



**International Journal of Sustainable Economy**

ISSN online: 1756-5812 - ISSN print: 1756-5804

<https://www.inderscience.com/ijse>

---

**Estimating the size of Nigeria's output connectedness with China, India and USA: a normalised generalised forecast error variance decomposition approach**

Anthony Orji, Ikenna P. Nwodo, Jonathan E. Ogbuabor, Onyinye I. Anthony-Orji

**DOI:** [10.1504/IJSE.2023.10045295](https://doi.org/10.1504/IJSE.2023.10045295)

**Article History:**

Received:	01 October 2021
Accepted:	05 January 2022
Published online:	15 December 2022

## **Estimating the size of Nigeria's output connectedness with China, India and USA: a normalised generalised forecast error variance decomposition approach**

---

Anthony Orji, Ikenna P. Nwodo,  
Jonathan E. Ogbuabor and  
Onyinye I. Anthony-Orji\*

Department of Economics,  
University of Nigeria,  
Nsukka, Nigeria  
Email: anthony.orji@unn.edu.ng  
Email: iyknwodo@gmail.com  
Email: jonathan.ogbuabor@unn.edu.ng  
Email: onyinye.anthony-orji@unn.edu.ng  
\*Corresponding author

**Abstract:** This paper investigated the size of Nigeria's output connectedness with China, India and USA, with particular focus on Nigeria's latest democratic era that began in 1999. The study used the normalised generalised forecast error variance decomposition (GFEVD) of the underlying vector error correction (VEC) model to construct the connectedness measures. The findings reveal that India and China are the largest contributors of spillover index in the system. Overall, the size of the connectedness index of the economies is 34.55%, which shows remarkable output spillovers among these countries. The policy implication of these results is that Nigerian economic authorities should closely monitor the output fluctuations around the world, especially those of Nigeria's top trade partners like India and China in order to mitigate adverse output shocks.

**Keywords:** connectedness; VAR model; democratic era; Nigeria; China; India; USA.

**JEL codes:** F02; C32; P16; N17.

**Reference** to this paper should be made as follows: Orji, A., Nwodo, I.P., Ogbuabor, J.E. and Anthony-Orji, O.I. (2023) 'Estimating the size of Nigeria's output connectedness with China, India and USA: a normalised generalised forecast error variance decomposition approach', *Int. J. Sustainable Economy*, Vol. 15, No. 1, pp.118–133.

**Biographical notes:** Anthony Orji is a PhD holder in Economics and Lecturer in the Department of Economics, University of Nigeria Nsukka. He is a member of the Nigerian Young Academy. He is also an Alumnus and Fellow of the African Program on Rethinking Development Economics (APORDE), Johannesburg, South Africa, Fellow of International Economic Issues and Development Policy, New Dehli, India, Fellow of the African Science Leadership Programme, South Africa and a former visiting scholar to the University of Laval, Quebec, Canada. He has published widely and attended

several national and international conferences. He is a member of many research organisations and has participated in several research projects funded by the following institutions: World Bank; Partnership for Economic Policy (PEP), African Economic Research Consortium (AERC) and others. His teaching and research interests are in development economics, macroeconomics, monetary economics, gender issues, finance and resource mobilisation.

Ikenna P. Nwodo is an Economist and an Alumnus of the Department of Economics University of Nigeria, Nsukka. He has attended some international conferences and publishes widely in the field of Economics and Finance.

Jonathan E. Ogbuabor is a renowned scholar, lecturer and researcher. He obtained his Master's degree from the University of York, UK and PhD in Economics from the Department of Economics, University of Nigeria Nsukka. He is also a Lecturer in the Department of Economics, University of Nigeria Nsukka. He is a member of many professional bodies including; the Nigerian Economic Society (NES), Institute of Chartered Accountants of Nigeria (ICAN), among others. He has attended many national and international conferences and publishes widely. His teaching and research interests are in the field of development economics, climate change, agriculture, energy economics, monetary economics, and applied econometrics.

Onyinye I. Anthony-Orji is a PhD holder in Economics and Lecturer at the School of General Studies (Social Sciences Unit) and the Department of Economics, University of Nigeria Nsukka. She has published widely in local and international journals and her research interest is in the areas of development economics, monetary economics, finance and resource mobilisation.

---

## **1 Introduction**

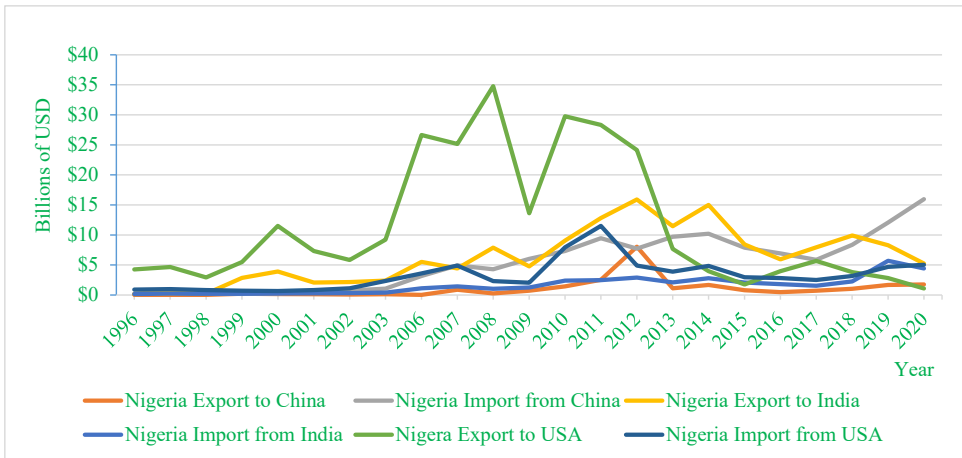
Nigeria returned to democratic rule in 1999 after many years of military dictatorships that began in a 1983. Following the seizure of political power by the military in 1983, Nigeria has witnessed several military coups, which heightened uncertainty in the country (Isaac et al., 2021). Such uncertainty may have adversely affected the country's domestic economic, financial and trade activities within itself and with the rest of the world (Anthony-Orji et al., 2019; Ogbuabor et al., 2020a, 2020b; Ekeocha et al., 2021a, 2021b). Thus, the return to democratic rule in 1999 ushered in a new era of improved external relations and increased economic activities for the country. Interestingly, China, India and the USA have emerged as Nigeria's top trade partners since 1999. This study is therefore motivated to investigate Nigeria's output connectedness with these top trade partners during this ongoing democratic era.

Many studies abound on the macroeconomic connectedness of economies around the world (e.g., Kose et al., 2003; Doyle and Faust, 2005; Canova et al., 2007; Diebold and Yilmaz, 2009, 2014, 2015b; Park and Shin, 2014; Asteriou and Moudatsou, 2015; Greenwood-Nimmo et al., 2015; Ogbuabor et al., 2018, 2016). The growing global interdependence or connectedness among economic entities around the world in recent decades actually necessitated these studies so as to enable better understanding and modelling of the dynamics of such interlinkages. In fact, the raging rise in international

real and financial interconnectedness among economies has been majorly attributed to the wave of globalisation, deregulation, privatisation and liberalisation sweeping across the globe as well as the rising specialisation in production among nations caused by disparity in technologies and endowments, and breakthrough in information and communication technology (Backus et al., 1993; Baxter, 1995; Park and Shin, 2014). Park and Shin (2014) also maintained that increased connectedness among countries could lead to shared prosperity, but not without concomitant transmission of real and financial shocks among countries. A vivid example of this is the global financial crisis (GFC) of 2007/2008.

Statistical facts reveal that the total export value flow from Nigeria to China decreased from US\$7.2 bn in 2017 to US\$1.0 bn in 2018 thus China emerged as the 16th largest Nigeria export market. On a similar note, China remains Nigeria’s first import market accounting for 19.4% (US\$8.3 bn) of Nigeria’s total imports in 2018. Similarly, India and USA are the first and second top two export destinations for Nigeria respectively with US\$7.92 bn and US\$5.67 bn of Nigeria’s total export value (International Trade Statistics, 2018). However, in 2019, India emerged as Nigeria’s 1st largest export market and 2nd top import market just behind China. More statistical trade facts involving Nigeria with the economies under review could be observed from Figure 1.

**Figure 1** Trade trend between Nigeria and China, India and USA (1996–2020) (see online version for colours)



Source: Authors’ plot using International Trade Statistics (2021)

Figure 1 shows the volume of trade activities in billions of US dollars (USD) involving Nigeria and China, India, and the USA over time. The graph shows that between 1996 and 2012, Nigeria’s total export value to the USA is larger than that of China and India but Nigeria’s total export to India overtook that of the USA from 2013 and has remained top till the present day. Similarly, Nigeria’s total import from China became very significant in 2008 and has remained larger than that of any economy. Presently, the trend shows that Nigeria’s total import from China is rising while exports to India and USA are falling and that of China is flat or horizontal.

According to Ogbuabor et al. (2018), the GFC increased the output connectedness of the Asian Pacific Economic Cooperation (APEC) economies even beyond pre-crisis level. This simply implies that countries are pulling one another down. They further stated that the spillover index rises gradually from short run through the long run. More revelations from their study note that the connectedness index is larger in the long run than in the short run. In the short run, the full and sub-sample connectedness index is 40.7%. But in the long run, the full and sub-sample estimates returned 84.7% and 82.8% connectedness index respectively. These indices are quite huge and underscore the connectedness co-movement among economies especially in the long run. The authors however maintained that their findings are consistent with the empirical revelations of Greenwood-Nimmo et al. (2015) and Doyle and Faust (2005), which suggests that spillover transmission due to the GFC most likely, influenced the real sector connectedness as business cycle becomes more synchronised. Ogbuabor et al. (2016) also noted that African economies are majorly shock receivers (whether output or financial) and quite steadily inconsequential, particularly through the long run. The authors further suggest that the spread of real output spillover slowly and gradually rose into the long run whereas financial shock spillover rose exponentially even in the short run. This simply implies that African economies, including Nigeria, are overwhelmingly shock recipients and systematically insignificant buttressing their positions as small open economies. The study summarises that advanced economies such as the USA, China, UK, among others, are more interwoven than African economies.

Similarly, Park and Shin (2014) maintain that small open economies are particularly very vulnerable to shock spillovers. This they found in their study of Korean economic integration with the global economy. Their findings suggest that the USA, China and Association of South East Asian Nations (ASEAN) as well as world energy market exert more influence on the economic activities of Korea. This means that the USA, China and ASEAN region have the capacity of propagating shocks to the Korean economy. Their recursive estimation containing over 30 rolling samples show that the advent of great recession is associated with increase in connectedness index of the Korean economy with the industrialised economies while its connectedness index decreased with the emerging economies. Strikingly, Korea's overseas trading partners explain 80% of the forecast error variance due to the Korean economy. Our study is particularly motivated following the works of Ogbuabor et al. (2016, 2018, 2020c) and Park and Shin (2014). We study Nigeria and its major trade partners in order to ascertain the direction of propagation of real output shocks as well as the degree and size of their connectedness. This is a clear deviation from previous studies that hitherto concentrated on developed economies and regional economic blocs.

**Table 1** Contributions of China, India, and USA to Nigeria's trade 2019 (in billion USD)

<i>Country</i>	<i>USA</i>	<i>China</i>	<i>India</i>
Nigeria export	\$2.8	\$1.7	\$8.3
Nigeria import	\$4.7	\$12.1	\$5.7
Trade balance	-\$1.9	-\$10.4	\$2.6
Total trade	\$7.5	\$13.8	\$14

*Source:* Authors' calculation using International Trade Statistics (2020) dataset

Statistical evidence shown in Table 1 reveals the importance of the three countries (USA, China and India) to Nigeria's commodity trade activities. Table 1 is a representation of the contributions of trade from each of the economies (USA, China, and India) to the Nigerian trading activities in 2019. It shows that India has the highest trade contribution to Nigeria followed by China with the USA as the least. In trade balance, Nigeria has a deficit trade balance with all the economies except for India. Nigeria being a small open economy will be most likely susceptible to real output variations from its major trade partners, notably China, USA and India given these huge statistics. This therefore implies that the high volume of trade between Nigeria and these economies could expose the Nigerian economy to output shocks and contagion risk arising from these economies.

The structure of this paper is as follows: Section 2 captures review of literature. Section 3 details the methodological approach. Section 4 presents the empirical results and discussion, while Section 5 concludes the paper with some policy implications.

## **2 Review of literature**

The theory of global business cycle aptly underpins the issues addressed in this study. Business cycle is equally regarded as economic or trade cycle (Madhani, 2010). Business cycle arises as a result of fluctuations in the output growth which is characterised with boom and burst. Economic cycles are mainly influenced by a summation of a pure random walk shock and not necessarily cycles. This theory argues that following the increase in world trade and financial interdependence, that regional and national businesses surge upwards creating broader business cycle. The trade linkage hypothesis also offers some support to the issues investigated in this study. This hypothesis suggests that when an economy is in trade with several partners, such an economy will have different channels through which shocks and contagion originating from the partners could be transmitted to it. This simply means that countries that trade more with each other are more likely to experience higher business cycle correlation than countries with less trade activity. Similarly, Kose and Yi (2001) note that greater trade connection can influence the global business cycle and financial contagion depending on the trade structure and nature of shocks affecting the economies. In view of this, this study is therefore anchored on the trade linkage hypothesis.

Empirical aspects of the literature have also investigated the output connectedness among countries (e.g., Ogbuabor et al., 2016; Greenwood-Nimmo et al., 2015; Diebold and Yilmaz, 2014, 2015a, 2016), though most of them centred on advanced economies and regional economic blocs. Adefabi and Rasaki (2018) examined foreign shock influence on the growth movements in Nigeria employing structural VAR (SVAR) model with quarterly data for the period 1990Q1–2016Q4. The variables included in the study were foreign debt, external GDP, oil price, external input prices, external interest rate and real interest rate volatility. The study found that global uncertainties affect Nigeria's growth with global interest rate, world input price volatility and foreign debt volatility being the main contributing factors to the nation's economic growth. This finding is indicative in the sense that one can suspect that foreign financial and external supply shocks play significant roles in the Nigerian economy. Ezema and Amakom (2011) studied the sources of Nigeria's economic spins or alterations with the application of McCarthy et al. (1994) model. The findings show that terms of trade impulses are very large in Nigeria resulting from fluctuations between the oil prosperity and bursts. Terms

of trade impulses that influence the Nigerian economy include variation in imports, economic density, export promotion and foreign debts. Ibrionke (2018) examined the channels/networks of spread of impulses using GVAR analytical framework. The results contradicted the general belief that global volatility is sourced from only macroeconomic indices. The results indicate that agent behaviour in terms of investment switching between markets of high and low volatility or outright sale and reallocation of assets cause capital outflow thus economic crisis.

Among the emerging market economies, India has emerged as a strong force to reckon with. Hence, Ibrahim and Abdulaziz (2018) investigated the Nigeria-India trade relations between 2000–2014 employing trade complementarity index and descriptive statistics as analytical tools. The findings show that Nigeria's imports from India are more diversified. Also, there is existence of partial match between Nigeria export supply and India import. The study also revealed that there has been steady increase in the trade profile of the two nations during the studied timeframe. Lakdawala and Singh (2019) explored the effect of external shocks on the Indian economy employing foreign instrument with domestic projections and structural vector autoregression (SVAR-IV). The result shows that external shocks expressively affect the Indian stock market, USD/INR exchange rates and foreign exchange reserves. Also, fluctuations in the world industrial production, oil price changes and the inconsistency of the domestic economic policies affects India's industrial production. These shocks put together account for between 15% to 35% of the fluctuations in inflation, financial variables and output for up to four-year horizon beginning with two-year horizon.

He and Chen (2014) employ frequency domain and VAR techniques with data spanning from 1979Q1 to 2010Q4 in order to offer a possible explanation to the stability of China's economy. Results show that good business practices, good policy and good luck hypotheses are the contributors to the stability of the China's macroeconomic conditions. Inoue et al. (2015) investigated the shock spillovers originating from the economy of China to Asia-Pacific countries involving 33 countries from 1979Q1 to 2014Q3. The findings are consistent with the results of Cashin et al. (2017). It shows that China's economic downturns largely influence economic activities of commodity exporters like Indonesia as well as countries that rely basically on exports like Japan, Malaysia, Thailand and Singapore. The results equally indicate that adverse real activity volatility of China affects the prices of crude oil, metal, and agricultural commodities. This study is interesting and an eye-opener in the sense that Nigeria being a primary commodity exporter and heavily reliant on the export of crude oil for her revenue and imports of consumer goods from China for her domestic consumption will likely be vulnerable whenever China sneezes or coughs.

Diebold and Yilmaz (2009) investigated how connected the world equity markets are over the period 1992M1–2007M11. The results show differing behavioural changes for equity returns and returns volatility spillovers. While equity returns spillovers show a clear mild trend devoid of bursts, returns volatility spillover shocks demonstrates no drift/trend but a clear burst/eruption. Bhattarai et al. (2020) explore the influence of US economic/monetary policy instability and the variations in the emerging market economies (EMEs) using VAR and Bayesian approach models with a monthly data spanning 1990M1 through 2014M11 covering 15 EMEs. The findings on average depict that an increase in the US interest rate leaves EMEs with a persistence rise in both short term and long-term interest rates. Also, the volatility in the US monetary policy causes a

spillover to the real output of emerging market economies (EMEs). Antonakakis and Badinger (2016) explore the real activity and real activity volatility connectedness of G-7 economies with a monthly data from 1958M2 to 2013M8. They employed a VAR-based volatility spillover index for their analysis. Their findings show that the linkage between real GDP and real GDP volatility are quite substantial with spread shock rising to an exceptional level for the period of GFC. USA was pointed as the major spreader of output growth and output growth shocks. Results of their generalised impulse response functions (GIRF) show that output volatility shocks slow down growth while output growth shocks slow down output volatility.

### 3 Methodological approach

Following the early works of Diebold and Yilmaz (2009, 2012, 2015a, 2016) and Ogbuabor et al. (2016, 2018), this study employs the network approach of Diebold and Yilmaz (2012) based on vector error correction (VEC) model for the analysis following the rejection of the null hypothesis of no cointegration. The connectedness measure is constructed based on the normalised generalised forecast error variance decomposition (NGFEVD) of the underlying vector autoregression (VAR) proposed by Koop et al. (1996) and Pesaran and Shin (1998). We therefore specify our unrestricted VAR( $p$ ) as:

$$Y_t = a_y + \sum_{i=1}^p \Phi_i Y_{t-p} + \varepsilon_t \quad (1)$$

where  $Y_t = (Y_{1t}, Y_{2t}, \dots, Y_{Kt})$  is a vector of  $K$  endogenous variables,  $a_y$  is an  $N \times 1$  vector of intercepts, and  $\Phi_i$  is the parameter matrix.  $\varepsilon_t \sim iid(0, \Sigma_\varepsilon)$  is a vector of independently and identically distributed innovations overtime,  $t = 1, 2, \dots, T$  is the time index,  $k = 1, 2, \dots, K$  is the variable folder and  $\Sigma_\varepsilon$  is a positive definite covariance matrix.  $K$ -endogenous variables include real outputs for Nigeria, China, India, and the USA, captured by the log of their respective per capita GDPs (measured in 2010 constant US dollars) from 1999Q1–2019Q4. All the variables were first indexed to 2010 base year before subjecting them to natural log transformation prior to estimation. The choice of GDP per capita as a measure of real output is indeed a good measure of the economic activity of any economy hence it remains the best measure of real output in this study. This follows economic theory and has been widely applied. Thus, this measurement approach is, however, abundant in the literature. For example; Kose et al. (2003), Muse and Uche (2018), Ogbuabor et al. (2016, 2018), Ogbuabor (2019), Greenwood-Nimmo et al. (2015, 2021), Uluceviz and Yilmaz (2021) and Obiora (2009).

Since the interest of this study is on the size of the spillover/connectedness index among these economies, the normalised GFEVD is extracted following the estimation of equation (1). This method is particularly preferred given its greater efficiency and reliability over methods such as conditional correction and Cholesky factorisation (Ogbuabor et al., 2016). The GFEVD is therefore given as:

$$GFEVD(Y_{it}, \varepsilon_{ji}, H) = d_{ij}(H) = \frac{\sigma_{\varepsilon, ii}^{-1} \sum_{h=0}^{H-1} (\mu_i' \omega_h \Sigma_\varepsilon \mu_j)^2}{\sum_{h=0}^{H-1} (\mu' \omega_h \Sigma_\varepsilon \omega_h' \mu_i)} \quad (2)$$



where  $i, j = 1, 2, \dots, N$ ,  $\sum_{\epsilon}$  is the estimated covariance matrix of the innovation vector,  $\epsilon$ ;  $\sigma_{\epsilon,ii}$  is the estimated standard deviation of the residual for  $i^{\text{th}}$  equation,  $\omega_h$  is the multiplicative coefficient matrix of  $h$ -lagged shock vector of the non-orthogonal infinite moving average VAR representation and  $\mu_i$  ( $\mu_j$ ) is  $N \times 1$  selection vector with one as the  $i^{\text{th}}$  ( $j^{\text{th}}$ ) element and zero elsewhere,  $H = 1, 2, 3, \dots, 16$  designates the forecast horizons. The outcome of this becomes  $K \times K$  matrix ( $d_{ij}(H)$ ) which is expressed as follows:

$$d_{ij}(H) = [d_{ij}(H)], \quad i, j = 1, 2, 3, 4 \tag{3}$$

Diebold and Yilmaz (2014) note that GFEVD does not usually yield unity in  $d(H)$  matrices, and as such interpretation is always complicated due to the rare orthogonality of shocks (innovations) in the GFEVD environment. Thus, following Diebold and Yilmaz (2014), we normalise matrix  $d_{ij}(H)$  as follows:

$$d_{ij}(H) = \frac{d_{ij}(H)}{\sum_{j=1}^K d_{ij}(H)} \tag{4}$$

where  $\sum_{j=1}^K d_{ij}(H) = 1$  and  $\sum_{j=1}^K d_{ij}(H) = K$  by construction.

Equation (4) shows that the total sum of GFEVD share in each row now gives 100%, thereby restoring the percentage interpretation to the GFEVD. We use equation (5) to construct the connectedness measures, including the own-contributions and cross-variable contributions defined as  $d_{ij}(H)$  and  $d_{ij}(H)$ , respectively such that  $i \neq j$ . Own-contribution shows the generalised forecast error variance (GFEV) that country  $i$  gives to itself, whereas cross-variable contribution shows the GFEV that country  $i$  gives to or receives from other economies in the system.  $d_{ij}(H)$  and  $d_{ij}(H)$  represent the principal diagonal and off-principal diagonal elements of the matrix, respectively. In line with the objective of this paper, we therefore define our total connectedness index ( $c$ ) as:

$$c = \frac{1}{N} \sum_{i,j=1}^N d_{ij}, \quad i \neq j \tag{5}$$

Equation (5) could either be gotten from averaging the directional *to-others* or *from-others* effect given as;  $\frac{1}{N} \sum_{j=1}^N T_j$  and  $\frac{1}{N} \sum_{j=1}^N F_j$  respectively, since by construction,  $\frac{1}{N} \sum_{j=1}^N T_j = \frac{1}{N} \sum_{j=1}^N F_j$ .

## 4 Empirical results and discussion

In this section we present the results of the estimation and the ensuing discussions.

### 4.1 Stationarity test results

Table 2 displays Elliott-Rothenberg-Stock (ERS) point-optimal as well as the extended ADF unit root test results for the variables under investigation.

**Table 2** Elliott-Rothenberg-Stock (ERS) point-optimal and the ADF breakpoint unit root tests

Variable	ERS level stat.	ERS 5% CV	ERS 1st diff stat.	ADF level stat.	ADF 1st diff stat.	ADF break date		Remark	
						At level	1st diff.	ERS	ADF
USA	5.526451	5.665600	7.511493***	-4.966638**	-	2008Q1	-	I(1)	I(0)
CHINA	0.593978	5.665600	12.29888***	-5.502351**	-	2006Q3	-	I(1)	I(0)
INDIA	6.359035***	5.665600	-	-3.945347	-5.660509**	2010Q1	2008Q1	I(0)	I(1)
NIGERIA	22.31514***	5.665600	-	-3.879849	-5.177330**	2012Q1	2003Q2	I(0)	I(1)

Note: Significant at \*\*\*1%, \*\*5%, and \*10%; ADF – augmented Dickey Fuller; CV – critical value.

The choice of using this type of unit root test lies in its efficiency capacity particularly with finite samples. We do know that ADF and PP are asymptotically similar, though they vary significantly in limited samples as a result of varying ways in which they treat serial correlation problem in the test equation. Specifically, Schwert (1989) notes that ADF and PP exhibits great size distortions with PP having higher size distortion consequence when a series has autoregressive moving average (ARMA) image with large and negative moving average (MA) components. The implication of this is the over rejection of  $I(1)$  null when it is actually true. However, Perron and Ng (1996) proposed valuable amendments to the PP tests in order to alleviate this huge size distortion. Similarly, equivalent complications have actually been uncovered by Caner and Kilian (2001) in Kwiatkowski-Phillips-Schmidt-Shin (KPPS) test. Another deficiency of the ADF and PP is that they have low predictive power against  $I(0)$  alternatives which are very close to being  $I(1)$ . That is, they lack clear distinguishing power between high persistent stationary processes from non-stationary processes. Additionally, inclusion of deterministic terms in the test equation declines the strength of ADF and PP unit root tests. This implies that tests in which intercept and trend are added in the test regression is less powerful than those in which only intercept is added in the test equation. Therefore, recent literatures have suggested the use of Elliot et al. (1996) and Ng and Perron (2001) proposed tests as they have been found to be most convenient and efficient with maximum predictive power against very persistent alternatives.

Secondly, to account for a possible endogenous structural break in the economy which could affect the series behaviour, the extended ADF test approach is adopted. This approach equally provides a robustness check on the ERS tests. Given the foregoing as well as the characteristics of our variables of interest, ERS and the extended ADF unit root tests are then applied. Therefore, results from both test approaches vary reasonably. That is, both the ERS and ADF tests show that our variables are fractionally integrated. For instance; under ERS test, the USA and China's real outputs are  $I(1)$  but  $I(0)$  under the ADF test. In the same vein, India and Nigeria's real outputs are  $I(0)$  under ERS but  $I(1)$  under the ADF test. The differences could be as a result of the test approaches peculiar to each test as ADF uses either innovative or additive outliers in the test equation. Additionally, the various break dates identified by the ADF test are associated with the country's respective policy change as well as external or internal shocks. For instance, the 2008Q1 break date identified for the USA could be linked to the 2007/2008 financial shock experienced in the USA triggered by the fall of Lehman Brothers which later spread across the globe and was termed 'Global Financial Crisis'.

#### 4.2 Cointegration test result

Table 3 presents the cointegration test result for the study. We can see that both the trace and maximum eigen statistic indicate at least one equilibrium relationship. Thus, we reject the null hypothesis of no cointegration in favour of the alternative that there is cointegration relationship among the variables at the 5% level. This implies that there exist a long run association among the variables under study, and as such, the underlying model for the study is estimated as a vector error correction (VEC) model.

**Table 3** Johansen cointegration test result

<i>No of CE(s)</i>	<i>Trace statistic</i>	<i>Probability values</i>	<i>Max-Eigen statistic</i>	<i>Probability values</i>
None*	58.47390	0.0037	31.07549	0.0171
1	27.39841	0.0923	13.55721	0.4024
2	13.84120	0.0874	9.871092	0.2205
3*	3.970106	0.0463	3.970106	0.0463

Note: \* indicates rejection of the null hypothesis at 5% level.

**Table 4** Connectedness table

<i>Country</i>	<i>USA</i>	<i>China</i>	<i>India</i>	<i>Nigeria</i>	<i>From others</i>
USA	49.45	7.09	25.79	17.67	50.55
China	1.64	64.88	27.86	5.61	35.12
India	1.16	8.19	87.95	2.70	12.05
Nigeria	8.64	15.53	16.30	59.53	40.47
To others	11.44	30.81	69.95	25.98	34.55

Table 4 shows the calculated connectedness table based on the normalised GFEVD from the underlying VEC. The matrix elements of Table 4 are constructed following equation (4). Items in *from-others* column and *to-others* row are constructed as the aggregation of spillovers for each row and column, respectively, excluding the own-effects or principal diagonal elements. Therefore, the total connectedness index, which tells us the total size of the output connectedness of the economies under study, is constructed following equation (5). This index (34.55%) is housed by the cell at the bottom right-hand corner of Table 4. This implies that the size or degree of the connectedness among the economies is 34.55%, which is quite substantial. This result reveals that all the economies under scrutiny are significantly interwoven, and a shock to any of the economy could be easily transmitted to other economies in the system.

Country-by-country analysis shows that the forecast error variance share due to USA by itself, China, India and Nigeria are 49.45%, 7.09%, 25.79%, and 17.69%, respectively. It could also be noted that the USA contributes 1.64%, 1.16%, and 8.64% of China, India and Nigeria forecast error variances respectively. Similarly, Nigeria received 8.64%, 15.53%, and 16.30% of the total forecast error variance from the USA, China and India, respectively; while it accounted for 17.67%, 5.61%, and 2.70% of the total forecast error variance due to the USA, China and India, respectively. The huge spillover index that Nigeria gives to the USA cannot be unconnected with the huge trade volume involving the two nations which Nigeria benefits largely from in recent time. Recall that from Table 1, USA was an important export destination and import origin for Nigeria in 2019 (UN Comtrade, 2019). In general, the total forecast error variance (50.55%) that the USA receives from the rest of the economies is largest when compared with any economy in the system. Also, the aggregate forecast error variance (69.95%) that India transmits to other economies is quite substantial and largest when compared with any economy in the system. This however gives India more spillover transmission power than any economy in the system. These results are however associated with the globalisation and liberalisation policy that the economies champion especially India, China, and USA.

Table 5 presents the short-run and long-run dynamics of the results. We find that the forecast error variance share due to USA by itself is 85.19% in the short run (horizon 1) against 24.78% (horizon 16) in the long run. This however depicts how the USA has become quite open and connected with other global economies over time, particularly India, China, and Nigeria. That is, the forecast error variance due to USA by itself depletes in the long run implying that other world economies have emerged to contribute huge spillover shock to the USA economy as a result of the USA increasing synchronisation with the rest of the world. In a similar pattern, Nigeria contributes 82.66% of the total forecast error variance due to itself in the short run (horizon 1), but the index depletes into the long run (horizon 16) with only 27.23% of the total forecast error variance. This equally buttresses the increasing interlinkage between Nigeria and the rest of the world where the world economies notably India (38.37%) and China (29.77%) took over the real output activities of the Nigerian state. In general, the short-run total connectedness index for the economies is 22.85% whereas the index rose significantly into the long run with 49.37% spillover index. The substantial increase in the connectedness index in the long run depicts the extent and degree of synchronisation among the economies understudy as a function of time.

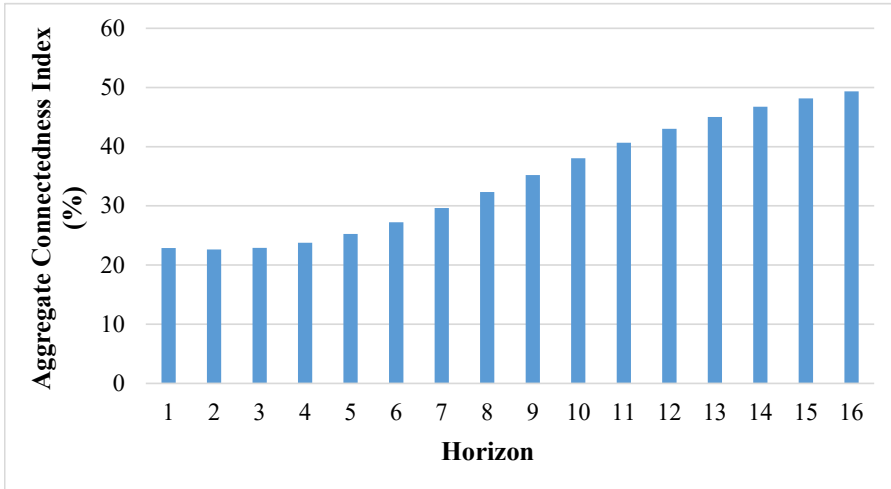
**Table 5** Time effect connectedness index

Country	Short-run connectedness index					Long-run connectedness index				
	USA	CHN	IND	NIG	From others	USA	CHN	IND	NIG	From others
USA	85.19	7.42	0.01	7.38	14.81	24.78	9.05	50.52	15.64	75.22
CHN	5.88	67.53	21.48	5.10	32.47	0.46	59.27	35.27	4.99	40.73
IND	0.01	23.29	73.22	3.48	26.78	1.05	3.15	91.25	4.56	8.75
NIG	7.16	6.24	3.93	82.66	17.34	4.63	29.77	38.37	27.23	72.77
To others	13.05	36.96	25.42	15.97	22.85	6.14	41.96	124.17	25.19	49.37

Note: USA – United States of America; CHN – China; IND – India; NIG – Nigeria.

To see how the economic synchronisation of the countries under investigation evolved overtime, we sieved out the total connectedness index for each horizon beginning from horizon 1 through 16 following equation (5). This is graphically shown in Figure 1. Overall, we find that the economies are less interwoven in the short run but become predominantly interconnected as we move into the long run. This finding is consistent with the patterns obtained by Diebold and Yilmaz (2014) and Ogbuabor et al. (2016). This implies that the connectedness index of these economies is conspicuously substantial and majorly dependent upon time.

Finally, the study also provided for robustness check on the empirical results through various connectedness measures. For instance; countries with negative net effects also have a negative influence index. This can be verified from table 4 by taking the difference between *to-others* and *from-others* (net-effect) indexes corresponding to the respective economies and thereafter dividing same by the sum-effect (*to-others* + *from others*), these yield influence index whose calculation is beyond the scope of this study. Also, the aggregate connectedness index depicted in Figure 2 serves as an additional robustness check as the pattern is consistent with earlier established total connectedness patterns by Ogbuabor et al. (2018, 2016), Park and Shin (2014) and Diebold and Yilmaz (2014).

**Figure 2** Aggregate connectedness index (see online version for colours)

## 5 Conclusions and some policy recommendations

In summary, we find that the connectedness index of the economies is 34.55%, which is very much significant. The results also show that India constitutes the largest spillover index in the system with 69.95% of the total forecast error variance whereas the total spillover shocks it receives from every other economy in system remain the least at 12.05%. This reveals how Indian economy has grown to become reasonably influential in global real sector activities in recent time, especially among the emerging economies. Also, China is the second largest spillover contributor in the system with a total spillover index of 30.81%, followed by Nigeria with 25.98%. Surprisingly, the USA remains the least spillover propagator in the system with a total forecast error variance of 11.44%. This is, however, not unconnected with the depleting influence of the USA in the global economy, particularly in the economies sampled herein. With this, one can cautiously say that the global real output activities lie on the shoulders of emerging markets such as India and China. Findings from the time-varying connectedness analysis show the total connectedness index rising from the short run to the long run. The spillover index rose significantly from 22.85% in the short run to 49.37% in the long run. This implies that with the evolution of time, world economies will become very much interwoven. This is due to the increased campaign for globalisation and liberalisation.

Sequel to our findings, we recommend that in as much as the economies under study become more interwoven in recent time, particularly after the return to democratic rule in Nigeria in 1999. Nigerian economic authorities are advised to be wary of adverse output shocks that could originate from her trade partners, especially India, China and USA. Nigerian economic authorities (both fiscal and monetary) should always be at alert and vigilant with respect to the economic decisions, policies and fluctuations arising from her trade partners, especially India and China, in order to mitigate any future adverse economic shock. Typical strategy in this regard could be to strengthen domestic institutions, boosting the local production by provision of incentives and granting of tax

relief to local industries, especially start-ups, as well as creation of friendly business atmosphere such as the provision of fiscal infrastructure and security of lives and property capable of attracting foreign investors. However, India and China are advised to sustain their current policy instruments and environment, especially in trade in order to remain dominant in global trade, while the USA is advised to improve on her present policy framework so as to reenergise and retake her position in global economic activities.

## References

- Adefabi, R.A. and Rasaki, M.G. (2018) 'External shocks and economic growth in Nigeria', *Acta Universitatis Danubius. Oeconomica*, Vol. 14, No. 7, pp.245–265.
- Anthony-Orji, O.I., Orji, A., Ogbuabor, J.E. and Nwosu E.O. (2019) 'Do financial stability and institutional quality have impact on financial inclusion in developing economies? A new evidence from Nigeria', *International Journal of Sustainable Economy*, Vol. 11, No. 1, pp.8–40.
- Antonakakis, N. and Badinger, H. (2016) 'Economic growth, volatility, and cross-country spillovers: new evidence for the G7 countries', *Economic Modelling*, Vol. 52, No. PB, pp.352–365.
- Asteriou, D. and Moudatsou, A. (2015) 'Business cycle synchronization in the enlarged EU: the role of bilateral trade and FDI', *Review of Development Economics*, Vol. 19, No. 1, pp.196–207.
- Backus, D., Kehoe, P.J. and Kydland, F.E. (1993) *International Business Cycles: Theory and Evidence*, NBER Working Paper 4493, National Bureau of Economic Research, Cambridge, MA.
- Baxter, M. (1995) 'International trade and business cycles', in Grossman, G. and Rogoff, K. (Eds.): *Handbook of International Economics*, pp.1801–1864, North Holland.
- Bhattarai, S., Chatterjee, A. and Park, W.Y. (2020) 'Global spillover effects of US uncertainty', *Journal of Monetary Economics*, Vol. 114, pp.71–89.
- Caner, M. and Kilian, L. (2001) 'Size distortions of tests of the null hypothesis of stationarity: evidence and implications for the PPP debate', *Journal of International Money and Finance*, Vol. 20, No. 5, pp.639–657.
- Canova, F., Ciccarelli, M. and Ortega, E. (2007) 'Similarities and convergence in G-7 cycles', *Journal of Monetary Economics*, Vol. 54, No. 3, pp.850–878.
- Cashin, P., Mohaddes, K. and Raissi, M. (2017) 'China's slowdown and global financial market volatility: Is world growth losing out?', *Emerging Markets Review*, Vol. 31, pp.164–175.
- Diebold, F.X. and Yilmaz, K. (2009) 'Measuring financial asset return and volatility spillovers, with application to global equity markets', *Economic Journal*, Vol. 119, No. 534, pp.158–171.
- Diebold, F.X. and Yilmaz, K. (2012) 'Better to give than to receive: predictive directional measurement of volatility spillovers', *International Journal of Forecasting*, Vol. 28, pp.57–66 [online] <https://doi.org/10.1016/j.ijforecast.2011.02.006>.
- Diebold, F.X. and Yilmaz, K. (2014) 'On the network topology of variance decompositions: measuring the connectedness of financial firms', *Journal of Econometrics*, Vol. 182, No. 1, pp.119–134.
- Diebold, F.X. and Yilmaz, K. (2015a) *Financial and Macroeconomic Connectedness: A Network Approach to Measurement and Monitoring*, Oxford University Press, USA.
- Diebold, F.X. and Yilmaz, K. (2015b) 'Measuring the dynamics of global business cycle connectedness', in Koopman, S.J. and Shephard, N. (Eds.): *Unobserved Components and Time Series Econometrics: Festschrift in Honor of Andrew Harvey's 65th Year*, pp.45–70, Oxford University Press, Oxford, UK.

- Diebold, F.X. and Yilmaz, K. (2016) 'Trans-Atlantic equity volatility connectedness: US and European financial institutions, 2004–2014', *Journal of Financial Econometrics*, Vol. 14, No. 2, pp.81–127.
- Doyle, B.M., and Faust, J. (2005) 'Breaks in the variability and comovement of G-7 economic growth', *Review of Economics and Statistics*, Vol. 87, No. 4., pp.721–740.
- Ekeocha, D.O, Ogbuabor, J.E, Orji, A. and Kalu, U.I. (2021a) 'International tourism and economic growth in Africa: a post-global financial crisis analysis', *Tourism Management Perspectives*, Vol. 40, No. 100896.
- Ekeocha, D.O., Ogbuabor, J.E. and Orji, A. (2021b) 'Public infrastructural development and economic performance in Africa: a new evidence from panel data analysis', *Economic Change and Restructuring* [online] <https://doi.org/10.1007/s10644-021-09334-8>.
- Elliot, G., Rothenberg, T.J. and Stock, J.H. (1996) 'Efficient tests for an autoregressive unit root', *Econometrica*, Vol. 64, No. 4, pp.813–836.
- Ezema, B.I. and Amakom, U. (2011) 'Terms of trade shocks: a major cause of distortion in the Nigerian economy', *Asian Journal of Business and Management Sciences*, Vol. 1, No. 1, pp.25–38.
- Greenwood-Nimmo, M., Nguyen, V.H. and Shin, Y. (2015) 'Measuring the connectedness of the global economy', *Melbourne Institute Working Paper*, Vol. 15, No. 7, pp.1-14, Melbourne Institute of Applied Economic and Social Research, The University of Melbourne.
- Greenwood-Nimmo, M., Nguyen, V.H. and Shin, Y. (2021) 'Measuring the connectedness of the global economy', *International Journal of Forecasting*, Vol. 37, No. 2, pp.899–919.
- He, Q. and Chen, H. (2014) 'Recent macroeconomic stability in China', *China Economic Review*, Vol. 30, No. 3, pp.505–519.
- Ibironke, A. (2018) 'International shocks: an examination of key channels of transmission', *World Journal of Economics and Finance*, Vol. 4, No. 1, pp.93–99.
- Inekwe, J.N. (2020) 'Liquidity connectedness and output synchronisation', *Journal of International Financial Markets, Institutions and Money*, Vol. 66, No. 12, p.101208.
- Inoue, T., Kaya, D. and Ohshige, H. (2015) *The Impact of China's Slowdown on the Asia Pacific Region: An Application of the GVAR Model*, Policy Research Working Paper 7442, World Bank, Washington, DC.
- International Trade Statistics (2018) *International Trade Statistics and Report*, United Nations Publication.
- International Trade Statistics (2020) *International Trade Statistics and Report*, United Nations Publication.
- International Trade Statistics (2021) *International Trade Statistics and Report*, United Nations Publication.
- Isaac, N., Orji, A., Anthony-Orji, O.I. and Nwankwo, M.C. (2021) 'Political regimes and private investment nexus in Nigeria: an empirical verification', *The International Journal of Interdisciplinary Global Studies*, Vol. 16, No. 2, pp.75-88, doi:10.18848/2324-755X/CGP/v16i02/75-88.
- Koop, G., Pesaran, M.H. and Potter, S.M. (1996) 'Impulse response analysis in nonlinear multivariate models', *Journal of Econometrics*, Vol. 74, No. 1, pp.119–147.
- Kose, A., Prasad, E. and Terrones, M. (2003) 'How does globalization affect the synchronization of business cycles?', *American Economic Review*, Vol. 93, No. 2, pp.57–62.
- Kose, M.A. and Yi, K.M. (2001) 'International trade and business cycles: is vertical specialization the missing link?', *American Economic Review*, Vol. 91, No. 2, pp.371–375.
- Lakdawala, A. and Singh, S. (2019) 'The effect of foreign shocks on the indian economy', Draft paper prepared for the 16th India Policy Forum [online] [http://ssingh.ucdavis.edu/uploads/1/2/3/2/123250431/al\\_ss\\_shocks\\_final\\_preconference.pdf](http://ssingh.ucdavis.edu/uploads/1/2/3/2/123250431/al_ss_shocks_final_preconference.pdf) (accessed 2021).
- Madhani, P.N. (2010) 'Rebalancing fixed and variable pay in a sales organization: a business cycle perspective', *Compensation and Benefits Review*, Vol. 42, No. 3, pp.179–189.



- McCarthy, D., Neary, J.P. and Zanalda, G. (1994) *Measuring the Effects of External Shocks and the Policy Responses to Them: Empirical Methodology Applied to the Philippines*, Policy Research Working Paper Series 1271, The World Bank.
- Muse, B.O. and Uche, C.C. (2018) 'Modelling the response of fiscal policy to external shocks: the case of Nigeria', *Asian Journal of Economics, Business and Accounting*, Vol. 7, No. 4, pp.1–11.
- Ng, S. and Perron, P. (2001) 'Lag length selection and the construction of unit root tests with good size and power', *Econometrica*, Vol. 69, No. 6, pp.1519–1554.
- Obiora, K.I. (2009) *Decoupling from the East Toward the West? Analyses of Spillovers to the Baltic Countries*, IMF Working Paper, No. 125, Washington.
- Ogbuabor, J.E. (2019) 'Measuring the dynamics of Czech Republic output connectedness with the global economy', *Ekonomický časopis*, Vol. 67, No. 10, pp.1070–1089.
- Ogbuabor, J.E., Anthony-Orji, O.I., Manasseh, C.O. and Orji, A. (2020c) 'Measuring the dynamics of COMESA output connectedness with the global economy', *The Journal of Economic Asymmetries*, Vol. 21, No. e00138.
- Ogbuabor, J.E., Egbiremolen, G.S.O., Aneke, G.C. and Charles, M.O. (2018) 'Measuring the dynamics of APEC output connectedness', *Asian-Pacific Economic Literature*, Vol. 32, No. 1, pp.29–44.
- Ogbuabor, J.E., Orji, A. and Anthony-Orji, O.I. (2020b) 'Are anticompetitive behaviours rampant in global retail energy markets? A study of price elasticity, asymmetric price adjustment and rent-seeking', *Energy Research & Social Science*, Vol. 70, No. 101783.
- Ogbuabor, J.E., Orji, A., Aneke, G.C. and Erdene-Urnukh, O. (2016) 'Measuring the real and financial connectedness of selected African economies with the global economy', *South African Journal of Economics*, Vol. 84, No. 3, pp.364–399.
- Ogbuabor, J.E., Orji, A., Manasseh, C.O. and Anthony-Orji O.I. (2020a) 'Climate change and agricultural output in the ECOWAS region', *International Journal of Sustainable Economy*, Vol. 12, No. 4, pp.403–414.
- Park, H., and Shin, Y. (2014) *Mapping Korea's international linkages using Generalized Connectedness Measures*, Working Paper 2014-16, Economic Research Institute, Bank of Korea.
- Perron, P. and Ng, S. (1996) 'Useful modifications to some unit root tests with dependent errors and their local asymptotic properties', *Review of Economic Studies*, Vol. 63, No. 3, pp.435–463.
- Pesaran, M.H. and Shin, Y. (1998) 'Generalized impulse response analysis in linear multivariate models', *Economics Letters*, Vol. 58, No. 1, pp.17–29.
- Schwert, W. (1989) 'Test for unit roots: a monte carlo investigation', *Journal of Business & Economic Statistics*, Vol. 7, No. 2, pp.147–159.
- Uluceviz, E. and Yilmaz, K. (2021) 'Measuring real-financial connectedness in the US economy', *The North American Journal of Economics and Finance*, Vol. 58, p.101554.
- UN Comtrade (2019) *United Nations International Trade Statistics 2019* [online] <https://comtrade.un.org/data/da> (accessed 2021).