinery	20.314	1.002	0.000	-10.5^{***}	21.843	0.546	0.000	-9.64^{***}
17	Vehicles, aircraft & vessels	20.891	1.337	0.000	-8.73^{***}	21.141	0.88	0.000	-11.12^{***}
18	Photographic & medical equipment	17.573	0.919	0.000	-9.16^{***}	20.439	0.712	0.000	-9.23^{***}
20	Toys & sports apparel	17.309	0.645	0.000	-9.94^{***}	18.57	0.672	0.000	-10.43^{***}
21	Works of art	16.814	1.939	0.000	−1.93	15.072	1.371	0.000	-7.98^{***}
22	Other unclassified goods	10.205	7.853	0.000	-9.91^{***}	11.594	7.834	0.000	-7.27^{***}
23	Equipment components	7.55	5.811	0.000	-12.7^{***}	18.277	4.499	0.000	-7.03^{***}
	Real GDP (South Africa)	13.695	0.22	0.000	-10.0^{***}	13.695	0.22	0.000	-10.02^{***}
	Real GDP (United States)	9.61	0.18	0.000	-8.18^{***}	9.61	0.18	0.000	-8.18^{***}
	ERV	102.355	59.43	0.056	-8.75^{***}	122.355	59.43	0.056	-8.751^{***}

NOTES ***, **, * represent 1%, 5%, and 10%, significance levels, respectively. Critical values for ADF unit root test are −3.51 (1%), −2.89 (5%) and −1.94 (10%).

Analysis of Results

The results obtained from the estimation of the full regressions in this study are voluminous, and the complete set of results is available upon reasonable request. In this section, we focus on the reported sign and significance of the long-run coefficient estimates of the exchange rate volatility variable in the import (table 4) and export (table 5) functions for China and the US. For comparative purposes, we present the results of the ARDL and QARDL models, with specific attention to the estimates for the 10th, 30th, 50th, 70th, and 90th quantiles.

A preliminary examination of the baseline ARDL regressions reveals that most industries are either insignificantly or positively affected by exchange rate volatility in terms of trade, with only a few industries experiencing a negative effect. Out of the 22 industries examined, the exchange rate volatility variables in the ARDL regressions indicate the following:

- Positive coefficients for: i) 8 export items to the US (prepared foodstuffs, wood products, footwear, stone & glass, machinery, photographic & medical equipment, live animals, vegetables); ii) 7 export items to China (iron & steel, plastics & rubber, wood products, other unclassified goods, machinery, vehicles, aircraft & vessels, mineral products); iii) 11 import items to the US (iron & steel, chemicals, plastics & rubber, wood products, wood pulp & paper, textiles, footwear, stone & glass, works of art, photographic & medical equipment, vegetables); iv) 8 import items to China (iron & steel, plastics & rubber, wood products, other unclassified goods, machinery, vehicles, aircraft & vessels, photographic & medical equipment).
- Insignificant coefficients for: i) 12 export items to the US (iron & steel, chemicals, plastics & rubber, wood pulp & paper, textiles, works of art, other unclassified goods, vehicles, aircraft & vessels, animal or vegetable fats, raw hides & leather, mineral products); ii) 14 export items to China (prepared foodstuffs, chemicals, wood pulp & paper, textiles, footwear, stone & glass, toys & sports apparel, works of art, equipment components, live animals, vegetables, animal or vegetable fats, raw hides & leather, precious metals); iii) 10 import items to the US (prepared foodstuffs, toys & sports apparel, other unclassified goods, equipment components, machinery, vehicles, aircraft & vessels, live animals, raw hides & leather, precious metals, mineral products); iv) 14 import items to China (prepared foodstuffs, chemicals, wood pulp & paper, textiles, footwear, stone

& glass, toys & sports apparel, works of art, equipment components, live animals, vegetables, animal or vegetable fats, raw hides & leather, precious metals).

- Negative coefficients for: i) 3 export items to the US (toys & apparel, raw hides & leather, precious metals); ii) 1 export item to China (live animals); iii) 3 import items to the US (works of art; animal or vegetable fats; vegetables); iv) 1 import item to China (live animals).

Overall, the results from the ARDL model suggest that only a few export and import items to both the US and China are not adversely affected by currency risk, with more positive and negative coefficients observed for trade items with the US and more insignificant estimates for trade items with China.

The findings from the quantile regressions align with those from the ARDL regressions and further reveal location asymmetries in a number of industries where the ARDL regressions found insignificant estimates. In such cases, significant estimates are observed at other quantiles away from the mean estimators. This occurs for 3 export items to the US (wood pulp & paper, works of art, mineral products), 9 export items to China (prepared foodstuffs, chemicals, wood pulp & paper, textiles, stone & glass, toys & sports apparel, works of art, equipment components, raw hides & leather), 3 import items from the US (equipment components, vehicles, aircraft & vessels, precious metals), and 8 import items from China (prepared foodstuffs, wood pulp & paper, textiles, footwear, toys & sports apparel, works of art, equipment components, raw hides & leather). After accounting for these location asymmetries, it is observed that most export and import trade items with China are positively affected by currency volatility, and to a lesser degree with US trade items.

All in all, our findings generally contradict most previous South African-based studies and we provide two reasons for this. Firstly, we argue that many previous studies included South Africa along with other countries that have different country-specific characteristics. This approach creates an aggregation bias in the panel estimates when generalized for all countries under investigation (Bahmani-Oskooee and Ltaifa 1992; Bahmani-Oskooee 1996; Sauer and Bohara 2001; Mukherjee and Pozo 2009; Omojimite and Akpokodje 2010; Musila and Al-Zyoud 2012; Vieira and MacDonald 2016; Meniago and Eita 2017; Bahmani-Oskooee and Arize 2020; Dada 2021). Secondly, we note that most previous studies conducted in South Africa have utilized cointegration techniques such as FMOLS, DOLS, E-G, and VECM, which can produce biased estimates if the series are not mutually cointegrated and are sensitive to sample size biasedness (Pesaran, Shin, and Smith 2001). Interestingly, we observe that previous studies that employed the ARDL model, similar to our own study, tend to produce similar positive estimates on the exchange rate volatility variable (Todani and Munyama 2005; Ekanayake, Thaver, and Plante 2012; Ishimwe and Ngalawa 2015; Bahmani-Oskooee and Gelan 2018).

Regarding the practical and policy implications of our findings, we highlight two main points. Firstly, we suggest that the flexible exchange rate regime maintained by the SARB has not been detrimental to trade with South Africa's top trading partners. Contrary to the implications drawn from previous studies, we argue that the SARB does not need to intervene in currency markets to smooth out exchange rate fluctuations. Secondly, our findings indicate that firms are willing to undertake risk under currency uncertainty which, in turn, may reflect the high levels of confidence that trading firms have in the domestic forward markets. Furthermore, our QARDL estimates indicate that this confidence is more pronounced in the case of China compared to the US, possibly due to the success of the bilateral currency swap agreement signed between South Africa and China in 2015.

Conclusions

We examined the relationship between exchange rate volatility and export/import trade between South Africa and its top trading partners from 1994:q1 to 2022:q4, using ARDL and QARDL models. Conventional economic theory suggests that flexible exchange rate regimes create currency risk for trading firms, which can have a negative impact on export and import volumes. Moreover, most empirical literature conducted in South Africa supports the idea of an inverse relationship between exchange rate volatility and trade. However, a cursory examination of the time series data reveals that while exchange rate volatility has been increasing since 1994, particularly after the adoption of the inflation targeting regime in 2001, total export and import trade volumes between South Africa and its major trading partners have also been increasing. This observation prompts us to re-evaluate the relationship at a disaggregated level, considering specific products and trading partners using the QARDL model as a novel econometric technique used to capture location asymmetries and apply these methods to more extensive and recent data.

TABLE 4 ARDL and QARDL Long-run Estimates for Export Items

Trade Sectors	Trade Industries	China						US					
		ARDL	QARDL					ARDL	QARDL				
			0.10	0.30	0.50	0.70	0.90		0.10	0.30	0.50	0.70	0.90
Manufacturing Sector	Prepared foodstuffs	insig	insig	insig	insig	+	insig	+	insig	insig	insig	insig	insig
	Iron & steel	+	+	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig
	Chemicals	insig	insig	insig	+	+	+	insig	insig	insig	insig	insig	insig
	Plastics & rubber	+	insig	insig	insig	+	insig	insig	insig	insig	insig	insig	insig
	Wood products	+	+	insig	insig	insig	+	+	insig	+	insig	insig	insig
	Wood pulp & paper	insig	+	insig	insig	insig	insig	insig	insig	insig	+	insig	insig
	Textiles	insig	insig	+	insig	insig	+	insig	insig	insig	insig	insig	insig
	Footwear	insig	insig	insig	+	+	insig	+	insig	insig	+	insig	insig
	Stone & glass	insig	insig	insig	insig	+	insig	+	+	insig	insig	insig	insig
	Toys & sports apparel	insig	+	+	+	insig	insig	-	-	-	-	insig	-
	Works of art	insig	insig	+	+	insig	insig	insig	insig	+	+	+	insig
	Other unclassified goods	+	insig	+	insig	insig	insig	insig	insig	insig	insig	insig	insig
	Equipment components	insig	insig	insig	insig	insig	+	insig	insig	insig	insig	insig	insig
	Machinery	+	+	+	+	+	+	+	insig	+	insig	insig	insig
	Vehicles, aircraft & vessels	+	insig	+	+	+	insig	insig	insig	insig	insig	insig	insig
	Photographic & medical equipment	+	insig	+	+	+	+	+	insig	insig	+	insig	insig
Agricultural Sector	Live animals	insig	insig	insig	insig	insig	insig	+	insig	insig	+	insig	insig
	Vegetables	insig	insig	insig	insig	insig	insig	+	+	insig	insig	insig	insig
	Animal or vegetable fats	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig
	Raw hides & leather	insig	insig	insig	+	+	+	insig	insig	insig	insig	insig	insig
Mineral Sector	Precious metals	insig	insig	insig	insig	insig	insig	-	insig	-	-	insig	insig
	Mineral products	+	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig	-

TABLE 5 ARDL and QARDL Long-run Estimates for Import Items

TRADE SECTORS	TRADE INDUSTRIES	China						US					
		ARDL	QARDL					ARDL	QARDL				
			0.10	0.30	0.50	0.70	0.90		0.10	0.30	0.50	0.70	0.90
Manufacturing Sector	Prepared foodstuffs	insig	insig	insig	insig	+	insig	insig	insig	insig	insig	insig	insig
	Iron & steel	+	+	insig	insig	insig	insig	+	insig	insig	insig	insig	insig
	Chemicals	insig	insig	insig	+	+	+	+	+	insig	insig	insig	insig
	Plastics & rubber	+	insig	insig	insig	+	insig	+	insig	insig	+	insig	insig
	Wood products	+	+	insig	insig	insig	+	+	insig	insig	insig	insig	insig
	Wood pulp & paper	insig	+	insig	insig	insig	insig	+	insig	insig	insig	insig	-
	Textiles	insig	insig	+	insig	insig	+	+	insig	+	+	insig	insig
	Footwear	insig	insig	insig	+	+	insig	+	insig	insig	insig	insig	insig
	Stone & glass	insig	insig	insig	insig	+	insig	+	insig	insig	insig	-	-
	Toys & sports apparel	insig	+	+	+	insig	insig	insig	insig	insig	insig	insig	insig
	Works of art	insig	insig	+	+	insig	insig	+	insig	insig	+	insig	insig
	Other unclassified goods	+	insig	+	insig	insig	insig	insig	insig	insig	insig	insig	insig
	Equipment components	insig	insig	insig	insig	insig	+	insig	insig	insig	insig	insig	+
	Machinery	+	+	+	+	+	+	insig	insig	insig	insig	insig	insig
	Vehicles, aircraft & vessels	+	insig	+	+	+	insig	insig	insig	insig	insig	insig	+
	Photographic & medical equipment	+	insig	+	+	+	+	+	insig	insig	insig	+	+
Agricultural Sector	Live animals	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig
	Vegetables	insig	insig	insig	insig	insig	insig	+	+	insig	insig	insig	insig
	Animal or vegetable fats	insig	insig	insig	insig	insig	insig	-	insig	insig	-	-	insig
	Raw hides & leather	insig	insig	insig	+	+	+	insig	insig	insig	insig	insig	insig
Mineral Sector	Precious metals	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig	+	insig
	Mineral products	+	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig	insig

The results obtained from the conventional ARDL model provide little evidence of adverse effects of exchange rate volatility on most export and import items. In fact, most industries show either insignificant or positive effects. Moving beyond the ARDL models, our estimation of the QARDL models reveals the presence of hidden positive cointegration relationships at quantiles beyond the mean and median distributions, particularly for export items to China and import items from China. This finding suggests that exchange rate volatility has a more positive impact on trade with China compared to trade with the United States. Theoretically, this can be attributed to the willingness of traders to undertake currency risk in their trade activities with China and highlights the success of currency swap agreements signed between South Africa and China. This raises an important policy question as to whether a currency swap agreement with the United States could potentially improve trade relations between the two countries.

Given the QARDL model's demonstrated efficacy in identifying hidden cointegration relationships among time series variables, we recommend for future research studies to replicate our empirical approach for different countries and their respective trading partners. Although there is a growing consensus regarding the nonlinear nature of this association, existing scholarly literature has predominantly concentrated on the NARDL model, which discerns the effects of ascending and descending levels of currency volatility on trade. In contrast, the QARDL model departs from this paradigm by highlighting spatial dissimilarities. Our investigation has demonstrated that this framework can be employed to discern the impact of currency volatility across various quantile distributions, encompassing both extremely low and extremely high degrees of volatility.

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