

Article

On the Macroeconomic Conditions of West African Economies to External Uncertainty Shocks

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Abstract: This study provides a detailed investigation of the time–frequency and frequency-domain analysis of the interconnectedness of country-level macroeconomic variables. Hence, the wavelet techniques—vector wavelet and wavelet multiple—employed with TVP-VAR are utilised as a robustness check. The macroeconomic variables considered are consumer price index (CPI), real exchange rate (EXR) and nominal effective exchange rate (NEER) for four selected West African economies—Côte d’Ivoire, Gambia, Ghana and Nigeria. The findings of the study reveal that there are significant comovements between the macroeconomic dynamics in a time–frequency domain for the selected economies. From the wavelet multiple technique, the study finds three interesting outcomes. First, there are traces of high comovements between the macroeconomic conditions of some countries in the long term. In addition, NEER has a strong exposure to external shocks due to the presence of periodic swings such as inflation, which makes it largely susceptible to shocks. Second, a high integration of macroeconomic variables, in the long term is found. Third, Global Economic Policy Uncertainty (GEPU) lags in the long term within the interdependencies of CPI as well as NEER but not EXR. This suggests that the presence of inflation most likely exposes these economies to external shocks. However, when this happens, external shocks act as a follower to influence economic activities within this region. The study advocates that governments and policymakers should deploy efficient inflation-targeting monetary policies to enhance price stability and minimise the adverse impact of GEPU for future monetary convergence.

Keywords: time–frequency; global economic policy uncertainty; monetary policy; fiscal policy; heterogeneity; wavelets



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1. Introduction

The formation of unions among regional blocs has induced several academic discourses around the world. Researchers have made increasing attempts to examine the degree of integration among some of the 16 West African economies toward the formation of unions or regional blocs. For instance, the West African Monetary Zone (WAMZ) comprises six member countries (Gambia, Ghana, Guinea, Liberia, Nigeria and Sierra Leone) that are import-dependent for consumables and capital goods. Additionally, the West African Economic Monetary Union (WAEMU) comprising Benin, Burkina Faso, Côte d’Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo is also pulling resources together to accomplish greater integration with unified external tariffs. Comparatively, the WAEMU established in 1994 is practically integrated relative to the WAMZ members (Ekpo 2020). This can be realised from WAEMU’s share of the West African CFA franc as a common currency to justify economic integration among the eight West African Francophone Member States.

Nonetheless, these economies are monoprodukt-based with primary products dominating the export sectors (Eregha 2019). They are susceptible to adverse movements in their economic activities, for instance, prices of goods and services, resulting in unpredictable macroeconomic condition fluctuations. As a result, they face the challenge of fundamental current account deficits that influence their foreign reserves due to the heightened level

of importation leading to adverse movements in macroeconomic variables, especially exchange rates and then inflation. To avert this predicament, most West African economies practised an either fixed or managed floating exchange rate system but could not resolve the exposure to external shocks.

As opined by [Friedman \(1953\)](#) and [Balg \(2006\)](#), the practice of a fixed exchange rate system for economies with current account deficits, due to excessive imports and engaging in the export of primary products, will always have adverse external shocks, instability in exchange rates and inflation and uncompetitive economy in the case of exports (see, [Eregha 2019](#)). In addition, [Obstfeld and Rogoff \(1998\)](#) indicate that if the price of goods and services of a country increases, it influences its competitiveness, leading to adverse impacts on balance of payments. According to [Eregha \(2019\)](#), exchange rates are either fixed for fear of excessive fluctuations, so as not to affect inflation through importation, or allowed some adjustable pegs or managed floating systems, allowing for more speculative behaviour, resulting in exchange rate expectations and uncertainty. One of the primary goals of the monetary zone's creation was to foster exchange rate and inflation stability among member nations in order to encourage output development, trade, and capital flows, since their excessive fluctuations are detrimental to economic stability. The need for monetary integration has become critical in resolving the problems of currency multiplicity and exchange rate volatility partly due to lower outputs and higher inflation ([Alagidede et al. 2008](#)) that often inhibit trade flows among African countries ([Owusu Junior et al. 2017](#); [Ekpo 2020](#); [Adeboje et al. 2022](#)).

Moreover, the purchasing power parity (PPP) concept has become one of international finance's most significant pillars. PPP is an important component of most macroeconomic models, as well as the theoretical underpinnings of the balance of payments and a country's or region's external competitiveness (see [Cassel 1922](#); [Balassa 1964](#); [Dornbusch 1988](#)). Because the law of one price assumes well-integrated commodity markets, [Dornbusch \(1988\)](#) claims that trade impediments and differences in the speed with which exchange rates and commodity prices respond to new information across different locations lead to significant and consistent deviations from PPP. Furthermore, among other institutional variables, flaws in commodity markets, the appreciation and depreciation of the U.S. dollar, short time series, misspecification and measurement errors ([Cheung and Lai 1993](#)) can lead prices and exchange rates to differ dramatically ([Alagidede et al. 2008](#)). This calls for a careful assessment of monetary convergence.

Accordingly, macroeconomic variable integration is one of the pertinent prerequisites for West Africa to accomplish convergence among member countries. Most researchers and academicians have postulated that the degree of convergence in unions such as WAMZ seems practically impossible in line with the concept of integration. A recent study by [Gammadigbe and Dioum \(2022\)](#) finds that in support of the theory of the endogeneity of optimum currency area, the intensity of trade is relevant for the convergence of ECOWAS countries' business cycles. However, [Adeboje et al. \(2022\)](#) advocate that trade integration has not led to expansion in employment in the West African region. This may be due to heterogeneity in West Africa's macroeconomic fundamentals toward their trading patterns across time and frequencies.

Hence, the ability for countries to converge hinges on the degree of interdependencies between and among several macroeconomic fundamentals that have a direct effect on trade. In this regard, the examination of integration among macroeconomic variable levels should be given much attention over time ([Mundell 1961](#); [Cooley and Prescott 1995](#); [Caetano and Caleiro 2018](#)). As indicated by [Doyle \(1997\)](#), interdependencies leads to increased economic relations and free flow of capital among countries, which promote the forming of unions. [Polachek \(1980\)](#) avers that countries gain from interdependence, for example, the diverse advantages obtained from trading with other nations which most governments try to maintain ([Mundell 1961](#); [Cooley and Prescott 1995](#); [Asafo-Adjei et al. 2021a](#)). As provided by [Bayoumi and Eichengreen \(1992\)](#), [Asafo-Adjei et al. \(2021a\)](#) and [Agyei et al.](#)

(2022), interdependence proposes common values in trading or socio-cultural ethos, which involve the maintenance of international order.

Owusu Junior et al. (2021) advocate that financial integration is the consequence of institutional, economic and political reforms. The ability of regional investors to acquire domestic assets, as well as the ability of local investors to access investment opportunities, is critical to integration (Arouri and Foulquier 2012; Shadlen 2005), access to international investment options (whether by legal means), home-grown diversification, etc. Owusu Junior et al. (2021) and Amoako et al. (2022) also enhance the exposure of macroeconomic variables to external shocks, which may minimise convergence. Investors' risk preference, relative optimism and perception of information are all behavioural characteristics that could influence the willingness to invest in other countries (Arouri and Foulquier 2012) and highly influence the degree of convergence. The benefits of convergence according to Alday (2021) is rooted in lower transaction costs to moderately low levels, which encourages the regionalisation of multinational enterprises. Khmeleva and Czegledy (2021) additionally find that the integration of regions into world economic relations helps find answers to global challenges.

Consequently, recent empirical studies on the degree of convergence in West Africa are replete with comovements and the degree of interdependencies through correlation analysis (Mogaji 2017; Owusu Junior et al. 2017, 2019; Adu et al. 2019; Gyamfi et al. 2019). This is necessary because in times of heightened degrees of comovements or interdependencies to facilitate convergence, it may elicit contagion on other economies irrespective of the nature of economic fundamentals of the other economies (see, Scott 2016; Owusu Junior et al. 2017). This suggests that similarities between economic indicators or regional blocs expedite the degree of convergence as espoused in the study of Adam et al. (2022) on the similarities of exchange rates in Southern African Development Community (SADC).

Studies on comovements on macroeconomic variables around the globe have witnessed methodologies such as GARCH (Engle et al. 1988; Pérez-Rodríguez 2006; Tamakoshi and Hamori 2014), Markov switching, VAR models and Granger causality tests (Antonakakis 2012; Beirne and Gieck 2014; Nikkinen et al. 2011), fixed effect (Moradi et al. 2021), beta and sigma convergence (Gammadigbe and Dioum 2022), etc. Despite the massive contribution by the extant literature, a nascent and fledgling body of literature has employed wavelet techniques (Soares 2011; Soares and Aguiar-Conraria 2014; Berdiev and Chang 2015; Aloui et al. 2016; Owusu Junior et al. 2017, etc.). The complexities that are inherent in time series analysis has increased the time–frequency domain, making wavelet analysis a common instrument for examining confined variations of power within a time series to define both prevailing modes of variability and how the modes change in time through decomposition (Owusu Junior et al. 2017, 2018, 2019; Tweneboah et al. 2019). This is to properly investigate the convergence due to failure by other techniques to reveal the time and frequency or frequency dimensions of the comovements. For instance, a study by Owusu Junior et al. (2017) assessed the comovements between real exchange rates in WAMZ through the univariate and bivariate Continuous Morlet Wavelet Transform.

The current study departs from the extant literature on monetary convergence by applying other forms of wavelet techniques to provide more insights on the level of comovements or integration of these macroeconomic conditions among member countries in light of external shocks. First, the vector wavelet is specifically employed in this study to examine the comovements among the selected West African countries for each macroeconomic variable simultaneously in a time and frequency domain. Unlike the biwavelet and partial wavelet coherence which facilitates comovements in time and frequency domains for few variables, the vector wavelet is ideal for more variables. The vector wavelet technique is therefore important in examining the spillover effects between each macroeconomic variable for a number of countries which the study of Owusu Junior et al. (2017) did not consider. In this regard, the degree of responsiveness of a country's macroeconomic variable to shocks from corresponding macroeconomic variables of union members, while

still maintaining the calendar time and intrinsic time dimensions, is well-accentuated by this technique.

To determine the general integration or interdependencies of each macroeconomic variable for all union members, the wavelet multiple approach is preferred. This technique has been employed by a plethora of literature on diverse finance and economic activities (see [Fernández-Macho 2012](#); [Kahraman and Ünal 2016](#); [Tweneboah 2019](#); [Tweneboah et al. 2019](#); [Owusu Junior et al. 2021](#); [Asafo-Adjei et al. 2021a, 2021b](#); [Agyei et al. 2022](#); and [Asafo-Adjei et al. 2022a](#) to mention a few). The application of the wavelet multiple approach would therefore contribute to the short-term ([Cassel 1922](#)) and long-term ([Rogoff 1996](#)) discussion on PPP. Additionally, it is relevant to perform the analysis on a time and/or frequency perspective ([Enders 2008](#); [Hendry 1995](#); [Hamilton 2020](#)).

The study makes a profound contribution to the literature in many ways. First, three country-specific macroeconomic variables are utilised to examine their extent of comovements or integration within West Africa. These include real exchange rate (EXR), nominal effective exchange rate (NEER) and inflation (CPI). Most empirical literature conducted on regional blocs from West Africa consider either real exchange rate or nominal effective exchange rate, thereby providing myopic views about the extent of convergence. The real and nominal variables are utilised to duly respond to the ex ante convergence standards, which concentrate on nominal convergence as well as the theory of Optimal Currency Area criteria that places much emphasis on the real economic variable convergence of countries in forming a currency union ([Mundell 1961](#); [Bayoumi and Eichengreen 1997](#); [McKinnon 1963](#); [Abban 2020](#)).

The study makes use of four selected West African economies to achieve its purpose. This is not startling for some important reasons. To begin with, the eight West African Francophone Member States forming the WAEMU are well-established to the extent of enjoying common macroeconomic fundamentals such as the use of a single currency ([Ekpo 2020](#)). Hence, the study selects a single Member State from the WAEMU as a representation on the West African economies. Emphasis is laid on Côte d'Ivoire because it is a significant producer of commodities such as cocoa and coffee. Additionally, due to the failure of the WAMZ in forming a reliable union, the study utilises three dominant countries (Gambia, Ghana and Nigeria) from the WAMZ with consistent data availability for the selected period and macroeconomic fundamentals. Hence, all other countries from West Africa are expunged due to the lack of consistent data availability. The majority representation by the WAMZ in this study is as a result of their weaker economic and financial integration, rendering the road toward monetary integration very bumpy ([Ekpo 2020](#)).

Second, owing to the susceptibility of macroeconomic variables in West Africa from excessive imports, engagement in the export of primary products and the uncompetitive economy in the case of exports (see, [Eregba 2019](#)), the role of Global Economic Policy Uncertainty (GEPU) is considered within the integration of these macroeconomic variables. The presence of GEPU amongst macroeconomic variables in West Africa is not exaggerated.

The GEPU index encompasses a wide range of concerns, such as regulatory conflicts, income inequality disputes and global pricing swings to name a few, which occur around the world. As a result of the GEPU index's establishment, various empirical studies have been conducted ([Huynh 2020](#); [Asafo-Adjei et al. 2020, 2021a](#); [Frimpong et al. 2021](#); etc.). It has a significant impact on the fluctuations of macroeconomic fluctuations around the globe ([Asafo-Adjei et al. 2020, 2021b](#); [Boateng et al. 2022](#); [Asafo-Adjei et al. 2022b](#)). It must be noted that fluctuations in macroeconomic variables heighten country risks, which translate into the vulnerability of economies to external shocks ([Abban 2020](#)). Hence, GEPU as a weighted average EPU measure of 21 countries is enough to consider shocks emanating from other external economies. As a result, the impact of GEPU cannot be ignored since it can cost economic players to alter pertinent decisions such as consumption, saving, investment and employment ([Gulen and Ion 2016](#)).

Third, two advanced forms of the wavelet approaches relative to the biwavelet and partial wavelet are employed. Specifically, the vector wavelet is used in this study to assess

the comovements between country-specific macroeconomic variables, whereas the wavelet multiple considers the role played by GEPU in the integration of the country-specific macroeconomic variables. Accordingly, the current study, to the best of our knowledge, is among the very few empirical studies that extensively investigates convergence in West Africa in a more pragmatic way.

The results of the study reveal that there are large comovements between the macroeconomic dynamics in a time–frequency domain for the selected economies. From the wavelet multiple technique, three interesting outcomes were found. First, there are traces of high comovements between the macroeconomic conditions of some countries in the long term. Second, macroeconomic variables are highly integrated, but in the long term. Third, GEPU lags in the long term within the interdependencies of CPI and NEER in West Africa but not EXR.

The remainder of the paper is organised in the following manner. Section 2 explains the research techniques; Section 3 describes the data sources and data used in the study; and Section 4 summarises the findings and analyses. The policy implications and the conclusion are highlighted in Section 5.

2. Methodology

The study examines the time–frequency comovement among country-specific macroeconomic variables using the vector wavelet and the degree of integration between the macroeconomic variables while considering the adverse impact of GEPU via the wavelet multiple. The relevance of using these techniques relates to the fact that financial time series experience rapid oscillations, exhibit asymmetric relationships and depict heterogeneous relationships (see, [Owusu Junior et al. 2018](#); [Frimpong et al. 2021](#); [Asafo-Adjei et al. 2021a, 2022a](#)). Hence, other static models such as ordinary least squares regression and structural VAR, GARCH models, among others, would not be enough to reveal such dynamics. In addition, in investigating the degree of integration, the wavelet multiple approaches are ideal in revealing the simultaneous snapshot of the full nexus, where even the biwavelet technique cannot suffice. Specifically, by using the multiple wavelet coherence, the multiple time–frequency dynamics are ascertained, whereas the wavelet multiple approaches provide the opportunity to investigate the lead–lag relations among the variables at specific frequencies.

2.1. Multiple Wavelet Coherence

The accessible way of considering the MWC is to associate it with the multiple correlation coefficient. In this technique, a comovement is examined between each macroeconomic variable for all countries simultaneously. The macroeconomic variables considered are inflation (CPI), exchange rate (EXC) and nominal effective exchange rate (NEER). Below is the mathematical demonstration of the MWC:

$$RM^2(Y, X, Z, P) = \frac{R^2(Y, X) + R^2(Y, Z) + R^2(Y, P) - 2R(Y, X) \cdot R(Y, Z) \cdot R(Y, P) \cdot R(X, Z) \cdot R(X, P) \cdot R(Z, P)^*}{[1 - R^2(X, Z)] + [1 - R^2(X, P)] + [1 - R^2(Z, P)]} \quad (1)$$

where “ RM^2 ” signifies the variable “ Y ” on the linear combination of three other variables of concern ([Ng and Chan 2012](#)).

The variables Y , X , Z and P represent country-specific macroeconomic indicators. A linear combination of each country’s macroeconomic indicator on other countries’ similar macroeconomic indicator to examine the extent of comovements is formed. This means that the dependency structure of the economic indicator of one country on a similar indicator of the other countries is extensively investigated in this study. For instance, from Equation (1), interdependencies are investigated for each macroeconomic variables but in a country-level perspective. Thereafter, the impact of three similar country-level macroeconomic indicators is regressed on the other, which in turns achieves four MWC for each macroeconomic indicator to provide a clearer view of convergence.

This can briefly be shown in Equation (2) for exchange rate as

$$RM^2(EXR_C, EXR_{GH}, EXR_N, EXR_{GB}) = \frac{R^2(EXR_C, EXR_{GH}) + R^2(EXR_C, EXR_N), R^2(EXR_C, EXR_{GB}) - 2R[R(EXR_C, EXR_{GH}) \cdot R(EXR_C, EXR_N) \cdot R(EXR_C, EXR_{GB}) R(EXR_{GH}, EXR_N) \cdot R(EXR_{GH}, EXR_{GB}) \cdot R(EXR_N, EXR_{GB})^*]}{[1 - R^2(EXR_{GH}, EXR_N)] + [1 - R^2(EXR_{GH}, EXR_{GB})] + [1 - R^2(EXR_N, EXR_{GB})]} \tag{2}$$

where *C*, *GH*, *N* and *GB* signify Côte d’Ivoire, Ghana and Nigeria and Gambia, respectively. This can analogously be presented for CPI and NEER as shown in Equation (2) by substituting EXR.

2.2. Wavelet Multiple

The Wavelet Multiple Correlations (WMC) approach is used in this study to determine the leading/lagging variable relative to the scales through linear combinations for the variables to provide the full picture of the nexus (Tweneboah et al. 2019; Asafo-Adjei et al. 2021a; Owusu Junior et al. 2021). Moreover, through the WMC, it is likely to assess the degree of interdependencies among more than two variables at the same time. Thus, the wavelet multiple provides the extent of lead/lag relationship and the degree of interdependencies among more than two variables, which is frequency-dependent. Let $X_t = x_{1t}, x_{2t}, \dots, x_{nt}$ be a multivariate stochastic process and let $W_{jt} = w_{1jt}, w_{2jt}, \dots, w_{njt}$ represent the resultant scale λ_j wavelet coefficients attained by employing MODWT. Fernández-Macho (2012) outlines the WMC represented by $\Omega X(\lambda_j)$ as a set of multiscale coherence calculated from Xt as follows: the square roots of the regression coefficient of determination (R^2) formed by the linear combination of $w_{ijt}, i = 1, 2, \dots, n$ variables for which this R^2 is maximum are designed at each wavelet scale λ_j . It is known from earlier studies that none of The auxiliary regressions should be run, since R^2 that corresponds to the regression of a variable z_i on a set of predictors $\{z_k, k \neq i\}$ can be represented as $R_i^2 = 1 - \rho^{-ii}$, where ρ^{ii} is the *i*th diagonal portion of the inverse of the complete correlation matrix *P*. Hence, WMC is achieved as in Equation (3)

$$\Omega X(\lambda_j) = \left(1 - \frac{1}{\max \text{diag} P_j^{-1}} \right)^{1/2} \tag{3}$$

where P_j is the ($n \times n$) correlation matrix of W_{jt} .

Regarding the theory of regression, and the fitted values of z_i as \hat{z}_t , then the WMC can be expressed as in Equation (4)

$$\Omega X(\lambda_j) = \text{Corr}(\tilde{w}_{ijt}, \hat{w}_{ijt}) = \frac{\text{Cov}(w_{ijt}, \hat{w}_{ijt})}{(\text{Var}(w_{ijt}) \text{Var}(\hat{w}_{ijt}))^{1/2}} \tag{4}$$

where w_{ij} is selected to maximise $\Omega X(\lambda_j)$ and \hat{w}_{ijt} are the fitted values in the regression of w_{ij} on the remaining wavelet coefficients at scale λ_j .

The wavelet multiple cross-correlations (WMCC) may be defined as generated by allowing a lag τ between observed and fitted values at each scale λ_j

$$\Omega X, \tau(\lambda_j) = \text{Corr}(w_{ijt}, \hat{w}_{ijt+\tau}) = \frac{\text{Cov}(w_{ijt}, \hat{w}_{ijt+\tau})}{\text{Var}(w_{ijt}) \text{Var}(\hat{w}_{ijt+\tau})} \tag{5}$$

where for $n = 2$, WMC and WMCC converge with the standard wavelet correlation and cross-correlation.

To estimate WMC and WMCC, let us realise the multivariate stochastic process X_t for $t = 1, 2, \dots, T$ be $X = \{X_1, X_2, \dots, X_T\}$. Relating a MODWT of order J to each of the univariate time series $\{X_{1j}, \dots, X_{Tj}\}$, for $i = 1, 2, \dots, n$, the J length – T vectors of coefficients of MODWT $\tilde{W}_j = \{\tilde{W}_{j1}, \tilde{W}_{j1}, \dots, W\tilde{W}_{j,T-1}\}$ for $j = 0, 1, \dots, J$ is obtained. In this study,

the univariate time series are individual country-level macroeconomic variables representing EXR, CPI and NEER in addition to the GEPU as a measure of external shock. Hence, the WMC and WMCC is performed specifically for each country-level macroeconomic variable but for the four countries at a time upon their respective combinations.

This can be represented in the study’s context as— $\{EXR_{1i}, \dots, EXR_{1T}\}$, $\{CPI_{1i}, \dots, CPI_{1T}\}$ and $\{NEER_{1i}, \dots, NEER_{1T}\}$ for $i = 1, 2, 3, 4$, representing Côte d’Ivoire, Gambia, Ghana and Nigeria. The J length – T vectors of the coefficients of MODWT $\tilde{W}_j = \{\tilde{W}_{j1}, \tilde{W}_{j2}, \dots, \tilde{W}_{j,T-1}\}$ for $j = 0, 1, \dots, J$ is obtained.

From Equation (5), a nonlinear function of all $n(n - 1)/2$ wavelet correlations of scale λ_j and a steady estimator of wavelet correlation from the MODWT can be represented by

$$\tilde{\Omega}X(\lambda_j) = \left(1 - \frac{1}{\max \text{diag } \tilde{P}_j^{-1}}\right)^{\frac{1}{2}} = \text{Corr}(\tilde{w}_{ijt}, \hat{w}_{ijt}) = \frac{\text{Cov}(\tilde{w}_{ijt}, \hat{w}_{ijt})}{\left(\text{Var}(\tilde{w}_{ijt})\text{Var}(\hat{w}_{ijt})\right)^{1/2}} \quad (6)$$

where \tilde{w}_{ij} : the regression of the same set of regressors $\{\tilde{w}_{kj}, k \neq i\}$ maximises the R^2 , \hat{w}_{ij} denotes conforming fitted values and $L_j = (2^j - 1)(L - 1)$ is the number of wavelet coefficients influenced by the boundary conditions associated with wavelet filter of length L and scale λ_j , but $\tilde{T} = T - L_j + 1$ is the number of wavelet coefficients unaffected by the boundary conditions.

In the same vein, a consistent estimator of the WMCC can be computed as

$$\tilde{\Omega}X, \tau(\lambda_j) = \text{Corr}(\tilde{w}_{ijt}, \hat{w}_{ijt+\tau}) = \frac{\text{Cov}(\tilde{w}_{ijt}, \hat{w}_{ijt+\tau})}{\left(\text{Var}(\tilde{w}_{ijt})\text{Var}(\hat{w}_{ijt+\tau})\right)^{1/2}} \quad (7)$$

In calculating the confidence interval (CI) of WMC, Fernández-Macho (2012) applies the transformation defined as $\arctan h(r)$, where $\arctan h(\cdot)$ is the inverse hyperbolic tangent function for simplicity’s sake (Tweneboah 2019). The confidence interval is built on a similar idea of the realisation of X in the estimation of WMC and WMCC, and hence for $\tilde{\Omega}X(\lambda_j)$ in Equation (7), the $\tilde{z}_j \sim F\aleph(z_j, (T/2^j - 3)^{-1})$, where $z_j = \arctan h(\tilde{\Omega}X(\lambda_j))$, $\tilde{z}_j = \arctan h(\tilde{\Omega}X(\lambda_j))$ and $F\aleph$ symbolise the folded normal distribution. Thus, an estimate $(1 - \alpha)$ CI is represented by

$$CI(1 - \alpha)(\tilde{\Omega}X(\lambda_j)) = \tanh \left[\tilde{z}_j - \frac{C_2}{\left(\frac{T}{2^j} - 3\right)^{\frac{1}{2}}}; \tilde{z}_j + \frac{C_1}{\left(\frac{T}{2^j} - 3\right)^{\frac{1}{2}}} \right] \quad (8)$$

where the $F\aleph$ critical values C_1 and C_2 are: $\Omega(C_1) + \Omega(C_1 - 2z^0) = 1 - \alpha/2$ and $\Omega(C_2) + \Omega(C_2 - 2z^0) = 2 - \alpha/2$, with $\Omega(\cdot)$ as the standard normal distribution function and $\tanh(z^0) = \Omega_X^0(\lambda)$ as the value of some WMC formulated under a null hypothesis of the absence of correlation.

3. Data Sources and Description

The study employs four macroeconomic variables for four West African countries—Côte d’Ivoire, Gambia, Ghana and Nigeria. The macroeconomic variables include inflation (CPI), nominal effective exchange rate (NEER), exchange rate (EXR) and Global Economic Policy Uncertainty (GEPU). The monthly data spans from February 1997 to May 2019, yielding a total of 268 observations. This is conducted to ascertain the dynamics of macroeconomic variables in some selected West African countries prior to the COVID-19 pandemic period but covers the Global Financial Crisis and Eurozone crisis from 2007–2013, European Sovereign debt crises, U.S.–China trade tension, Brexit and the Post Crisis period. Data on

GEPU was gleaned from the website <https://www.policyuncertainty.com/index.html> as developed by Baker et al. (2016), whereas data on CPI, NEER and EXR were obtained from the IMF IFS Database. The analysis was based on the returns of daily indexes as shown $r_t = \ln P_t - \ln P_{t-1}$. Where r_t is the continuously compounded return, and P_t and P_{t-1} are current and previous values, respectively.

Preliminary Analysis

Figure 1 shows the time-varying plots of macroeconomic variables for four West African countries in addition to the Global Economic Policy Uncertainty (GEPU). It is clear from the CPI of each country that there is a persistent increase in general price levels over the years. This is similar to the behaviour of the GEPU, which has a considerable impact on most economic activities (Asafo-Adjei et al. 2020, 2021b). Furthermore, the exchange rate for Gambia, Ghana and Nigeria trends upwards but downwards for Côte d'Ivoire. Countries with a rise (fall) in the exchange rate record a fall (rise) in the nominal effective exchange rate. The returns of the macroeconomic variables display volatility clustering which is in line with the stylised facts of financial time series.

Table 1 portrays the descriptive statistics of the macroeconomic variables employed in this study. The positive means of most macroeconomic variables indicate their persistence over the sampled period with less variability. The kurtosis values beyond 1.5 demonstrate that the macroeconomic variables have a leptokurtic distribution with the skewness values depicting both negative and positive outcomes. For this reason, most of the macroeconomic variables are not normally distributed. Moreover, the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test with a null hypothesis of stationarity is utilised in this study. It can be seen that all the macroeconomic variables demonstrate stationary series (p -value > 0.05) with a failure to reject the null hypothesis.

Table 1. Descriptive Statistics.

| Statistic | GEPU | | |
|------------------|---------------|---------------|--------------|
| Mean | 0.0052 | | |
| Std. dev. | 0.1769 | | |
| Skewness | 0.4998 | | |
| Kurtosis | 4.1119 | | |
| Jarque–Bera | 24.9618 *** | | |
| KPSS | 0.0769 | | |
| Country specific | CPI | EXR | NEER |
| | | Côte d'Ivoire | |
| Mean | 0.0008 | 0.0000 | 0.0004 |
| Std. dev. | 0.0033 | 0.0100 | 0.0044 |
| Skewness | 0.6432 | −0.0168 | 0.0249 |
| Kurtosis | 7.9101 | 3.3004 | 3.5796 |
| Jarque–Bera | 287.6979 *** | 1.0205 | 3.7793 |
| KPSS | 0.2610 | 0.1005 | 0.0420 |
| | | Gambia | |
| Mean | 0.0021 | 0.0026 | −0.0023 |
| Std. dev. | 0.0031 | 0.0144 | 0.0137 |
| Skewness | 1.8019 | −0.5964 | 0.8970 |
| Kurtosis | 18.5064 | 11.6988 | 11.4160 |
| Jarque–Bera | 2830.0380 *** | 860.8572 *** | 826.8640 *** |
| KPSS | 0.1594 | 0.1869 | 0.2417 |
| | | Ghana | |
| Mean | 0.0051 | 0.0055 | −0.0053 |
| Std. dev. | 0.0060 | 0.0113 | 0.0128 |
| Skewness | 1.8796 | 0.1655 | 1.2627 |
| Kurtosis | 17.1587 | 14.9502 | 21.9801 |

Table 1. Cont.

| Statistic | GEPU | | |
|-------------|---------------|-----------------|-----------------|
| Jarque–Bera | 2396.3540 *** | 1595.9130 *** | 4093.9430 *** |
| KPSS | 0.3519 | 0.2277 | 0.2204 |
| | | Nigeria | |
| Mean | 0.0040 | 0.0043 | −0.0040 |
| Std. dev. | 0.0061 | 0.0375 | 0.0376 |
| Skewness | 0.2809 | 14.5327 | −14.1077 |
| Kurtosis | 6.1244 | 226.3823 | 217.8888 |
| Jarque–Bera | 112.5313 *** | 566646.3000 *** | 524535.5000 *** |
| KPSS | 0.0327 | 0.1897 | 0.1690 |

Note: (***), (**) and (*) denote significance at 1%, 5% and 10%, respectively.

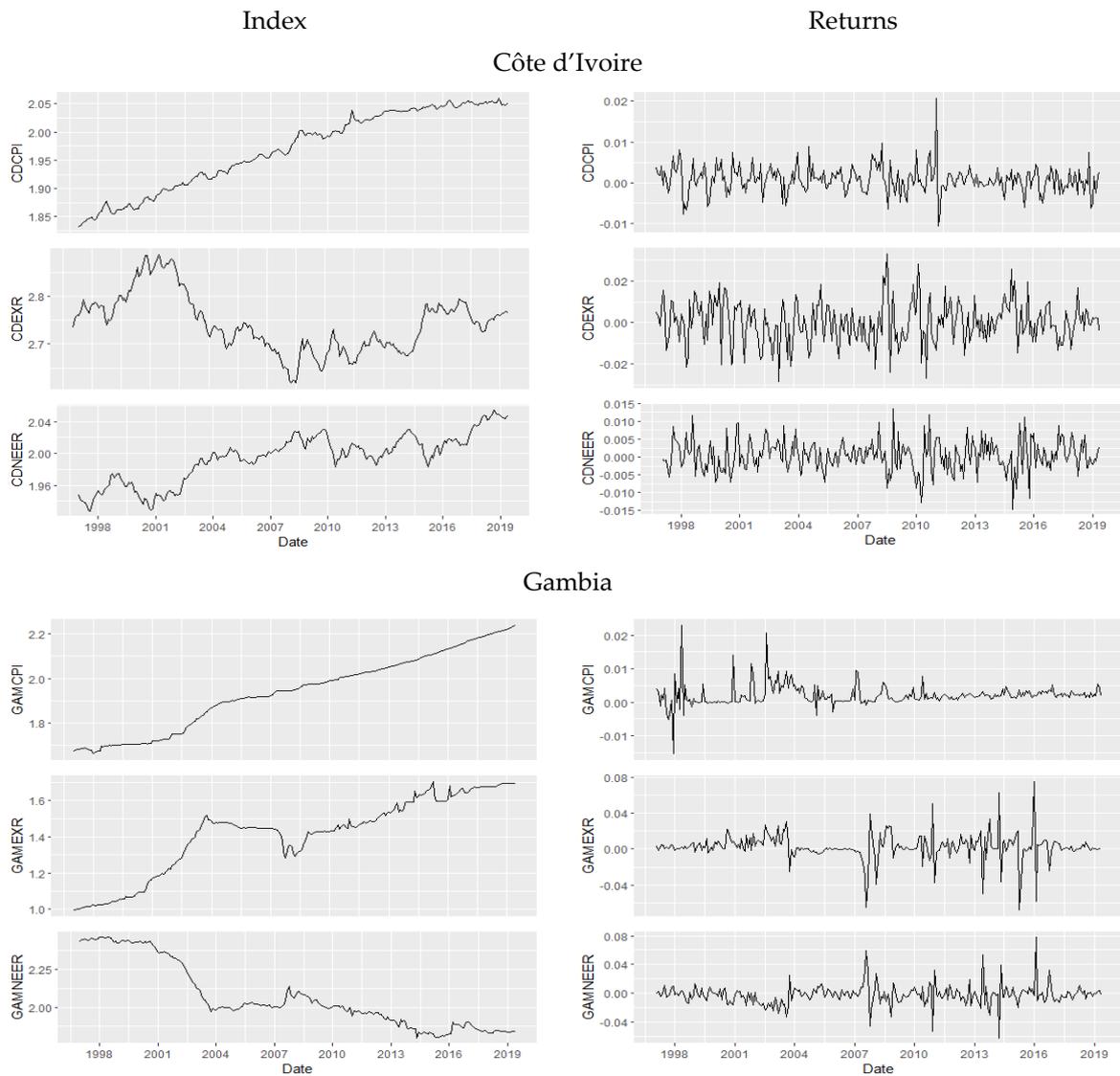


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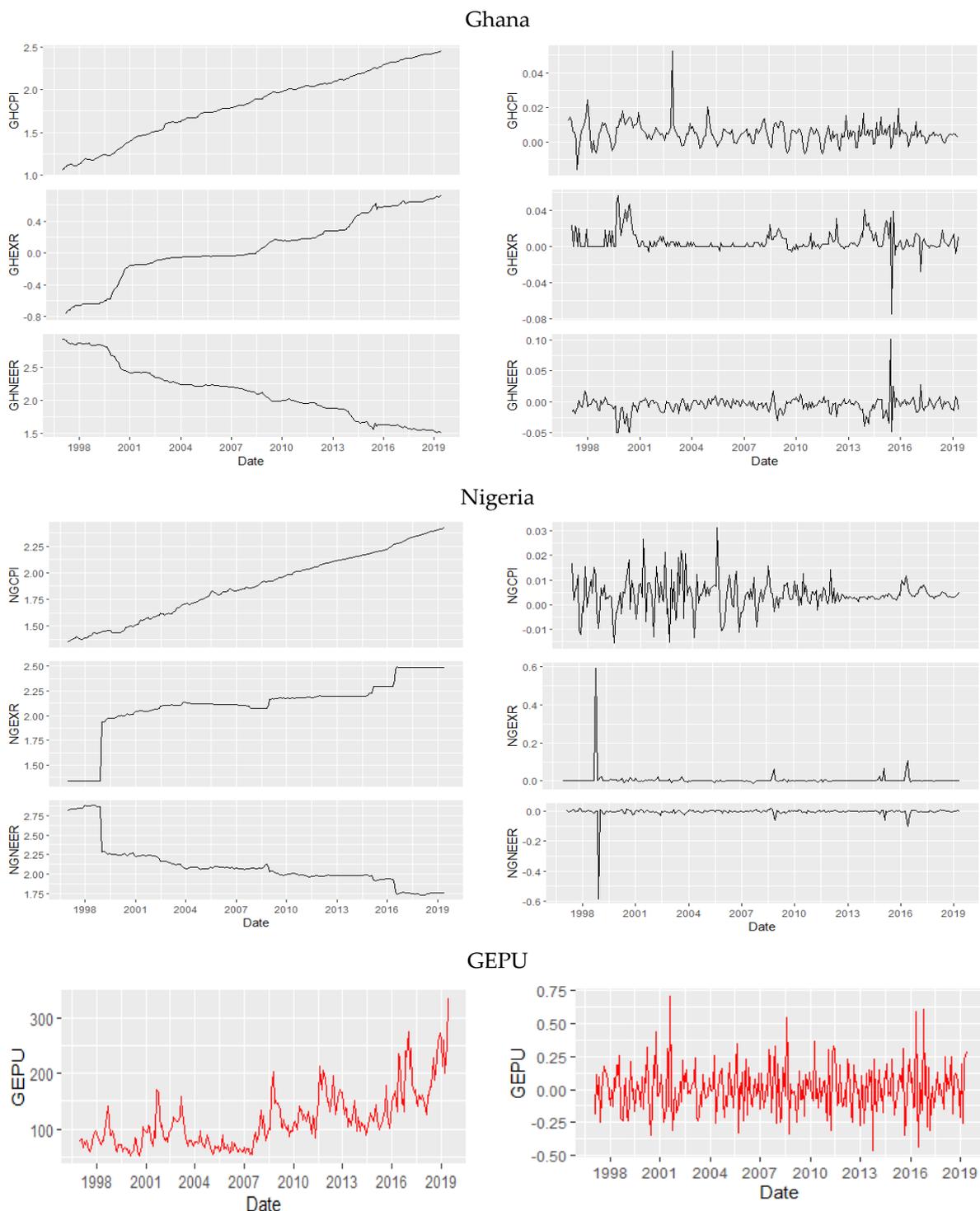


Figure 1. Plots of prices and return series of macroeconomic variables.

4. Results and Discussion

The study presents the empirical analysis in two parts. The first section deals with the time-frequency analysis of the comovements among the macroeconomic variables of the four West African countries for the sampled period. The second section contains the degree of interdependencies among the macroeconomic variables of the four West African countries, in addition to external shocks in a frequency domain. As a result, both the vector wavelet coherence and the wavelet multiple are employed for the first and second sections, respectively. The monthly data is used and set lj , $j = 1 \dots 5$ of the wavelet factors, which are

connected to times of, respectively, 2–4 months (short term), 4–16 months (medium-term) and above 16 months (long-term).

4.1. Time–Frequency Domain

The degree of interdependence between the series is represented by the surface colour and the colour palette. The red (warm) colour signifies parts that have major interactions, while the blue (cold) colour shows a lower series of correlations (Owusu Junior et al. 2018; Frimpong et al. 2021; Asafo-Adjei et al. 2021a). The results outside the cone of influence are not significant since they are beyond the 95% confidence level.

Figure 2 provides an overwhelming outcome on the comovements among all the macroeconomic variables in time–frequency domain for the four West African economies. For this reason, the vector wavelet coherence is employed. Since the vector wavelet has a feature of assessing the possible influence of one or more interdependent variable(s) on a dependent variable, the possible combinations to capture this dynamic is presented. Thus, the dependency structure of each member country on the remaining members for each macroeconomic variable is adequately captured to reveal hidden relationships, which is lacking in most empirical literature on convergence in West Africa (Alagidede et al. 2008; Adam et al. 2010; Agyapong and Adam 2012; Owusu Junior et al. 2017, 2019; Adam and Ofori 2017; Gyamfi et al. 2019; etc.).

The outcome from Figure 2 shows that all macroeconomic variables presented in this study are highly interconnected in the short, medium and long term. This contradicts with prior studies conducted within this region (Alagidede et al. 2008; Adam et al. 2010; Owusu Junior et al. 2017, 2019). This may be as a result of the consideration of integration in a univariate or bivariate case, wherein economic interactions do not operate in isolation. In comparison with the study of Adu et al. (2019), real effective exchange rate in WAMZ exhibited heterogeneous dynamics to shocks from oil price, suggesting a costly monetary union, when the structural VAR model was employed. However, the model used could not examine the direct interdependencies among the macroeconomic indicators of all countries at the same time to give a clearer picture since macroeconomic interactions do not happen in isolation.

The strong comovements between 2006 and 2013 can be traced to the Global Financial Crisis (GFC) and Eurozone crisis from 2007–2013, which adversely impacted most economic activities around the globe, although connectedness is also strong for other time–frequencies. This is not startling because during the 2008 GFC, inflationary pressures were on the surge in West Africa (Abban 2020). Additionally, the contagion effect of the Eurozone crisis significantly impacted other world economies, including West Africa, to consider flights to safety (Brunnermeier and Reis 2019; Caetano et al. 2021). Consequently, high inflation significantly impacted the dynamics of exchange rate to fall, in line with the assertion made by Krugman et al. (1998). The outcome obtained from this study contradicts that of Caetano and Caleiro (2018), who found a broad decline in business cycle synchronisation in Europe, and Abban (2020) in Africa. Hence, the high connectedness during crises periods implies that economies in the region begin to converge, demonstrating similar response to shocks. This depicts that macroeconomic variables in the four West African countries are highly susceptible to crises, particularly the GFC and Eurozone crises.

There have been several attempts to form subregional economic blocs with the goal of a single currency formation for the ECOWAS region and Africa as a whole (Adam et al. 2010; Owusu Junior et al. 2017, 2019). In the bid to alleviate the multiplicity of currencies in West Africa, it is relevant that the possible impact of economic events is taken into consideration. Moreover, there is a growing concern for achieving convergence in the region regarding macroeconomic indicators, since they could hinder cross-border trade and investment. However, since these economies do not exist in isolation, it is important that their nexus are ascertained simultaneously across time and frequency to provide a clear picture of the integration.

Accordingly, due to being monoprodukt based, with primary products dominating the export sectors of this regional bloc (Eregha 2019), they demonstrate similar responses to shocks. Hence, the West African economies are vulnerable to fluctuations in macroeconomic fundamentals. This can be traced to their prices of goods and services, resulting in unpredictable macroeconomic conditions fluctuations. Consequently, they similarly encounter the challenge of fundamental current account deficits that influence their foreign reserves due to the heightened level of importation leading to adverse movements in macroeconomic variables, especially exchange rates and then inflation. In this regard, the region should not be only mindful of the degree of integration in forming a monetary union but the contagion effect of their macroeconomic fundamentals in the increase in correlations from the onset of crises.

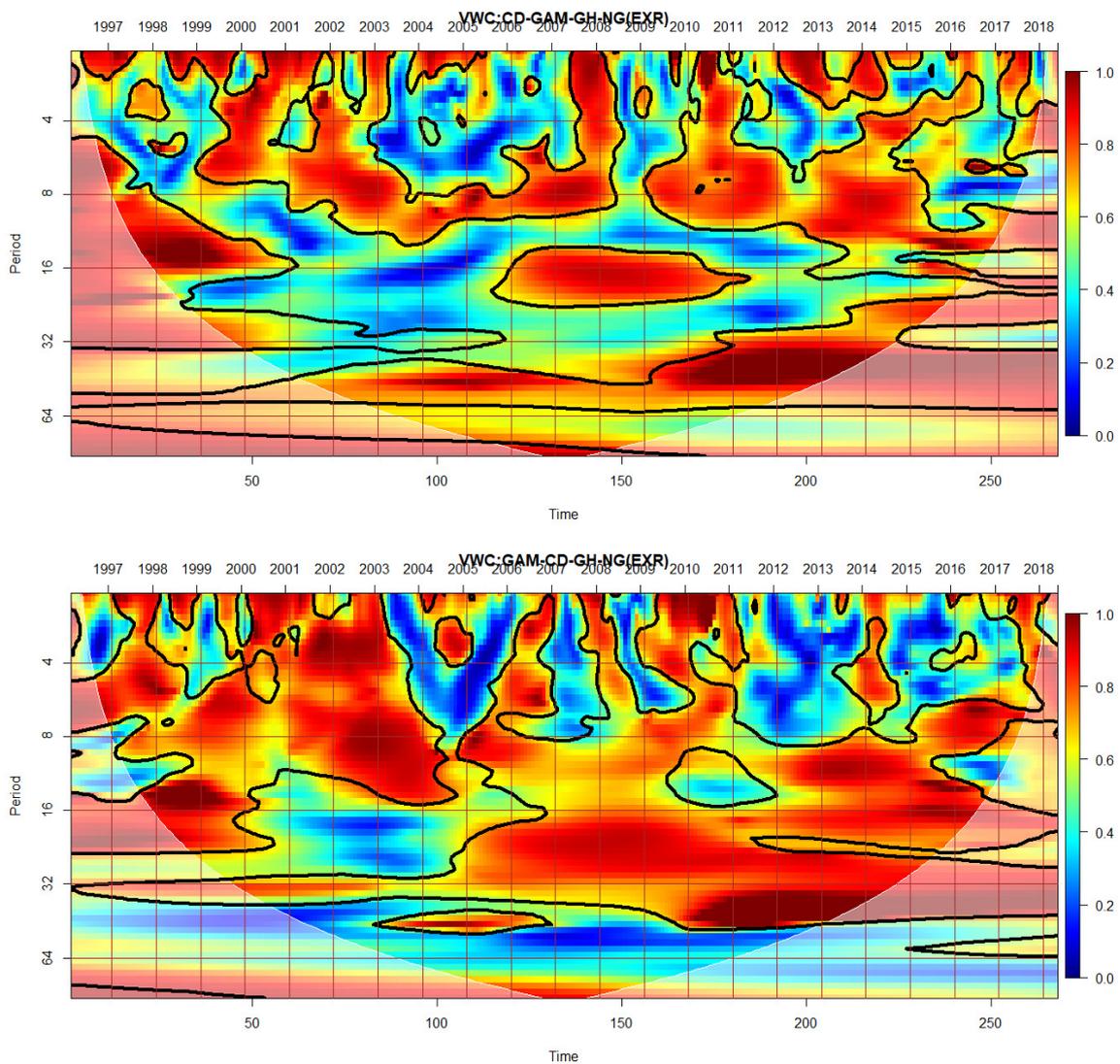


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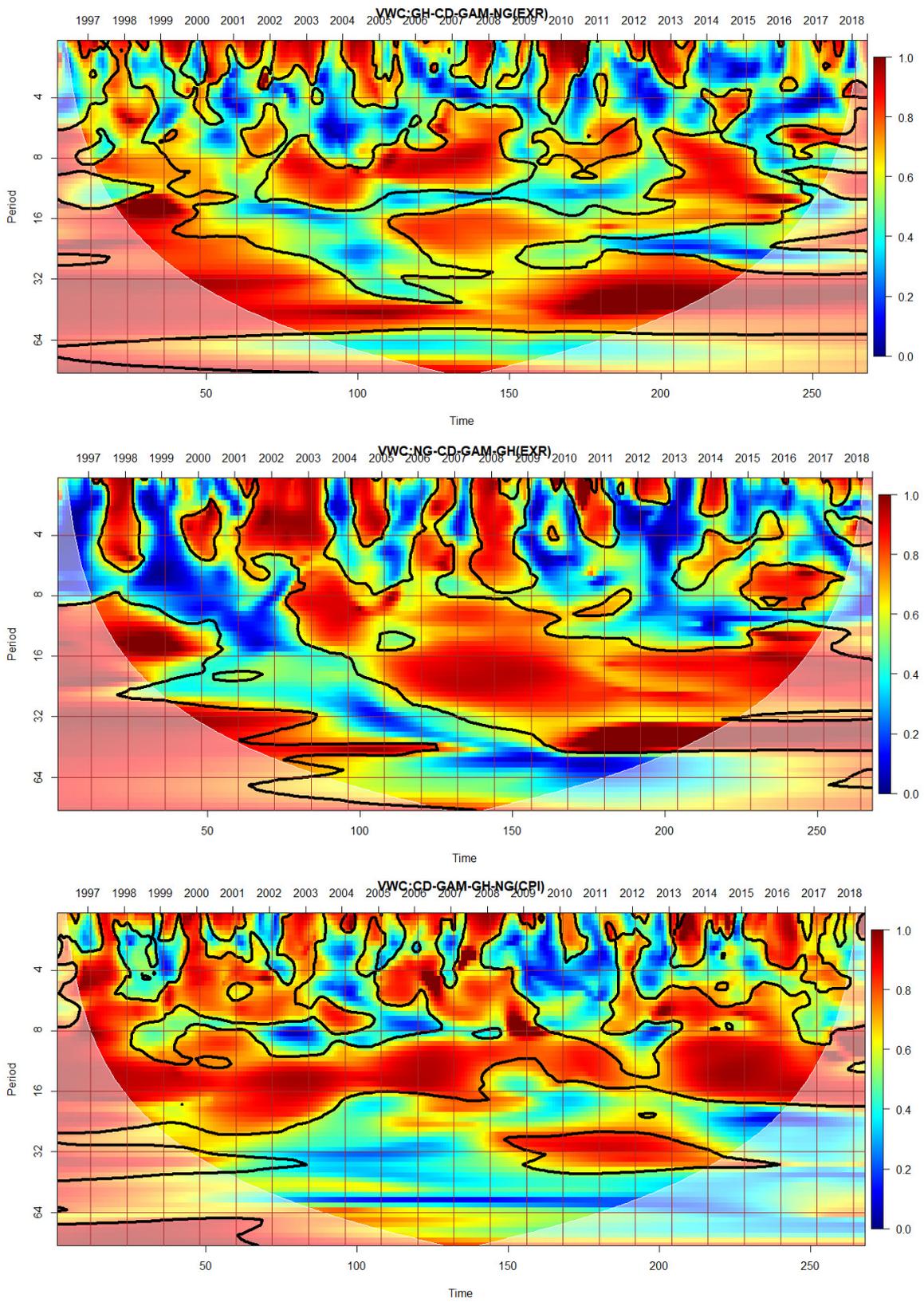


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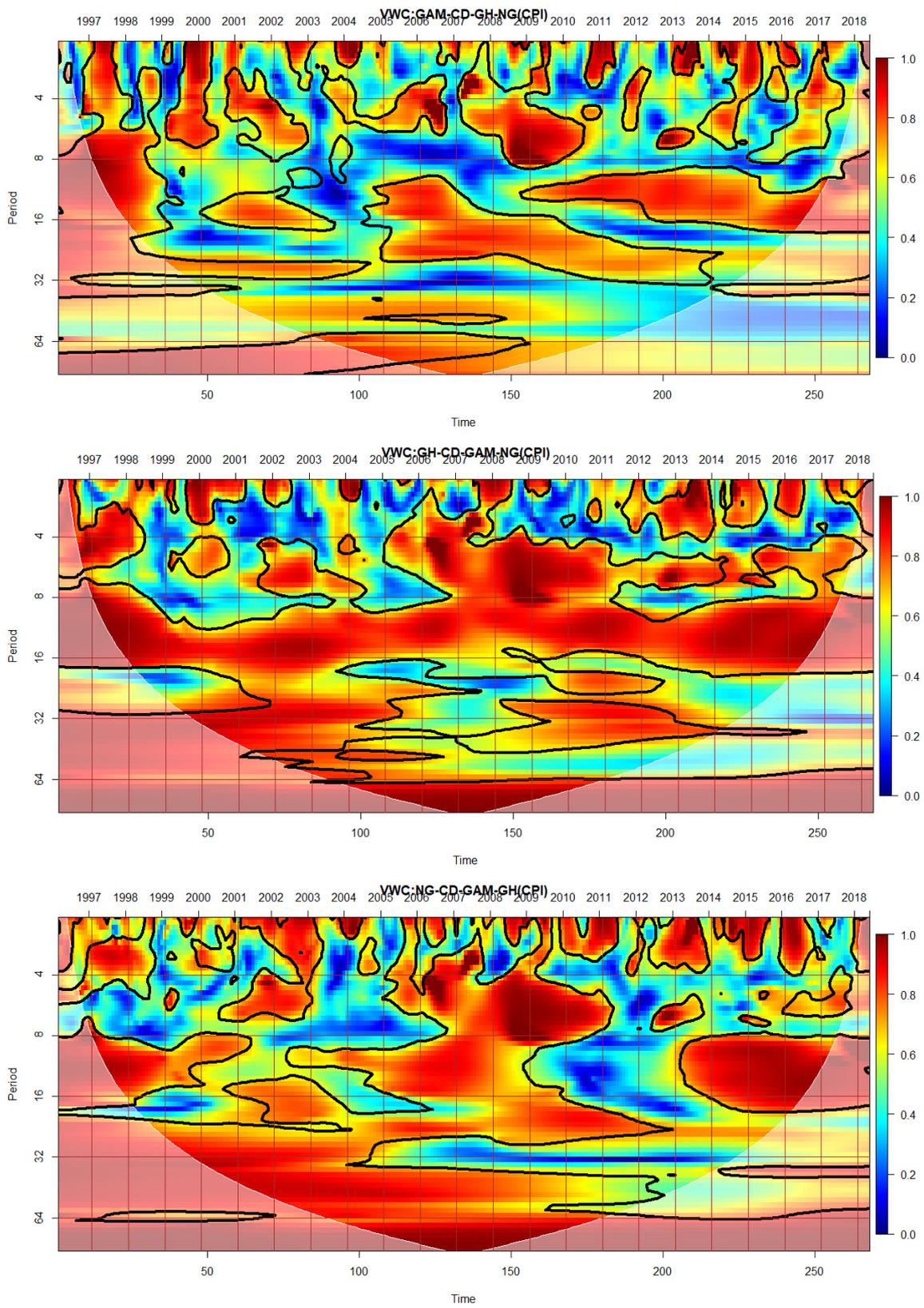


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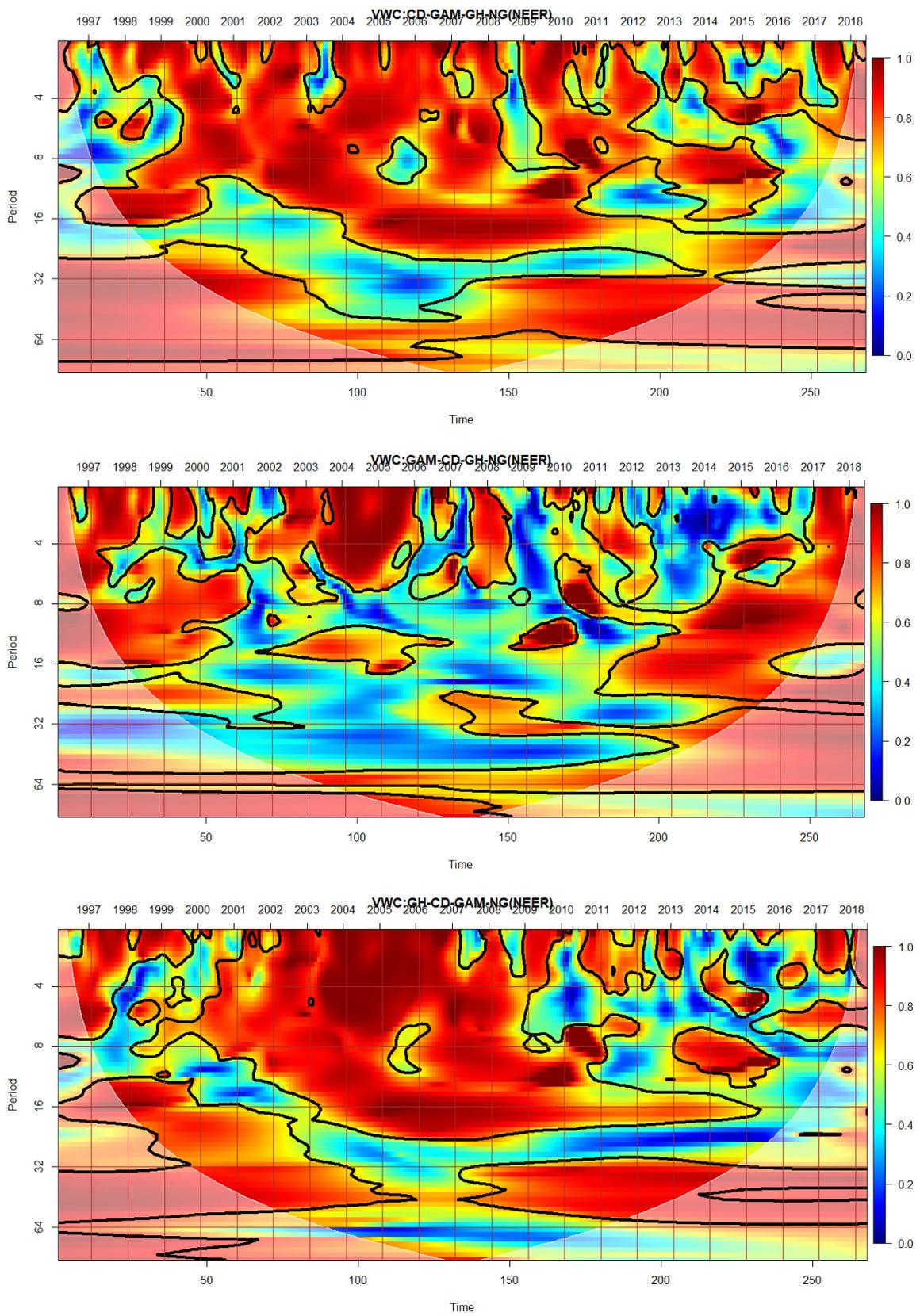


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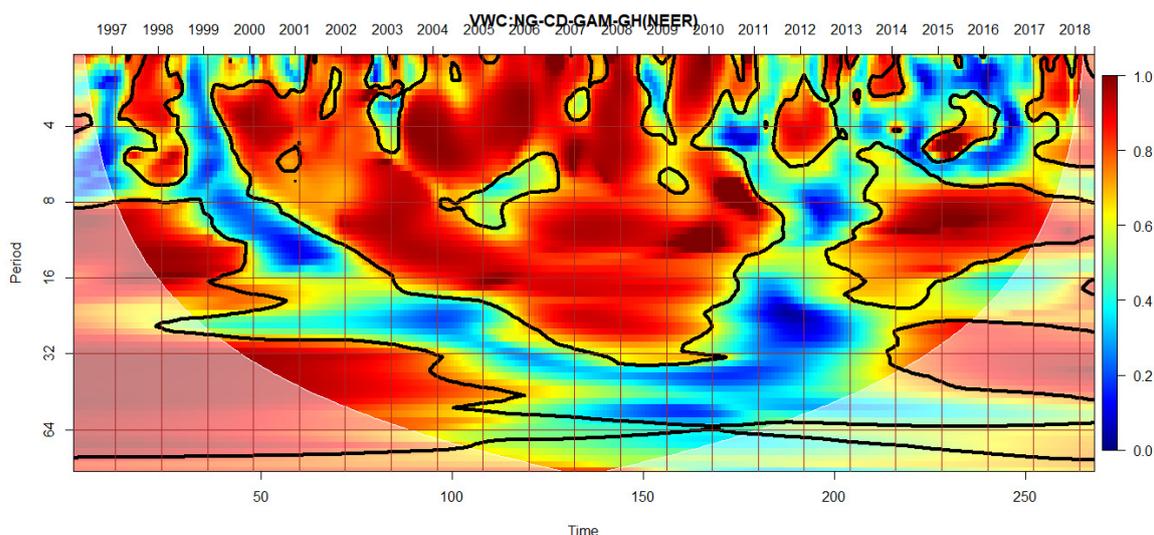


Figure 2. Multiple wavelets among country-level macroeconomic indicators.

4.2. Frequency Domain

4.2.1. Bivariate Contemporary Correlation (BCC)

At five wavelet scales, the bivariate contemporary correlations (BCC) are considered as shown in Figure 3. The codes for the variables are Côte d’Ivoire (C1), Gambia (C2), Ghana (C3), Nigeria (C4) and GEPU (C5). For calculating wavelet correlation coefficients, the horizontal axis displays the possible combinations. If we switch from left to right, the similarities between the pairs (C1–C5) become weaker. On the vertical axis, the wavelet scales reflect periods. The bivariate contemporary correlation (BCC) matrix addresses the correlation between the realizations of two possible combinations of time series in the same frequency (Asafo-Adjei et al. 2021b).

From Figure 3, integration between the macroeconomic variables in the four countries is weaker in the short and medium terms. However, in the long term, there are traces of high comovements between the macroeconomic conditions of the four countries. For instance, CPI demonstrates high comovements in the long term between Côte d’Ivoire and Gambia and Ghana and Nigeria. At that point, Côte d’Ivoire and Gambia are highly interconnected with external shocks (GEPU). It is not surprising to find that real exchange rate in West Africa is highly interconnected but demonstrates fewer linkages with external shocks. This is because real exchange rate is adjusted for the relative price of domestic and foreign goods and services, thus reflecting the competitiveness of a country with respect to the rest of the world. In other words, the real exchange rate is shielded against fluctuations in prices of domestic and foreign goods, which becomes quite convoluted for external shocks to penetrate. On the contrary, NEER has a strong exposure to external shocks due to the presence of periodic swings such as inflation, which makes it largely susceptible to shocks. The NEER represents a country’s competitiveness in terms of foreign exchange markets, but due to the uncompetitive nature of the region in the international arena coupled with excessive imports, high inflation and low value addition on exports, these economies are easily susceptible to external shocks.

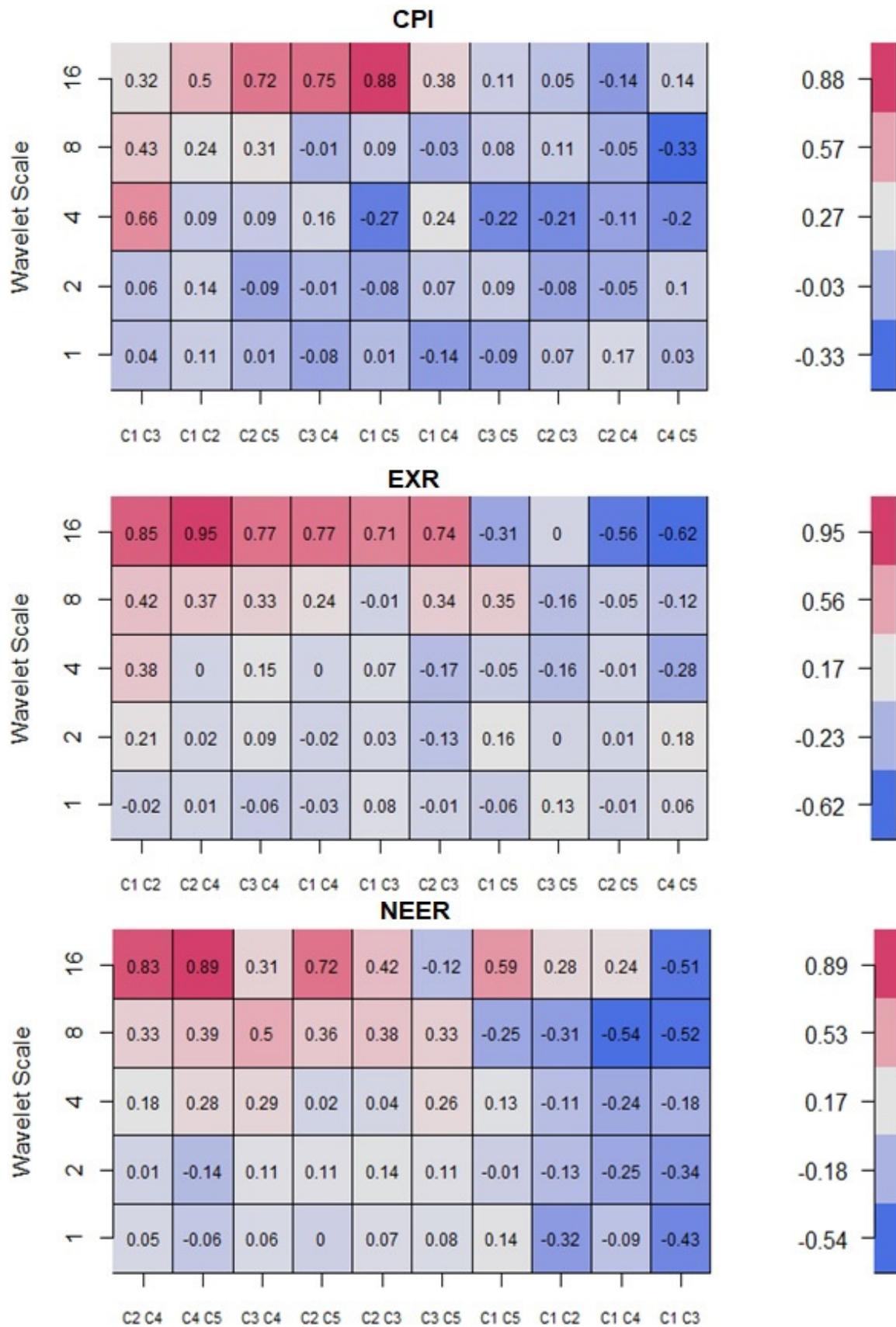


Figure 3. Wavelet bivariate correlations matrix (February 1997 to May 2019). The codes for the variables are Côte d’Ivoire (C1), Gambia (C2), Ghana (C3), Nigeria (C4) and GEPU (C5).

4.2.2. Wavelet Multiple Correlation (WMC)

This section discusses the Wavelet Multiple Correlations (WMC) for the macroeconomic variables into frequency localization by the maximal overlap discrete wavelet transform (MODWT) (Fernández-Macho 2012). It indicates the degree of integration among the study variables without necessarily indicating leading or lagging variables. Figure 4 and Table 2 establish the degree of integration among macroeconomics in the presence of external shocks from the short-, medium- and long-term dynamics in a continuous manner. The degree of interdependency is comparatively high for the monthly return series, reaching as high as approximately 0.9456 (CPI), 0.9977 (EXR) and 0.9925 (NEER) for the Wavelet Multiple Correlations. The lower panel has 0.7221 (CPI), 0.9869 (EXR) and 0.9574 (NEER), whereas for the upper panel 0.9904 (CPI), 0.9996 (EXR) and 0.9987 (NEER) are found. There is a continuous increment in multiple correlations over the horizon, except for CPI which mostly experiences an upward and downward trend. Thus, monthly returns of one variable can be explained by the remaining variables to a degree of about 94.6%, 99.8% and 99.3%, respectively, for CPI, EXR and NEER, leading up to scale 32-month interdependence. Consequently, it is found that macroeconomic variables in West Africa are highly integrated but in the long-term.

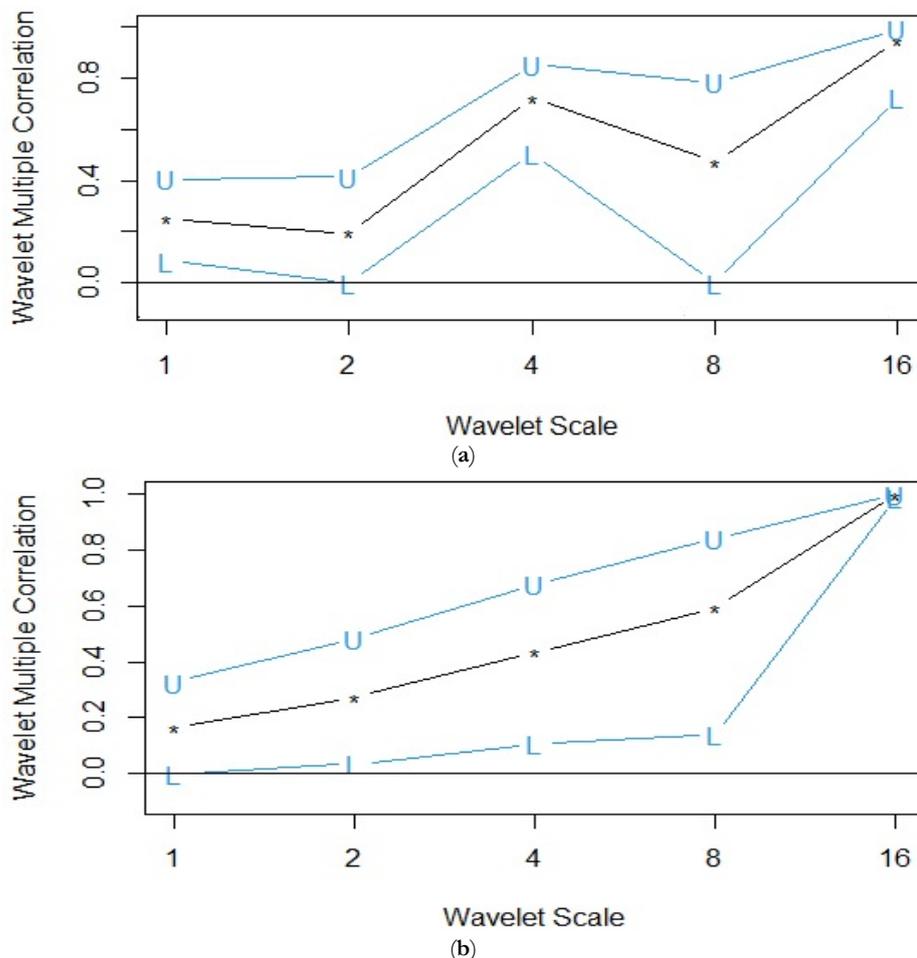


Figure 4. Cont.

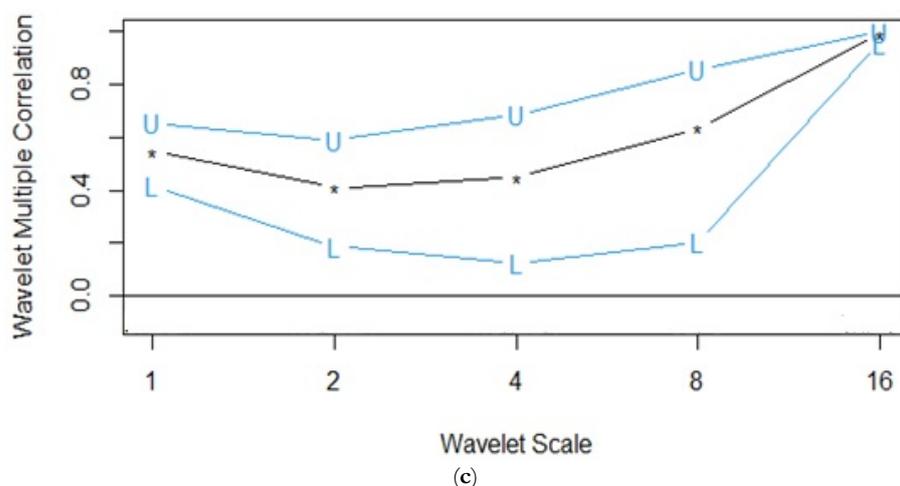


Figure 4. Wavelet multiple correlation of macroeconomic variables (February 1997 to May 2019). U—upper limits; L—lower (at 95% confidence interval). **Note:** (a–c) represent integration with CPI, EXR and NEER.

Table 2. Wavelet Multiple Correlations (WMC).

| Scale | WMC “Lower” | Correlation | WMC “Upper” |
|-------------|---------------|---------------|---------------|
| CPI | | | |
| 1 | 0.0855 | 0.2515 | 0.4038 |
| 2 | 0.0000 | 0.1931 | 0.4141 |
| 3 | 0.5041 | 0.7224 | 0.8539 |
| 4 | 0.0000 | 0.4730 | 0.7847 |
| 5 | 0.7221 | 0.9456 | 0.9904 |
| EXR | | | |
| 1 | 0.0000 | 0.1660 | 0.3264 |
| 2 | 0.0342 | 0.2721 | 0.4809 |
| 3 | 0.1060 | 0.4335 | 0.6762 |
| 4 | 0.1386 | 0.5935 | 0.8416 |
| 5 | 0.9869 | 0.9977 | 0.9996 |
| NEER | | | |
| 1 | 0.4160 | 0.5470 | 0.6557 |
| 2 | 0.1864 | 0.4083 | 0.5906 |
| 3 | 0.1227 | 0.4472 | 0.6853 |
| 4 | 0.2034 | 0.6350 | 0.8600 |
| 5 | 0.9574 | 0.9925 | 0.9987 |

4.2.3. Wavelet Multiple Cross-Correlations (WMCC)

The WMCC coefficients are presented in Table 3 depicting five wavelet scales. From Figure 5, the scales on the y-axis have similar meanings as indicated in the preliminary stage of the discussion of multiple wavelets. Following Asafo-Adjei et al. (2021a), the x-axis, however, represents the lag length of the series. In this case, 12 months for positive and negative lags each. Localisations at positive lag denote lagging variables, whereas negative lag denotes leading variables at the respective scales. At the zero lag of localisation, there is no lead or lag. Localisation implies the maximum values in the linear combination of all variables at the wavelet scales, which are indicated by dashed lines within the dotted lines (at all lags). A variable listed on a scale indicates the variable with the potential to lead or lag all the other variables. It implies that, at that scale, it has the maximum value in the linear combination of all the variables at the respective scales. The economic implication of the WMCC is that they indicate the degree of interdependence between the variables and

determine the most influential variable at a specified wavelet scale to act as either a leading (first mover to respond to shocks) or lagging (the last variable to respond to shocks after the remaining variables) variable.

From Figure 5 and Table 3, the presence of GEPU within the country-specific macroeconomic variables enable us to control for external economic policy shocks, which has an adverse impact on economic activities. Specifically, GEPU lags in the long term within the interdependence of CPI and NEER but not EXR. This suggests that the presence of inflation most likely exposes these economies to external shocks. However, when this happens, the external shocks act as a follow to influence economic activities within this region.

Nonetheless, it becomes necessary to reason that the practice of exchange rate systems with current account deficits in most economies in West Africa due to excessive imports and engaging in the export of primary products would rather result in greater susceptibility to external shocks. This heightens instability in exchange rates and inflation, thereby rendering the economy uncompetitive in the case of exports (see, Eregba 2019).

Moreover, instability in the macroeconomic variables, specifically exchange rate overvaluation, drives import license rents and huge export taxes among others to incite the presence of black markets (Pinto 1989), of which West African economies are no exception. This creates multiple exchange rates to misallocate resources. However, any attempt to unify the official and black-market exchange rates, which further increase deficits, would escalate inflation (Pinto 1989). This can be inferred from African countries such as Sierra Leone and Zambia in the nineteenth century. Hence, indeed, there is a tradeoff between the relevance of unification for effective resource allocation and the cost of inflationary pressures. It goes to suggest that the presence or unification of exchange rate black markets with the official exchange rate within the region also contributes to macroeconomic instability in West Africa.

Therefore, it is necessary that policymakers institute sound policy measures to minimise the adverse influence of external events on the interactions of possible macroeconomic variables in the short, medium and long term. Since macroeconomic variables have been revealed to have a significant impact on most economic activities, investors within these economies should hedge against the adverse influence of macroeconomic conditions with the appropriate hedging instrument across time and frequencies, having in mind the region's contagion effect.

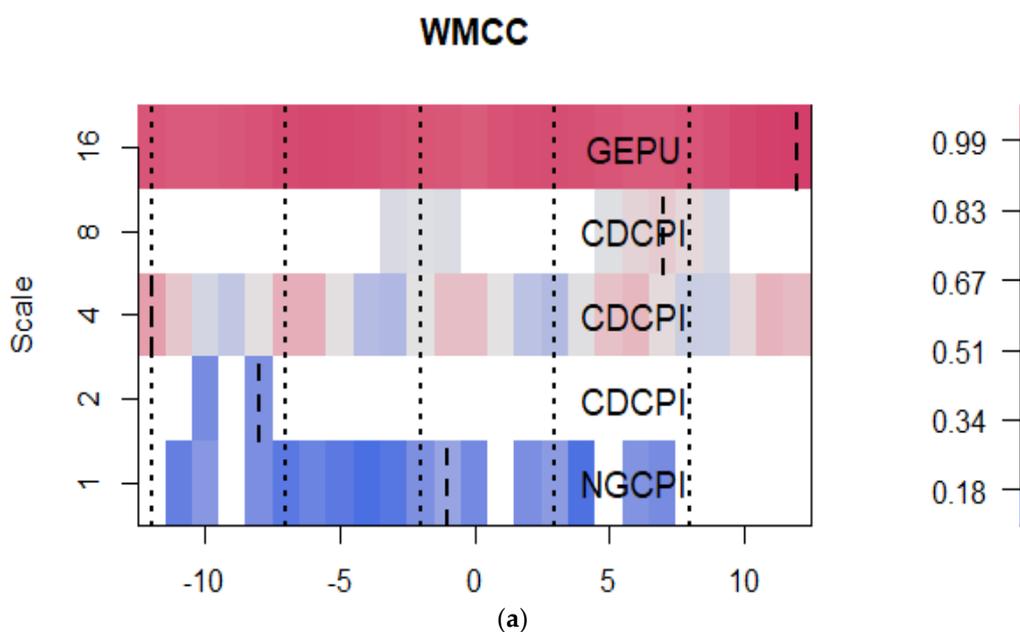


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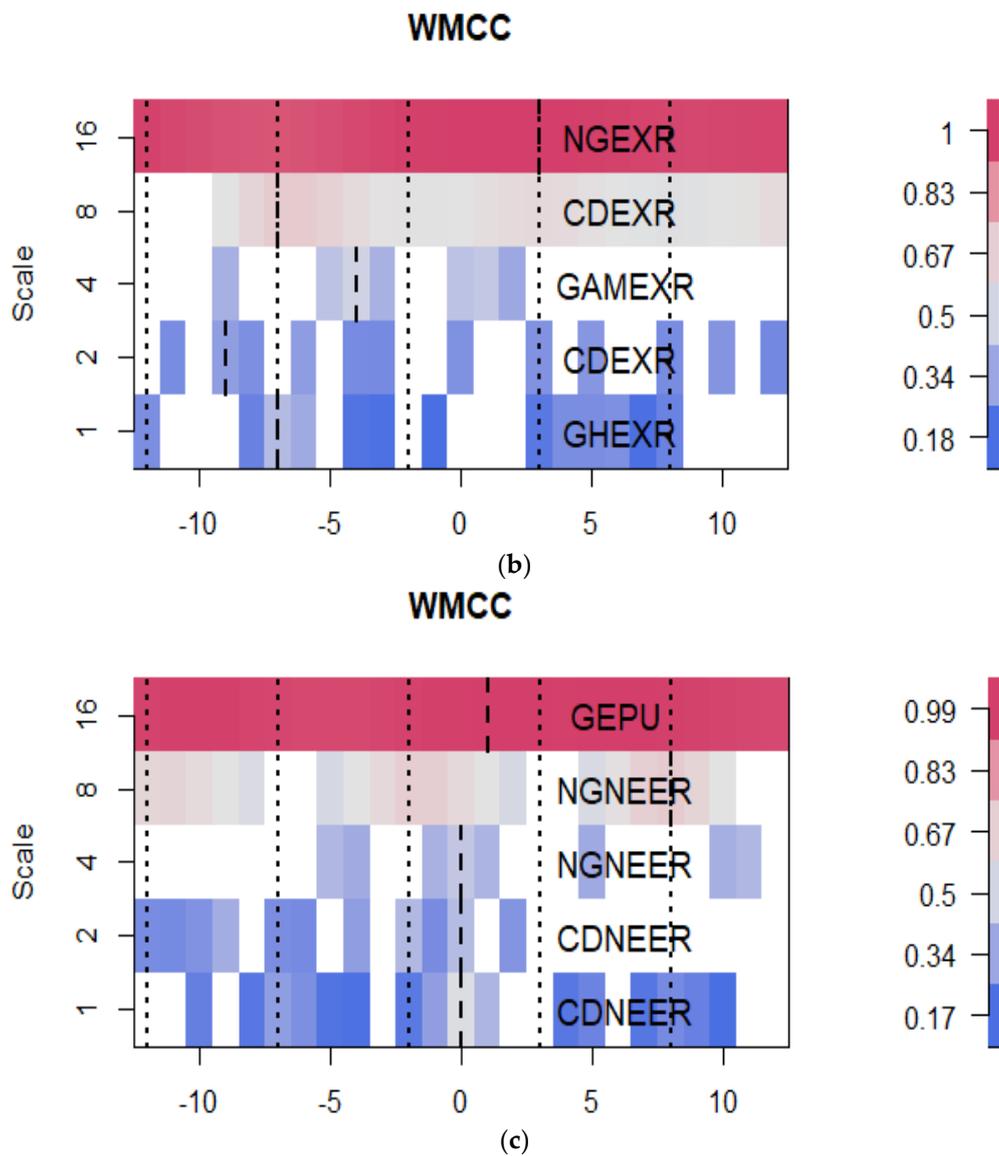


Figure 5. Wavelet multiple cross-correlation of macroeconomic variables (February 1997 to May 2019). **Note:** (a–c) represent interdependencies with CPI, EXR and NEER.

Table 3. Wavelet Multiple Cross-Correlations (WMCC).

| Scale | Localizations | Time Lag (Months) | Leading/Lagging Variable |
|------------|---------------|-------------------|--------------------------|
| CPI | | | |
| 1 | 0.3346 | -1 | Nigeria |
| 2 | 0.2722 | -8 | Côte d’Ivoire |
| 3 | 0.8057 | -12 | Côte d’Ivoire |
| 4 | 0.6838 | 7 | Côte d’Ivoire |
| 5 | 0.9945 | 12 | GEPU |
| EXR | | | |
| 1 | 0.4086 | -7 | Gha\’na |
| 2 | 0.3107 | -9 | Côte d’Ivoire |
| 3 | 0.4960 | -4 | Gambia |
| 4 | 0.6874 | -7 | Côte d’Ivoire |
| 5 | 0.9984 | 3 | Nigeria |

Table 3. Cont.

| Scale | Localizations | Time Lag (Months) | Leading/Lagging Variable |
|-------|---------------|-------------------|--------------------------|
| NEER | | | |
| 1 | 0.5470 | 0 | Côte d'Ivoire |
| 2 | 0.4083 | 0 | Côte d'Ivoire |
| 3 | 0.4472 | 0 | Nigeria |
| 4 | 0.6839 | 8 | Nigeria |
| 5 | 0.9949 | 1 | GEPU |

4.3. Robustness

To confirm the robustness of the findings, the time-varying parameter vector autoregressive (TVP-VAR) technique of Antonakakis et al. (2020) is utilised in this study. Since the TVP-VAR is robust in dealing with the problem of rolling-window sizes (Bossman et al. 2022) among several variables simultaneously, it is an appropriate time–domain technique to examine the patterns of connectedness to supplement the time–frequency as well frequency-dependent approaches already discussed.

Figure 6 presents the time-varying connectedness among country-level macroeconomic indicators in the midst of external shocks (GEPU). The GEPU is inculcated into the TVP-VAR estimations because the former was found to have a long-term impact on the dynamics of convergence as found by the prior literature (Frimpong et al. 2021; Asafo-Adjei et al. 2021b; Amoako et al. 2022; Boateng et al. 2022; etc.). It can be seen from Figure 6 that the degree of connectedness was strong prior to 2000. This is not overwhelming because, during this period, there were clear episodes of overvaluation of exchange rate relative to the post-2000 periods, and most economies' exchange rates trend downwards to a common equilibrium path (Adu et al. 2019). The degree of connectedness begins to submerge as the years increase, especially the CPI. Between 2005 and 2015, connectedness is strong from 2008 to 2013 (shown by the dotted lines), confirming the outcome obtained by the time–frequency technique.

The connectedness levels among each macroeconomic integration within the region are below 50%, highlighting a weaker degree of convergence over time. This is due to the presence of economies whose macroeconomic fundamentals are exceedingly characterised by a lack of macroeconomic restraint (Abban 2020) and the adverse influence of external shocks. In part, the findings on time-varying connectedness deviate from the multiple wavelet (time–frequency) to mean that the connectedness is stronger rather at time–frequencies.

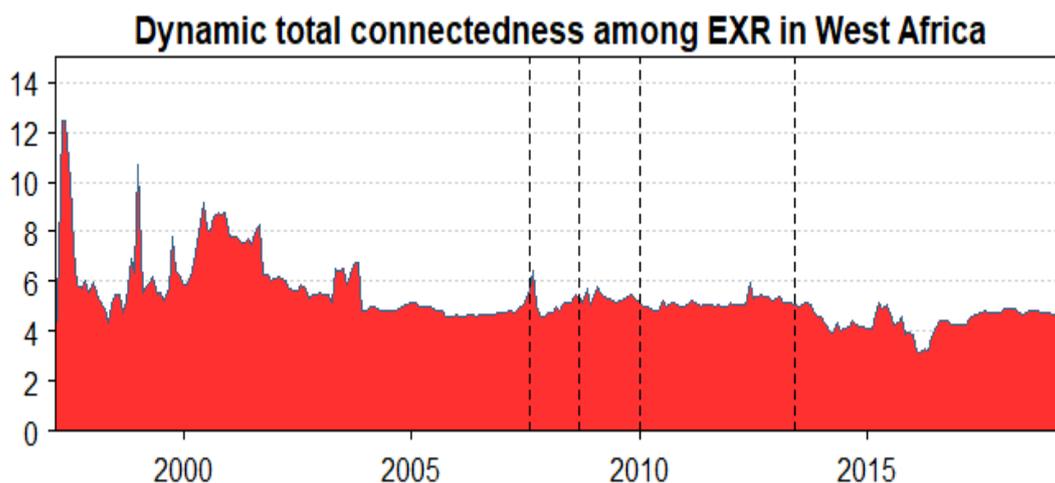


Figure 6. Cont.

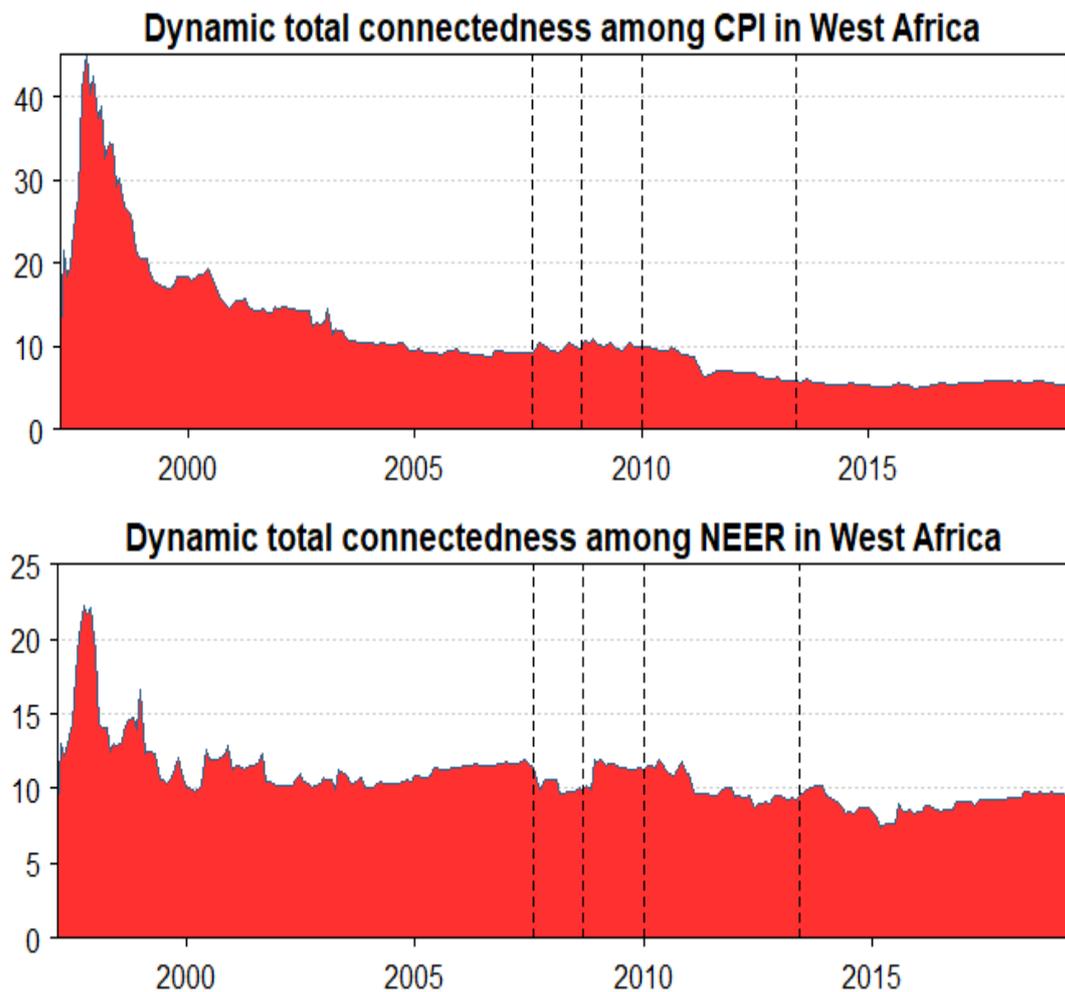


Figure 6. Dynamic total connectedness among country-level macroeconomic indicators in West Africa in the midst of external shocks.

5. Conclusions

The study presents the interconnectedness between each of three important country-specific macroeconomic variables in four West African countries in a time–frequency domain through the vector wavelet. Moreover, the wavelet multiple technique was employed to provide the extent of lead/lag relationship and the degree of integration among each of the three country-specific macroeconomic variables in the four countries while incorporating the role of GEPU in frequency dependence. The country-specific macroeconomic variables utilised are inflation (CPI), real exchange rate (EXR) and nominal effective exchange rate (NEER).

The study documents an overwhelming outcome from the vector wavelet and wavelet multiple. Findings from the vector wavelet provide that there is a very high comovement of macroeconomic dynamics of the four countries in a time–frequency domain for the selected economies. It was found that strong comovements occurred between 2006 and 2013 throughout the horizons. This can be traced from the Global Financial Crisis and the Eurozone crisis from 2007–2013, which adversely impacted most economic activities around the world. This outcome suggests that macroeconomic variables in most West African countries are highly susceptible to global financial and economic crises. In addition, the advocacy of Ekpo (2020) that West African economies face issues of political will, huge infrastructure deficit and fiscal imperatives is welcomed in this study.

From the wavelet multiple technique, three interesting outcomes were found. First, there are traces of high comovements between the macroeconomic conditions of some

countries as indicated by the BCC. The high comovements signify high convergence. This is particularly important as Alday (2021) found that convergence is rooted in lower transaction costs. Khmeleva and Czegledy (2021) also noted that the integration of regions into world economic relations helps provide responses to global challenges.

Specifically, NEER has a strong exposure to external shocks due to the presence of periodic swings such as inflation, which makes it largely susceptible to shocks. The NEER represents a country's competitiveness in terms of foreign exchange markets, but due to the uncompetitive nature of the four countries in West Africa in the international arena coupled with excessive imports, high inflation and low value addition on exports, these economies are readily susceptible to external shocks. Second, it was revealed that macroeconomic variables in the four countries are highly integrated but in the long term, as indicated by the WMC. Third, GEPUs lag in the long term within the interdependencies of CPI but not EXR from the WMCC. This suggests that the presence of inflation most likely exposes these economies to external shocks. However, when this happens, the external shocks act as a follow to influence economic activities within this region. The high integration among the macroeconomic variables is also elicited in the study of Gammadigbe and Dioum (2022) on business cycle convergence in West Africa.

It is recommended that efficient country-level policies should be geared towards inflation to enhance price stability and minimise external uncertainty shocks to overlay future convergence in West Africa.

Additional studies can consider the flow of information between the macroeconomic variables using entropy techniques. Other macroeconomic variables and economies from West Africa can be incorporated to examine the extent of convergence to provide additional insights from the region. Moreover, since inflationary pressures would lead to a fall in exchange rates (Krugman et al. 1998), further studies may investigate integration among exchange rates in West Africa while considering inflationary pressures to give a realistic view of interdependencies. It would be worthwhile to investigate integration among various regional blocs by inculcating country-level variables such as productivity.

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