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Article

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Examining the currency-equity nexus in frontier African markets: a wavelet-based approach

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ABSTRACT

This research examines the co-movement between exchange rates and equity prices in a selection of frontier African markets (Ghana, Mauritius, and Tunisia). The analysis encompasses data from 4 January 2010 to 31 March 2023. Employing advanced econometric techniques, the study investigates the interconnectedness of frontier markets and the direction of volatility spillovers between currency and equity markets. Our findings reveal that Ghana, Mauritius, and Tunisia are characterized by strong sensitivity to price variations and high volatility. Moreover, significant volatility transmission and spillover effects are observed across the selected markets. Finally, the analysis finds the presence of non-linear dynamics in both the time and frequency domains. In light of these findings, policymakers and investors should incorporate the potential for abrupt and persistent changes, as well as volatility spillovers, into their decision-making processes when considering investments in the Ghana, Mauritius, and Tunisia markets. This research is anticipated to contribute to the development of more robust investment strategies for managing risk exposure within diversified portfolios.

IMPACT STATEMENT

This study investigates the relationship between currency and equity markets in frontier African economies using a wavelet-based approach. Focusing on Ghana, Mauritius, and Tunisia, it uncovers significant volatility spillovers and complex, time-varying dynamics. The findings reveal non-linear market behaviors, emphasizing the need for adaptive investment strategies in these volatile regions. By offering deeper insights into the currency-equity nexus, the research provides valuable guidance for investors and policymakers, enabling more informed decision-making and the development of resilient strategies for managing risks in frontier African markets.

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1. Introduction

This study explores the co-movement between exchange rates and stock market performance in frontier African economies. We focus on three markets with significant capitalization which are Ghana, Mauritius, and Tunisia. We address the dearth of research on the impact of the currency-equity effect on the financial systems of selected countries. These countries were selected because they have the largest capitalization among frontier African economies Tunisia (\$7.2BN), Mauritius (\$7.8BN), and Ghana (\$7.5BN) (African Securities Exchanges Association (ASEA) and Oxford Business Group (OBG), 2022). An examination of the selected frontier economies (Mauritius, Tunisia, and Ghana) reveals recent depreciation episodes in their respective currencies (Mauritian rupee, Tunisian dinar, and Ghanaian cedi). Notably, these depreciations coincided with the most significant negative impact observed on their equity capital performance, particularly during the pandemic. The equity capital market fell about 21% for Mauritius, 9.1% for Tunisia, and 6.5% for Ghana according to the Oxford Business Group report (ASEA, 2022). Frontier African markets account for 60% of Sub-Saharan gross domestic product (GDP) and population (International Monetary

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Fund (IMF), 2023). A significant share (approximately two-thirds) of small, open economies in Sub-Saharan Africa and Northern Africa exhibit heightened vulnerability to exchange rate volatility. This vulnerability stems from different factors, including free-floating exchange rate regimes and dependence on external economic conditions, current account deficits, economic slowdowns, inflationary pressures, and rising interest rates. As a consequence, African economies face potential disruptions to their overall economic performance and equity stock market stability (Njindan lyke, 2017). These variations have intensified global risk aversion, prompting a flight to safe-haven assets and a decline in investment inflows toward frontier African markets. Consequently, despite their abundant natural resources, in frontier African countries, they continue to display a limited presence in global trade, foreign direct investment, and portfolio investment (Klagge & Zademach, 2018). The currencies of Sub-Saharan Africa's frontier economies have displayed a declining trend since the 2008/2009 global financial crisis. This decline has been expanded by recent events, including the COVID-19 pandemic and the Russia–Ukraine war, which have significantly affected critical sectors such as financial, supply chains, and energy markets (Agyei et al., 2022; Amewu et al., 2022). The increased vulnerability of frontier markets in Sub-Saharan and North Africa, represents an important section of the region's economic scope, highlighting the need for more investigation to bring understanding to the internal dynamics of African markets.

The multifaceted nature of the relationship between equity stock markets and currency markets is, as seen in existing empirical literature with a significant return of co-movement and volatility spillover, found in some emerging and frontier markets while others have examined the intricate dynamics between currency fluctuations and equity market performance in these volatile regions (Bouri et al., 2018, 2019, 2020; Tang & Yao, 2018).

Declines in currency prices have often resulted in the fall of stock prices as capital outflows increase while inflows fall alongside a decline in investor confidence (Ahmad et al., 2016; Alagidede & Panagiotidis, 2009; Patro et al., 2014). However, the effect and nature of the relationship vary from trade balances, foreign exchange reserves, and macroeconomic policies exerting their influence in some cases (Aloui et al., 2018; Aloui & Hkiri, 2014; Chkili & Nguyen, 2014). In the short- and long-term countries with strong fundamental policies have displayed strong comovements patterns (Balcilar et al., 2021). Also, stock prices are a contributing element in predicting changes in exchange rate prices with weak unidirectional asymmetric causal effect from exchange rate to stock prices (Xie et al., 2020). Coronado et al. (2021) found instantaneous spillovers across the returns for currency and stock markets with underlying portfolio diversification for investors to take advantage in the US market. Usman et al. (2022) found the local stock index and SP500 index contributed to the extreme shocks in currency returns. Furthermore, Chkili (2012) examined the time-varying relationship between exchange rates and stock returns in emerging markets, highlighting the impact of economic and financial crises. In a systematic review Obuya et al. (2024) found exchange rate volatility to have a positive effect on stock market returns in developed countries.

Moreover, other studies on BRICS, Asian, and some African economies have found the following; Aydin et al. (2023) found a relationship between exchange rates and stock prices for ASEAN and BRICS countries before COVID-19 confirming the results from Narayan et al. (2020) study on Japan. Using the wavelet analysis Mohamed Dahir et al. (2018) found that for BRICS countries a positive relationship exists for Brazil and Russia, a negative relationship for South Africa, and no relationship for China. In the work of Hussain et al. (2023) exchange rate volatility was found to be connected to stock return volatilities during pandemic-induced crises for Russia, India, Brazil, and South Africa with weak volatility connected from China to any of the other countries in the BRICS. Using nonlinear dynamic analysis on Asian countries found volatility effects were present between different asset markets, showing a bi-directional relationship between stock prices and exchange rates (Sakemoto, 2017). Again, in Turkey, a negative unidirectional relationship was found between the stock market and exchange rates however at different frequencies using the wavelet coherence approach (He et al., 2021). Hung (2019) examined central and eastern European countries' temporal significant financial contagion between stock markets and exchange rate markets using the GARCH-BEKK framework alongside the constant and dynamic conditional correlation (CCC and DCC) models. Kumar (2013) found a bi-directional volatility spillover between stock markets and exchange rates among IBSA countries. In Tanzania, stock prices have a unidirectional effect on exchange rates (John & Kisava, 2017). Mkhombo and Phiri (2023) that comovements between exchange rates and stock returns occur during periods of high inflation and lower interest rate movements. Xu et al. (2022) used advanced

econometric models to analyze the dynamic interactions between exchange rates, oil prices, and stock markets in emerging economies, revealing complex interdependencies and the impact of global risk factors. Nițoi et al. (2018) explored the time-frequency co-movement between stock markets and exchange rates in frontier markets, emphasizing the significance of global financial cycles and regional economic policies. Salisu et al. (2022) emerging markets volatility responds positively to geopolitical risk. Sui and Sun (2016) studied spillover effects between exchange rates and stock markets in emerging economies, emphasizing the impact of global economic uncertainty. Furthermore, Basher et al. (2012) investigated the dynamic interactions between exchange rates, oil prices, and stock markets in frontier markets, uncovering complex interdependencies and the effects of external shocks.

From empirical literature, comprehensive studies have explored currency and stock market volatility in developed, and emerging economies, and frontier markets in other regions whereas the focus on African Frontier markets remains limited (Jamil & Mobeen, 2021; Lee, 2009; Sayed & Charteris, 2022). Živkov et al. (2021) commendably identified the most liquid African stock markets and short-term volatility spillovers within select markets. However, their work does not delineate the optimal investment horizon for frontier African markets. This knowledge gap necessitates further investigation to identify the timeframe that maximizes investor returns within this asset class and how these markets respond to exchange rate fluctuations and global events.

Our paper addresses the gap by investigating the nexus between currency volatilities and selected individual frontier African equity markets (Ghana, Mauritius, Tunisia). We employ the continuous Morlet wavelet transform (CMWT) to examine the co-movements across different time scales (Omane-Adjepong & Dramani, 2018). This approach seeks to capture both time (variant and frequency) features which in turn provides an understanding of the linkages that exist within the selected individual economies. In using high-frequency data to examine very short-term to long-term horizons, the CMWT provides understating aiding in investment decision-making in the selected frontier African currency-equity markets. The findings from this study will equip investors with a profound thought of the dynamic relationship between exchange rates and stock market performance in frontier African economies. This knowledge will empower them to make informed investment decisions and potentially identify optimal entry or exit points within these markets.

The article is sectioned as follows: Section 2 presents the empirical methodology; Section 3 presents the empirical results. Section 4 presents a discussion of concluding remarks and gives implications of the key findings.

2. Empirical methodology

In applying the wavelet analysis, we first consider the linear and non-linear causal relationship between the currency and equity markets by using the Granger test (Granger, 1969) as a conventional method for testing parametric linear, time series model by estimating the conditional mean, and the Diks and Panchenko (2005, 2006), hereafter the DP test, to detect Granger non-causality which is more consistent and robust against other mean and non-linear variance techniques (see Akosah et al., 2020). We proceed further to employ the continuous wavelet transform to examine co-movement in the currency-equity market.

2.1. Linear granger causality framework

The Granger technique (Granger, 1969) is used to explore informational linkages between stock and currency markets. Given any two stationary data pairs, say ES_t and CU_t , say variable ES_t Granger causes CU_t linearly provided lags of ES_t offer useful information for explaining the current values of B_t , and vice versa. Where ES_t is equity markets and CU_t represent currency markets.

The bivariate Linear Granger causality is specified in a VAR system as follows:

$$ES_t = \varphi_1 + \sum_{i=1}^k \alpha_{1i} ES_{t-i} + \sum_{j=1}^k \beta_{1j} CU_{t-j} + \varepsilon_{1t} \quad (1)$$

$$CU_t = \varphi_2 + \sum_{i=1}^k \alpha_{2i} ES_{t-i} + \sum_{j=1}^k \beta_{2j} CU_{t-j} + \varepsilon_{2t} \quad (2)$$

where φ_1 and φ_2 are the constant terms of the system of the equation; α and β denote estimated coefficients; k is the optimal lag order based on the Akaike Information Criterion (AIC) and ε_{1t} and ε_{2t} represent residuals from the VAR model. Again, the null hypothesis for Eq. (1) states that changes in the price of equity stock markets do not Granger cause currency volatilities. In Eq. (2), currency volatilities do not Granger cause changes in the price of equity stock markets. Additionally, we employ the Wald test to examine the joint hypothesis for $\alpha_{1i} = 0$ and $\beta_{2j} = 0$.

However, due to the low power limitation that characterizes linear models when detecting non-linear informational linkages between variables, higher non-linear predictive power is often not captured by the linear model, thus we employ the non-linear model (Omane-Adjepong & Alagidede, 2019).

2.2. Non-linear granger causality

Among the various non-linear models, we employ the non-linear test by Diks and Panchenko (2005, 2006), hereafter the DP test, due to its consistency, flexibility, and robustness. This test is built on the HJ and initial nonparametric tests (Baek and Brock, 1992; Hiemstra and Jones, 1994). The DP test diminishes the issue of over-rejection rates that characterize the HJ test under the null hypothesis.

Our adoption of the D&P test is, thus, not misplaced as we denote the information set for the lags of ES_t and CU_t respectively as $C_{X,t}$ and $C_{Y,t}$ before time $t = 1$; and \sim the equivalent distribution (Diks & Panchenko, 2005, 2006). Consequently, we the modeling section of Bekiros and Diks (2008) with the replacement of X, Y, and Q for variables that represent our selected variables of interest we assume that A_t is said to Granger cause B_t provided that,

$$(CU_{t+1} \dots, CU_{t+k}) | (C_{X,1} \dots, C_{Y,k}) \sim (CU_{t+1} \dots, CU_{t+k}) | C_{X,1} \quad (3)$$

where k is an integer $k \geq 1$, representing the forecasting horizon. For the lag vectors $A_t^{l_r} = (ES_{t-l_r+1}, ES_t)$ and $CU_t^{l_s} = (CU_{t-l_s+1}, CU_t)$, given $(l_r + l_s \geq 1)$ we test the conditional independence using a determinate number of lags l_r and l_s Under a null hypothesis of:

$$H_0 : CU_{t+1} | (ES_t^{l_r} : CU_t^{l_s}) \sim CU_{t+1} | CU_t^{l_s} \quad (4)$$

We further reduce the two variable representations and use A, B, and W due to ease in modeling adopting the Bekiros and Diks (2008) model. Considering that the null hypothesis of Granger non-causality is an assertion about the invariant distribution of $(l_r + l_s + 1)$ dimensional vector $Q_t = (A_t^{l_r}, B_t^{l_s}, W_t)$ where the lead vector $W_{t=B_{t+1}}$, the time index is dropped and written as $Q = (A, B, W)$ (see Bekiros & Diks, 2008).

We set $l_r + l_s = 1$, and $k = 1$ and assume the trivariate in Q follows a continuous random variable. The null hypothesis of the non-causality in (4) may be redefined as a joint probability density function $f_{A,B,W}(a, b, w)$ with its marginal satisfying the following condition:

$$\frac{f_{A,B,W}(a, b, w)}{f_B(b)} = \frac{f_{A,B}(a, b)}{f_B(b)} * \frac{f_{B,W}(b, w)}{f_B(b)} \quad (5)$$

For every determinate value of b from our test, the continuous random A and W are independent conditioned on $Y = y$.

Therefore, under the revised null hypothesis H_0 ,

$$q = E[f_{A,B,W}(A, B, W)f_B(B) - f_{A,B}(A, B)f_{B,W}(B, W)] \quad (6)$$

The estimate of q is expressed based on the indicator function as:

$$T_n(\varepsilon) = \frac{(2\varepsilon)^{-m_A-2m_B-m_W}}{n(n-1)(n-2)} \sum_i \left[\sum_{k, k \neq i} \sum_{j \neq i} (I_{ik}^{ABW} I_{ij}^B - I_{ik}^{AB} I_{ij}^{BW}) \right] \quad (7)$$

Wherever, $I_{ij}^Q = I(|Q_i - Q_j| < \varepsilon)$, where $K = j$, is not excluded explicitly as they each contribute zero to the t-statistic (Broock et al., 1996).

We represent the local density estimators of a m_Q , variate as a random vector of Q at Q_i as

$$\hat{f}_Q(Q_i) = \frac{(2\varepsilon)^{m_Q}}{n-1} \sum_{ij \neq i}^Q \quad (8)$$

The test statistic reduces to:

$$T_n(\varepsilon) = \frac{(n-1)}{n(n-2)} \sum_i (\hat{f}_{A,B,W}(A_i, B_i, W_i) \hat{f}_B(B_i) - \hat{f}_{A,B}(A_i, B_i) \hat{f}_{B,W}(B_i, W_i)) \quad (9)$$

The appropriate sequence ε_n for bandwidth, values should have estimators and test statistics that are consistent and match the weighted average of the local contributions $\hat{f}_{A,B,W}(A, B, W) \hat{f}_B(B) - \hat{f}_{A,B}(A, B) \hat{f}_{B,W}(B, W)$ which tend to be zero in for the probability under the proposed null hypothesis.

Given that $m_A = m_B = m_W = 1$, to achieve a consistent test, the bandwidth is selected based on the sample size (see Powell & Stoker, 1996).

when, $\varepsilon_n = X_n^{-\beta}$ for a constant X to be positive ($X > 0$) and, ($\beta \in (0.25, 0.67)$), This will help to achieve an asymptotic and normally distributed t-statistic when the dependence between is absent for Q_i . We extend this to our time series following the Denker and Keller (1983) mixing conditions on the assumption that the covariances between the local density estimators are accounted for.

From the linear and non-linear Granger causality, the use of the VAR system allows for the extraction of linear predictive power leaving incremental predictive power that could account for the non-linear causality or predictive power in the series. On the other hand, the non-linear Diks and Panchenko (DP) test and Granger causality test face significant limitations with non-stationary time series data, prevalent in financial markets. The DP test, designed for detecting non-linear dependencies, struggles with structural breaks and varying volatility, often yielding false positives or inconclusive results. Similarly, the Granger causality test assumes stationarity, leading to misleading inferences when applied to non-stationary data, as it violates underlying statistical assumptions. These constraints underscore the necessity for more robust methods like wavelet-based strategies, which effectively handle non-stationarity by capturing localized time-frequency patterns, offering a more accurate analysis of financial time series. We, therefore, employ the wavelet approach as it captures the time and frequency features of our series and offers a robust technique that is useful in examining the non-stationary nature of time series. In comparing the wavelet approach to vector autoregression (VAR) models and dynamic conditional correlation (DCC) models respectively, we find that the VAR examines linear interdependencies over multiple time series while the DCC examines time-varying correlations underscoring the dynamics prevalent in the long-term linear relationships and dynamic correlations. Again, the wavelet technique considers abrupt changes and varying frequencies outperforming the VAR and DCC models which could lead to misleading conclusions due to the presence of trends, volatility, and structural breaks underpinning the data if not correctly examined. Ensuring that the true relationships are not obscured the wavelet approach thoroughly examines the data by identifying any underlying issues such as economic cycles, and market shocks among others, and accurately models, captures, and ultimately yields robust and reliable results.

2.3. Continuous wavelet transformation (CWT) and coherence

We employ the Morlet wavelet to examine the frequency and time-space behavior of the series due to the presence of high properties in the localized frequency and time (Aloui et al., 2018; Wu et al., 2020). We use the CWT by examining the variations in non-stationary variables across time and space. Firstly, we decompose the time series to ensure that localized time-frequency space and zero means are a function of wavelet transformation. We further extract the needed information from the local neighborhood using the series that has been decomposed.

The wavelet coherence (WC) is specified below as:

$$\varphi_{u,s}(t) = \frac{1}{\sqrt{s}} \psi\left(\frac{t-u}{s}\right) \psi(\cdot) \in L^2(\mathbb{R}) \quad (1)$$

We denote $\frac{1}{\sqrt{s}}$ as the stabilization element validating unit for the wavelet disparity. $||\psi_{u,s}(t)||^2 = 1$; u is the location boundary, which presents the exact location of the wavelet.

Where s is the expansion level located in the boundary, which determines the spread of the wavelet.

2.4. Morlet wavelet

$$\phi^M(t) = \frac{1}{\pi^{1/4}} e^{i\omega_0 t} e^{-t^2/2} \quad (2)$$

We denote the significant incidence of the wavelet by ω_0 as 6. The convolution on the discrete sequence, scaled, and translated wavelet used in the CWT is:

$$W_s(u, s) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \psi\left(\frac{t-u}{s}\right) dt \quad (3)$$

Extracting the wavelet $\psi(\cdot)$ on the time series, $W_s(u, s)$ is obtained.

Also, the main advantage lies in the CWT's ability to decompose the series and rebuild it under the function:

$$\begin{aligned} x(t) \in L^2() : x(t) &= \frac{1}{c_\psi} \\ \int_0^\infty \left[\int_0^\infty W_s(u, s) \psi_{u,s}(t) du \right] \frac{ds}{s^2}, s > 0 \end{aligned} \quad (4)$$

From Eq. (4), the power spectrum is examined using the adjusted measurement

$$||\chi||^2 = \frac{1}{c_\psi} \int_0^\infty \left[\int_{-\infty}^\infty |W_s(u, s)|^2 du \right] \frac{ds}{s^2}, s > 0 \quad (5)$$

In modeling out the red noise from the spectrum series background AR (1) provides the allowance. Based on the null hypothesis, the pockets found in the wavelet power spectrum (WPS) allow for the peaks to be examined to establish their significant levels.

The local WPS established from the distribution using the Monte Carlo simulation presents the individual time (n) and scale (s) (see Torrence and Webster, 1999).

$$D \left[\frac{W_n^x(s)^2}{\delta_x^2} < p \right] \Rightarrow \frac{1}{2} p_f \chi_v^2 \quad (6)$$

f is represented as p_f , the mean spectrum at Fourier frequency from the series. The wavelet scale is aligned with the Fourier frequently. ($s \approx 1/f$), $v=1$ is the real wavelet, and $v=2$ denotes the complex wavelet where δ_x^2 is the modified variable.

The behavior of time-frequency in the currency-equity market is investigated using the CWT to locate the common power between the series (Aloui et al., 2018). The region's location is found using the power of CWT to locate the co-movements in the time-frequency dynamics.

Using a specific variable series (χ) against another (Y), the wavelet spectra of the individual series $W_n^x(s)$ and $W_n^y(s)$ are used in determining the CWT in the series as:

$$W_n^{xy}(s) = W_n^x(s) W_n^{y*}(s) \quad (7)$$

The highest common power from the CWT shows the area, time, and space with $W_n^{y*}(s)$ as the intricate conjugate of $W_n^y(s)$.

2.5. Cross-wavelet power

The cross-wavelet power $|W_n^{xy}(s)|$ from the CWT indicates the covariance is shared on all individual levels.

In this case, a two-time series from the W.C plot represented by $\chi = \{\chi_n\}$ and $y = \{y_n\}$, which is the frequency and time gaps for the series covary. This allows for the detection of co-movements among the variables showing the absolute square values from the WC plots for the normalized WPS.

The coefficient of the square wavelet is:

$$R^2(x, y) = \frac{|S(s^{-1}W_{xy}(u, s))|^2}{S(s^{-1}|W_x(u, s)|^2)S(s^{-1}|W_y(u, s)|^2)} \quad (8)$$

The smoothing parameter (S) balances the resolution and significance level removing all issues related to WPS and the wavelet cross-spectrum (WCS).

2.6. Wavelet coherence

The inequality equation $0 \leq R^2(x, y) \leq 1$ represents the coherence with values from 0 to 1. 0 represents a low correlation and 1 is a robust correlation value. The lag oscillation is positioned in the phase form for the variables as the frequency with ϕ_{xy} , explaining the phase difference between $x(t)$ and $y(t)$ as:

$$\phi_{xy} = \tan^{-1} \left(\frac{\Im\{W_n^{xy}\}}{\Re\{W_n^{xy}\}} \right), \phi_{xy} \in [-\pi, \pi] \quad (9)$$

The smoothened CWT is in two parts when \Im and \Re , representing the imaginary and real parts. The directional arrows are also indicated on the WC plot, with unique different phase forms of the variables. The phase forms of $a(t)$ and $b(t)$ where arrows point to the right (in-phase) and the left (antiphase), downwards the second variable is in lead, and upwards the first variable in lead (see $b(t)/a(t)$).

3. Empirical results

We consider historical time series data for leading stock frontier markets with the highest market capitalization (as of 4 January 2010) and a relatively lengthier data span. In no particular order of arrangement, stock markets; Ghana Stock Exchange Composite Index (GSE-CI), Tunisia stock market (TUNINDEX), the stock exchange of Mauritius (SEMDEX); exchange rate market; the United States Dollar against the Ghanaian Cedi (US/GHS); Tunisian dinar (US/TND), Mauritian rupee (US/MUR), are examined. The daily stock returns and local currency to the United States dollar rate dataset spans from 4 January 2010 to 31 March 2023. African frontier markets have experienced significant developments from 2010 to 2023, reflecting both opportunities and challenges. These markets, characterized by rapid economic growth and increasing investor interest, have seen substantial changes in infrastructure, regulatory frameworks, and market performance.

Frontier markets in Africa such as Tunisia, Ghana, and Mauritius since 2010 have experienced robust economic growth driven by the telecommunications industry, banking, and natural resource sector. Since 2012 many African economies have taken financial, transparency, and efficiency, to improve growth and development. The Securities and Exchange Commission (SEC) of Africa has introduced new regulations, and improved corporate governance, and investor protection. These reforms implemented in capital markets have increased foreign investment and improved market liquidity. Through technological advancement, African frontier markets stand a chance to influence the transformational agenda of Africa's capital market. Fintech and banking solutions have also increased financial inclusion, improved participation, and revolutionized financial transactions leading to market development. Since the introduction of these reforms market performance has been mixed with significant gains and downturns occurring with influence from external and global factors such as currency, and interest rate fluctuations, political instability, corruption, inadequate infrastructure, global financial crises health pandemic (COVID-19), wars, and commodity price variations, among others. Volatility due to oil price and exchange rate shocks has riddled some frontier markets while others have shown a high level of resilience coupled with steady growth due to the diversification efforts of their respective governments. The inflow of foreign investment an important element of the development of frontier markets is hinged on investor interest in higher returns in low-yield markets which African markets often find themselves. The low influx of capital through private equity and venture capital investments needs to grow to support the expansion of businesses and encourage start-ups in African frontier markets. Global disruptions, and a growing need for sustainable, environmental, social, and governance (ESG) in investment portfolios and

decision-making measures need to be improved and monitored by the regulatory agencies. Challenging African frontier markets offer substantial growth potential and opportunities for investors willing to navigate the intricate complexities in the market. For these reasons and more, we selected this period based on data availability and based on the development of stock markets in the African context.

The data is sourced from investing.com/indices (for all countries except Ghana equity data which was sourced from gse.com.gh/trading-and-data/) which provides average prices of stocks and currencies across multiple exchanges globally. Recent empirical studies, including Živkov et al. (2021), used data from the same platform. We converted the daily prices into percentage log returns using $r_{i,t} = \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right) * 100$, for $i = 1, \dots, 2$ and $t = 1, \dots, 3129$ considering holiday effects; where $P_{i,t}$, $P_{i,t-1}$, are the closing prices for the i th market at days t and $t-1$, respectively (see Omane-Adjepo & Alagidede, 2019). We converted the daily prices into percentage log returns which is a common practice in financial analysis, for wavelet applications. The conversion of the series helps to stabilize any form of variance and normalize the distribution in the return series. However, this can also lead to autocorrelation and heteroscedasticity. In the case of autocorrelation which could occur when the returns are not independent over time, could distort the analysis. This violation could influence the assumption of the independence level in the series models. Wavelet transformations on the other hand when employed, with autocorrelation present in the series could lead to misleading results as the coefficients from the series could capture persistent patterns rather than the true signals that underline the series. This is addressed through pre-whiten or through wavelet techniques designed to handle autocorrelation. In the case of heteroscedasticity, which could arise when the condition of the variance return changes over time. The financial return series is often plagued with volatility clustering where the series displays high-volatility characteristics. This problem can complicate the performance of the wavelet transformation as the technique assumes a relatively stable variance for accurate time-frequency localization. In such circumstances, employing the GARCH or wavelet-based models can adapt to the changing volatility in the series can help address heteroscedasticity issues. Although the wavelet technique is powerful in decomposing series into time frequency components, it requires careful implementation. We pre-process the return series to mitigate issues arising from autocorrelation and heteroscedasticity to help provide better insights into the financial market behavior and dynamics. This comprehensive approach enhances the robustness of wavelet-transformed financial data, facilitating more accurate and meaningful interpretations.

3.1. Summary measures

We present a summary of the descriptive measures of the relationship between currency (exchange rates) and equity stock market prices for three African economies. The descriptive statistics for the selected variables are reported in Table 1.

3.2. Descriptive statistics

From Table 1, the mean for Ghana's GSE is negative zero and for the exchange rate is 0, Tunisia's mean value for TUNINDEX is 0 and the exchange rate is 0, and for Mauritius' SEMDEX is 5 and the exchange rate is 1. These show the average mean values of each of the variables for the country. The maximum and minimum values for Ghana GSE are 2 and -2 , for exchange rates 0 and -0 , for Tunisia, TUNINDEX 0 and -0 for exchange rates 0 and -0 , for Mauritius 0 and -0 , and exchange rates 0 and -0 . These show

Table 1. Descriptive statistics.

	Ghana		Tunisia		Mauritius	
	GSE	Exc	TUNINDEX	Exc	SEMDEX	Exc
Mean	-0.000226	0.00067	0.0001991	0.00026	5.24E-05	1.26E-04
Maximum	2.307714	0.15276	0.1405697	0.07721	0.102661	0.037286
Minimum	-2.298583	-0.1584	-0.135486	-0.0957	-0.10104	-0.04987
Std. dev.	0.1066516	0.01111	0.0062971	0.00696	0.005526	0.006057
Skewness	-2.073241	-0.3543	-0.176555	-0.584	-1.81926	-0.21166
Kurtosis	441.72848	40.7165	150.4292	22.4114	106.9075	5.794401

the highest and lowest figures in each of the variables. The standard deviation for all variables for each of the three (3) countries revolves around zero (0). This shows the deviation from the sample concerning each variable. The skewness of stock equity markets is all negative and lower than three (3). This indicates they are negatively skewed with the left tail of the curve bigger than the right side. The kurtosis for all the variables for the selected economies is greater than zero indicating the presence of leptokurtic distribution. This means that the tail of the distribution is heavy and kurtosis is higher than the normal distribution.

In our analysis, the sample period is from 2010 to 2023, with over 3000 observations per country. Descriptive statistics of the macroeconomic data are represented in [Table 1](#), which demonstrates the variations in the distribution of the series.

3.3. Linear granger causality analysis

3.3.1. Non-linear relationship D&P test

Leveraging the Granger causality framework, this study explores the causal linkages between African stock markets and their corresponding currency markets. The empirical results, presented in [Table A1](#), reveal a nuanced landscape of market interactions across the selected economies of Ghana, Mauritius, and Tunisia. Notably, no statistically significant evidence of unidirectional causality is observed from the equity stock market to the currency market in Ghana and Mauritius. Conversely, a significant unidirectional causality emerges from the Mauritian currency market to its equity stock market at the optimal lag length. This suggests that short-term fluctuations in the Mauritian exchange rate exert a statistically significant influence on stock prices, potentially reflecting capital flight behavior in response to currency depreciation. Again, the causality test for Tunisia indicates a significant unidirectional relationship, implying that short-term movements in equity stock prices influence exchange rates.

Employing a non-linear causality framework, this study delves deeper into the relationship between African stock and currency markets, complementing the initial linear analysis [Table A1](#). This investigation acknowledges the potential limitations of linear models in capturing intricate market dynamics, particularly the influence of unobserved non-linear events. To address this, the D&P test was deployed to corroborate or refute the existence of causal linkages among the markets in Ghana, Mauritius, and Tunisia ([Table A2](#)). The analysis commences with stationarity testing of the transformed series, a crucial prerequisite for ensuring suitability for non-linear causality assessment. Subsequently, the D&P test is applied after eliminating linear predictive power using a pre-estimated Vector Autoregressive (VAR) model with lag length determined by the Akaike Information Criterion (AIC). Consequently, any statistically significant causal relationships identified from the residuals can be attributed to non-linear predictive power, potentially reflecting the influence of unobserved factors.

We implement the same approach used by Bekiros and Diks (2008) and expand the bandwidth selection process to 0.5, 1.5, and 2.0. This corresponds to short-, medium-, and long-term horizons. The non-linear causality analysis delves deeper into market dynamics as shown in [Table A2](#) by capturing complex relationships and interactions in the selected African financial markets where linear models often miss, sudden market shifts, feedback loops, and varying volatilities. The findings for Ghana reveal an absence of statistically significant non-linear relationships between the equity stock market and currency markets in the short, medium, and long term. Conversely, a short-term non-linear causality emerges from the currency market to the equity stock market, potentially reflecting the heightened sensitivity of stock prices to short-term exchange rate fluctuations. We find a bi-directional non-linear relationship for all the time horizons examined which suggests that a complex interplay exists between the equity stock and currency market for Mauritius. However, we find a unidirectional non-linear relationship from the currency to the equity stock market for Tunisia across all the horizons. Furthermore, we find that where no statistically significant relationship is found between the equity stock market and the currency market in the short-term, in the medium-to-long term the relationship is significant for Tunisia (see [Table A2](#)). The non-linear patterns identified in these markets will help investors better predict market behavior and manage any unforeseen risk. For policymakers, understanding these non-linear dynamics will aid in crafting more effective regulations and interventions to address systemic risks, and promote market stability. As stakeholders to provide a comprehensive view of the market mechanisms and potential future trends,

these unique patterns necessitate further investigation to identify the underlying economic or financial mechanisms that contribute to this temporal disparity in causal linkages (IMF, 2023). We further examine the time-frequency relationship between the equity stock market and currency markets for which the linear and non-linear Granger causality is unable to examine.

3.3.2. *Co-movement of African indices on African stock exchanges*

Building upon the initial analysis, this investigation delves deeper by examining the co-movement patterns between stock and currency markets within the selected frontier African economies. The well-established preeminence of the US dollar as the primary medium of exchange for international trade in Africa necessitates its selection as the reference currency for this inquiry. This choice aligns with the extant literature documenting the dominant position of the US financial market (Owusu Junior et al., 2018). Exchange rate volatility constitutes a critical metric for assessing a nation's competitive positioning within the global market. By analyzing exchange rate fluctuations, we gain valuable insights into the fundamental health of a country's domestic and international market structures (Adusei & Gyapong, 2017; Junior et al., 2019). Under flexible exchange rate regimes, economies exhibit heightened sensitivity to exchange rate volatility, a phenomenon accentuated by the rise of global financial interconnectedness.

Employing biwavelet coherence (WC), this investigation delves into the strength of interdependence between the selected variables. WC plots provide a spatiotemporal visualization of pairwise co-movements, with wavelet coherency serving as a frequency-domain correlation measure. Additionally, these plots depict phase differences, potentially revealing lead-lag relationships between the markets. The horizontal and vertical axes represent time and frequency, respectively. Regions with elevated coherence values (depicted in warm colors, e.g., red) indicate statistically significant covariation between the paired time series, signifying a robust interdependence. Conversely, cooler-colored regions (e.g., blue) reflect a weaker dependence. This color scheme effectively communicates the intensity of interdependence across the frequency spectrum, offering valuable insights into the dynamic interplay between the variables.

The biwavelet coherence (WC) plots draw on the statistically rigorous Monte Carlo simulation to establish a 95% confidence level threshold, depicted by the thick grey contour. This threshold effectively demarcates regions of statistically significant interdependence between the time series variables (Grinsted et al., 2004). The gray contour within the WC plot represents the cone of influence (COI), a crucial concept for ensuring the reliability of co-movement interpretations. Only data points located within the COI are deemed suitable for analysis due to potential edge effects at the beginning and end of the time series (Torrence & Compo, 1998). WC plots effectively depict lead-lag relationships between the paired series through strategically positioned arrows. Zero-phase arrows indicate synchronous movement, suggesting a contemporaneous response of both series to a common factor. Arrows pointing right signify an in-phase relationship, implying that the series co-move in the same direction. Conversely, leftward arrows depict an anti-phase relationship, where the series exhibits movements in opposite directions. The precise direction of the arrow's tilt provides further distinction regarding lead-lag dynamics. Rightward or leftward tilts, combined with upward or downward directions, respectively indicate that the first or second series in the pair is leading. Figures 1–3 showcase the biwavelet coherence plots for the frontier equity stock markets and exchange rates of Ghana, Mauritius, and Tunisia.

3.3.3. *Wavelet coherence*

The dynamics of Ghana's exchange rate exert a significant influence on the country's trade performance. Founded during the 1980s economic reforms, the Ghana Stock Exchange was established to foster long-term capital mobilization to propel economic growth and development (Kwofie & Ansah, 2018). The Ghanaian stock market has functioned effectively as a mechanism for capital mobilization, facilitating investment in productive economic endeavors. As illustrated in Figure 1, the co-movement between stock prices and exchange rates appears primarily concentrated in the short-term horizon. Periods of heightened co-dependence were observed in 2011, 2016, and 2019, with a maximum correlation coefficient of 0.8 within the study period. The wavelet coherence (WC) plot suggests a weak interdependency in the medium term (2011, 2016) and a short-term (monthly) leadership of exchange rates over stock prices in 2019. Our research aligns with the conclusions reached by Mohammed Dahir et al. (2018) and

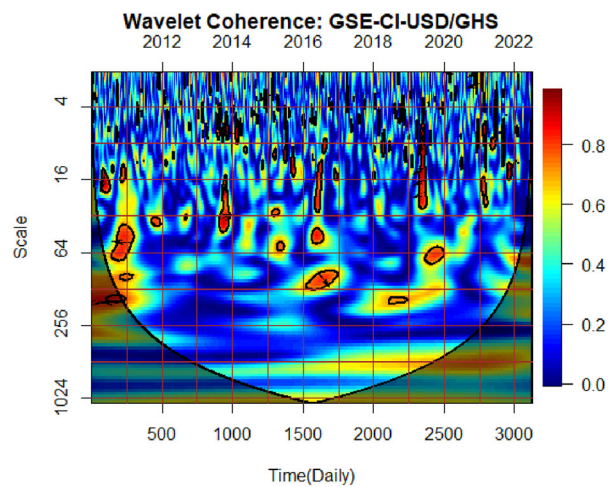


Figure 1. Ghana.

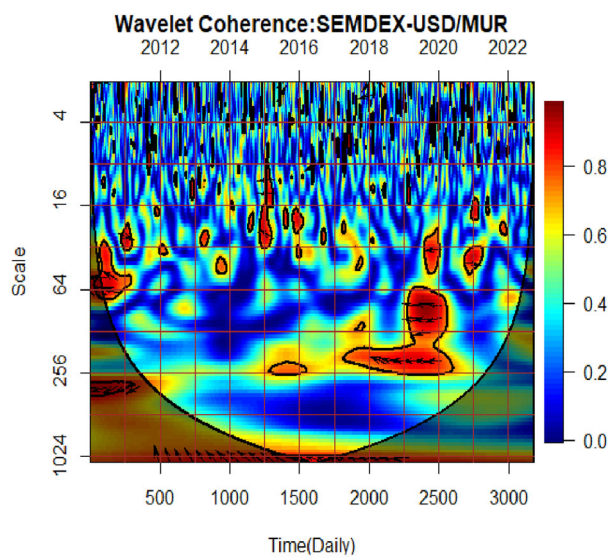


Figure 2. Mauritius.

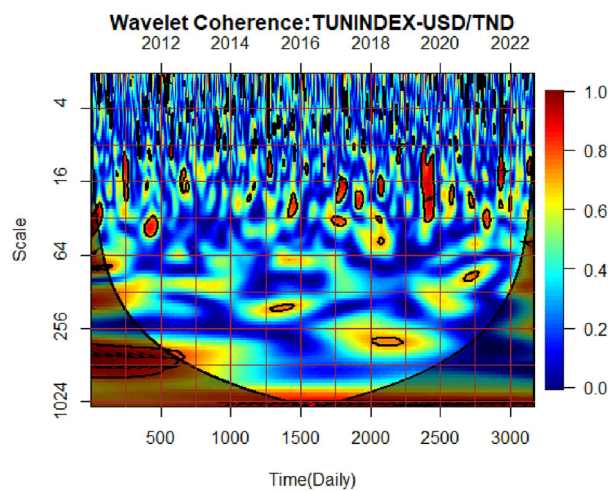


Figure 3. Tunisia.

Owusu Junior et al. (2018), demonstrating a weak correlation between the GSE-CI and the US dollar. This limited interdependence presents a potential hedging opportunity for investors seeking to mitigate risk. However, employing medium- to long-term hedging strategies within the Ghanaian market may incur losses during periods of lower market volatility, potentially negating the diversification benefits that such strategies aim to achieve.

Furthermore, our analysis suggests a co-movement between exchange rate leadership and external macroeconomic events. Specifically, periods of exchange rate leadership coincided with events such as the European sovereign debt crisis, global recessionary fears, pent-up currency pressures, and US interest rate hikes, all of which contributed to a depreciation of the Ghanaian cedi. A confluence of factors served to suppress investor risk appetite within the Ghanaian market. However, 2016 witnessed a confluence of positive developments. Ghana's economic growth reached an impressive 8.5%, the highest rate in the preceding five years, fueled by an upsurge in oil and gas production. Furthermore, the International Monetary Fund credit agreement facilitated a reduction in both the national budget deficit and the public debt burden, contributing to a more robust economic trajectory. Significantly, the Securities Industry Act of 2016 (Act 929) severed the Ghana Stock Exchange's reliance on government payroll, thereby granting it financial and operational independence. This newfound autonomy empowered the GSE to discharge its mandated functions with enhanced effectiveness and efficiency.

Notwithstanding the favorable economic indicators in 2016, the Ghanaian stock market exhibited a contractionary trend, registering a negative return of 15.33%. This seemingly counterintuitive performance can be ascribed to the persistence of economic uncertainty. In response, investors adopted short-term risk mitigation strategies, favoring financial instruments and low-risk investment vehicles such as government securities. Furthermore, the Securities and Exchange Commission's (SEC), 2016 annual report underscores the government's reliance on substantial borrowing to fulfill its financial obligations (SEC, 2016). This strategy resulted in a market glut of government bonds, consequently diminishing investor appetite for equity, corporate bonds, and other instruments. Shifting the focus to a more recent event, the first quarter of 2019 witnessed a depreciation of the Ghanaian cedi relative to the US dollar. This depreciation was attributable to a multi-faceted phenomenon. The energy sector contracted sharply due to a decline in oil prices. Additionally, manufacturing activity and trade with key partners exhibited a slowdown during the closing quarter of 2018. Further exacerbating market anxiety was the Central Bank's unscheduled rate reduction implemented in January 2019 (IMF, 2019). Moreover, the constraints imposed by the IMF program limited the Central Bank's capacity to maintain its desired level of international reserves (IMF, 2024). This, in turn, hindered its ability to intervene in the weakening currency. Consequently, a period of speculative short-selling ensued until the cedi's rebound in the second quarter. The broader economic recovery was also accompanied by a subsequent improvement in stock market returns.

Mauritius, like many of its African counterparts, exhibits a high import dependence, rendering its economy particularly susceptible to currency fluctuations. The recent depreciation of the Mauritian rupee has exerted a significant impact on both household budgets and broader economic performance. While Mauritius achieved high-income nation status in 2020, this classification was subsequently revised to upper-middle-income in 2021, a development partly attributable to the COVID-19 pandemic's disruptive effects. However, Mauritius has displayed noteworthy resilience compared to its regional peers. The World Bank (2023) reports a moderate growth rate for the nation, even amidst the confluence of challenges posed by the Ukraine war, the pandemic's lingering effects, a global slowdown in demand, and a domestic inflation rate of 4%. A critical factor underpinning this resilience is the tourism sector, a cornerstone of the Mauritian economy. While the pandemic inflicted significant damage on the sector, with tourist arrivals plummeting from 1.4 million in 2019 to a mere 180,000 in 2021, signs of recovery are now emerging. This decline in tourism resulted in an estimated cumulative shortfall of over 120 billion rupees in foreign currency inflows, representing a substantial 33% contraction in foreign exchange earnings.

The Stock Exchange of Mauritius (SEM) has exhibited robust growth since its establishment in 1989, achieving a market capitalization exceeding USD 12 billion within its first three decades. The exchange has strategically positioned itself as a premier international and multi-currency listing platform for Africa's frontier markets, effectively attracting prospective investors. This strategic shift, implemented in

2010, involved the internationalization of the SEM's regulatory and operational frameworks. This initiative demonstrably fostered a surge in investor participation across African stock markets, excluding South Africa. In 2019, the SEM attained its highest daily turnover on record, registering a significant 57% increase to approximately USD 15 million. This impressive performance stood in stark contrast to the decline observed in other African markets during the same period compared to 2018 (MFW4A, 2020). However, by December 2020, the official market capitalization had contracted by 18%, reaching USD 7.0 billion. This decline is primarily attributable to the exogenous effects of the COVID-19 pandemic. Furthermore, foreign investor participation in the SEM witnessed a notable decrease, reaching its lowest level since the 2015–2016 period. Foreign investors accounted for only 41.2% of trading volumes between 2020 and 2022 (Khemraz-Chikhuri, 2022). This reduction in foreign investor activity likely coincides with the significant volatility experienced in the exchange rate market. The slowdown in domestic economic activity, triggered by both the pandemic and the Ukraine war, significantly contributed to this exchange rate volatility. Furthermore, these factors negatively impacted the earnings of listed companies, ultimately leading to deferred dividend payments as reflected in their financial reports. Figure 2 reveals intricate dynamics between stock market movements and exchange rate fluctuations in Mauritius. The co-movement patterns exhibit heterogeneity, characterized by periods of both positive and negative correlations. Specifically, the presence of a left-phasing arrow during the 2010–2011 and 2017–2021 intervals indicates an anti-phase relationship with an intensity of 0.8. This signifies an inverse association, where a decline in one market coincides with an increase in the other. Furthermore, the biwavelet coherence map suggests that during periods of robust underlying economic fundamentals, volatility spillovers between the stock and currency markets are primarily triggered by exogenous shocks. Significantly, the figure underscores that the most enduring (annual) volatility effects emanate from a confluence of external and internal shocks impacting both markets.

The Tunisian economy has exhibited a persistent slowdown since the 2011 Arab Spring revolution. This sluggishness has been further amplified by the recent COVID-19 pandemic and the ongoing war in Ukraine (Asharq Al Awsat, 2023; World Bank, 2023). A confluence of factors has contributed to this subdued economic performance, including overly complex and burdensome regulations governing investment, trade, and access to finance. These constraints have stifled market growth and facilitated a rapid rise in national debt. The resulting market turbulence has demonstrably impacted investor sentiment, leading to a decline in capital inflows in Tunisian financial markets (Jeribi et al., 2015). Furthermore, excessively restrictive currency market regulations have compounded these challenges. Figure 3 underscores the limited degree of interdependence between Tunisia's currency and equity markets. While short-term periods of co-movement are evident, the prevailing pattern appears to be one of zero-phase co-movement. In zero-phase relationships, both the stock market and exchange rates exhibit synchronized movements, often triggered by the implementation of specific policy measures. However, a noteworthy exception exists for the period 2019–2020. During this timeframe, the presence of a leftward-pointing downward arrow suggests a phase relationship, indicating that exchange rate fluctuations preceded and potentially influenced equity stock prices within the Tunisian market.

An examination of Tunisian monetary policy and exchange rate restrictions suggests a potential correlation with reduced foreign direct investment within the nation's stock market (Mechri et al., 2018). Wavelet coherence analysis, as depicted by the Wavelet Coherence Indicator (WCI), reveals minimal long-term interdependence between the relevant variables from 2019 to 2020. However, during the initial phases of the COVID-19 lockdown, the WCI plot portrays a transient period (16–32 weeks) of heightened co-movement (intensity of 0.8) between exchange rate fluctuations and the stock market. This transitory relationship implies that exchange rate movements may have exerted a short-lived influence on the stock market during this specific timeframe. Financial institutions continue to constitute the primary participants within the Tunisian equity market. Foreign investor activity has exhibited a marked decline, with foreign transactions representing a mere 20.9% of total market activity by 2022. This decline can be ascribed, in part, to the stringency of regulations governing foreign exchange operations and the complexities associated with the repatriation of dividends or interest capital by both individuals and firms (Ben Ayed et al., 2020; US Embassy Tunis, 2023). Furthermore, the depreciation of the Tunisian dinar has likely contributed to the reduced inflow of foreign investment into the Tunisian stock market.

4. Discussion

This investigation employs wavelet analysis to comprehensively examine the time-frequency dynamics of co-movement between equity and currency markets in Ghana, Mauritius, and Tunisia. Wavelet analysis offers a distinct advantage by enabling the exploration of how these variables interact at various temporal scales and how their interconnectedness evolves. Notably, wavelets excel at capturing non-stationary features embedded within the data series, a limitation that plagues alternative methodologies. Prior research has yielded conflicting results (Aloui & Hkiri, 2014; Rua, 2010), highlighting the superiority of wavelets in effectively capturing the erratic behavior of the series in both the time and frequency domains.

The wavelet analysis reveals that co-movements beyond a four-year horizon fall outside the Cone of Influence (COI) in the long term. This signifies a lack of statistically significant relationships at these time scales, contrasting with prior studies that suggested persistent co-movements beyond 2048 days (Owusu Junior et al., 2018). On the other hand, we find significant co-movements are only noticeable within the 1024 days. Furthermore, the observed co-movement patterns exhibit heterogeneity, encompassing both in-phase (positive correlation) and anti-phase (negative correlation) relationships. The direction of causality, as indicated by the arrows pointing upwards (stock market leading) or downwards (exchange rate leading), varies across the examined countries and timeframes.

Frontier markets in Ghana, Mauritius, and Tunisia exhibit a dynamic interplay between stock market fluctuations and exchange rate movements. Our research suggests that recurrent events can exert short-term pressures on exchange rates, potentially impacting stock market performance. Furthermore, disruptions that cast doubt on the sustainability of future dividend payments can trigger investor risk aversion behavior. In response to such events, investors may strategically withdraw capital from the stock market and redeploy it into longer-term instruments within the frontier market itself. This portfolio reallocation serves as a risk mitigation strategy, aiming to shield investor wealth from the potential volatility associated with these periodic events. Our findings further reveal that investors in the selected African frontier markets (Ghana, Mauritius, and Tunisia) often construct diversified investment portfolios. This diversification strategy is motivated, in part, by a desire to minimize exposure to systemic risks, including the potential for exchange rate fluctuations to negatively impact overall portfolio returns. African frontier markets examined in this study display the Arbitrage Pricing theory dynamics. This is evident in the propensity of the short-term markets to be sensitive to price volatility. However, the stock prices in these markets are often in equilibrium in the long-term. These disparities spur investors to engage in the diversification of their investment portfolios and implement hedging strategies that would mitigate their risk exposure and increase returns (Hammami & Boujelbene, 2022; Zaiane & Jrad, 2020). The results also draw attention to the dynamic relationship between stock volatility and investor behavior as risk-averse investors on the African frontier reduce their transaction volumes during heightened volatility periods. Unlike risk-tolerant investors, who tend to increase their trading activity during these periods. Moreover, the type of diversification strategy may exert quantifiable transaction costs on market liquidity.

5. Conclusion

A multitude of African frontier markets have been beset by a convergence of negative economic forces. These include export disruptions, a decline in the terms of trade, depreciation of local currencies relative to the US dollar, and a subsequent contraction in investment inflows and reduced competition. The cumulative impact of these challenges has been a pronounced scarcity of foreign exchange reserves, severely impeding both trade finance activities and foreign direct investment. In the past decade, a noteworthy policy shift has been observed within the monetary frameworks of many African frontier economies. A transition has occurred from fixed exchange rate regimes to more flexible exchange rate systems while initially beneficial and transitory, has not provided sustained advantages due to ongoing market volatility and spillover effects. Frontier equity markets in Africa are particularly prone to fluctuations, deterring both domestic and foreign investors and limiting capital mobilization. The interplay of demand and supply forces, originating from both domestic and international markets, continues to exert a significant influence on exchange rate dynamics. This dynamic can lead to the transmission of volatility and spillover effects across these selected African frontier markets. Frontier equity stock markets in Ghana, Mauritius, and Tunisia are characterized by a susceptibility to pronounced fluctuations and heightened volatility. These market

dynamics act as a significant disincentive to investor participation, both domestic and foreign, thereby constraining the market's capacity to mobilize capital for investment purposes.

To mitigate this challenge, frontier economies should prioritize the implementation of a multifaceted policy framework designed to cultivate a more robust investor appetite for their stock markets. Potential policy interventions could encompass; the adoption of stricter regulatory frameworks and the promotion of enhanced corporate governance practices to foster a more stable and predictable market environment; the cultivation of a diversified range of value-added products within the domestic economy, creating attractive investment propositions for both local and international market participants; in the short term, a focus on essential imports, such as medicine, food, and fuel, in sectors where domestic production capacity remains limited; over the medium to long term, the prioritization of policies that foster self-sufficiency within key industries, with the ultimate goal of reducing reliance on exports and cultivating a more diversified and resilient economic structure; the introduction and subsequent regulation of innovative payment system technologies to facilitate streamlined foreign currency inflows into the stock market. Again, regulators and investors need to account for volatility spillovers and manage risk in the market. Strong and sound strategies from diversification, and portfolio rebalancing are important mechanisms to prevent adverse price movements due to extreme changes in macroeconomic factors in one market (Aloui et al., 2018; Cao et al., 2020; Du et al., 2020; Kolm & Ritter, 2019), all found that the various strategies above among others help in balancing the returns during high volatility periods on the market (Acerbi & Tasche, 2002; Pflug, 2000; Rockafellar & Uryasev, 2002). Furthermore monitoring, and implementing transparency measures to reduce third-party risk amount others can reduce cross-border spillovers they navigating the complex relationship between stock market prices and exchange rate changes (Chen et al., 2024; OECD, 2013).

Our study finds that flexible exchange rate regimes enjoy short-lived advantages but does not examine the limited long-term benefits to enable a generalization due to the uniqueness of each market and country. There is a need for researchers to consider exploring the specific conditions under which advantages can be sustained under flexible exchange rate regimes. By addressing the shortcomings and implementing recommendations African markets can take advantage of opportunities for effective policy implementation to attract investors.

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Authors' Contribution

Genevieve Gyasi was involved in the conception and design, or analysis and interpretation of the data; the drafting of the paper, revising it critically for intellectual content; and the final approval of the version to be published. Joseph Magnus Frimpong and Kwame Mireku were involved in the conception and design, revising it critically for intellectual content; and the final approval of the version to be published. All authors agreed to be accountable for all aspects of the work.

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Data availability statement

The data that support the findings of this study are openly available at investing.com and the Ghana Stock Exchange. These data were derived from the following resources available in the public domain: <https://www.investing.com/indices/> for all countries except Ghana's equity data which was sourced from <https://gse.com.gh/trading-and-data/> data available on reasonable request from the corresponding author Genevieve Gyasi. The data was obtained from investing.com and the Ghana Stock Exchange database. Daily data was obtained for all three countries and is easily accessible. All rights and permissions to the data used are under investing.com and the Ghana Stock Exchange.

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Appendix

Table A1. Linear Granger causality test results.

African frontier stocks and exchange rates			
Direction	T-statistics	p-value	Optimal Lag
GHANA			
GSE-Cl↗ EXC	5.8	0.45	6
EXC↗GSE-Cl	3.5	0.74	
MAURITIUS			
SEMDEX ↗ EXC	12.1	0.06	6
EXC→SAMDEX	12.4	0.054	
TUNISIA			
TUNINDEX → EXC	18	0.00044	3
EXC↗TUNINDEX	5.9	0.12	

Table A2. Non-linear relationship D&P test.

Direction	African frontier stocks & exchange rates					
	$\varepsilon = 0.5$ T statistic	p-value	$\varepsilon = 1.5$ T statistic	p-value	$\varepsilon = 2.0$ T statistic	p-value
GHANA						
GSE-Cl \nrightarrow EXC	0.876	0.19058	−0.049	0.51956	−1.486	0.93135
EXC \nrightarrow GSE-Cl	***	***	0.377	0.35308	0.629	0.26466
MAURITIUS						
SEMDEX \rightarrow EXC	***	***	***	***	***	***
EXC \rightarrow SEMDEX	***	***	***	***	***	***
TUNISIA						
TUNINDEX \nrightarrow EXC	0.767	0.2215	***	***	***	***
EXC \nrightarrow TUNINDEX	***	***	***	***	***	***