Dynamics of Stock Markets Interdependence in the Pre-and Post Global Financial Crisis Period: Evidence from Toda-Yamamoto Causality Test

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Authors' contributions

This work was carried out in collaboration between all authors. All the Authors contributed in design of the study, statistical analysis, wrote the protocol, wrote the first draft of the manuscript managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

This paper analysed the causal relationship between the three largest African stock markets; Nigeria, South-Africa and Egypt. The analysis was conducted for two sample periods using the index of the stock markets. The pre-crisis period between January 2000-April 2008, and the crisis/post-crisis period between May 2008-December 2016. The study employed Toda and Yamamoto robust causality test. The result from the study found evidence of no causal relationship between the three selected stock markets in the pre-crisis period. In the crisis/post-crisis period, we found a unidirectional causality from South-Africa to Nigeria stock markets. Beside this, there is no evidence of causal relationship between the stock exchange markets. Therefore, the study concluded that there is no strong difference between the causal relationship in the two analysed periods which signifies benefits of diversification between the three stock exchange markets.

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1. INTRODUCTION

The direction of causality among stock exchange markets has been one of the contentious issues in studying the interdependence among selected stock exchange markets. Although many studies were conducted focusing on covariance, cointegration and correlation, the issue of causality has been left behind despite its theoretical and practical importance. The Markowitz theory has stated that greater interdependence among stock markets implies limitation in international diversification. This is supported by [1] and [2] among many studies which had given evidence that interdependence among stock markets have led diversification of investments to become less effective This indicates less desirability for international portfolio diversification, inefficiency in the transmission of information and the risk of contagion of financial crisis.

A sub-genre of correlation analysis concentrates exclusively on the correlation structure amongstock markets during crisis periods. Studies which fall into this category infer increased correlation during and after extreme market events. This is further explained by [3,4] and [5] who had argued that interdependence between stock exchange markets is dynamic and changes according to the state of the markets, that is pre-crisis period is marked by financial fragility with stock markets giving high return attracting investment from other markets, while periods of crisis and post-crisis are marked with high correlation and fewer diversification benefits. This is supported by literature such as [6,7] and [8] among others.

Although studies in the stock market interdependence among selected stock exchange markets are well established in America, Asia and Europe, this is not the case in Africa. Also, despite multiple studies on covariance, cointegration and correlation, there are few works of literature such as [7] that directly study the causality between stock markets. previous studies assume the only causality after finding cointegration between the selected stock markets. Therefore, this paper examined the causal relationship between Nigeria, South-Africa and Egypt stock exchange markets. The three selected are the largest stock markets in Africa. The motivation for the paper comes from the trend of the share index data of the three markets depicted in Fig. 1 (Appendix). From the figure, the trend did not provide sufficient evidence that the interdependence between the selected stock markets in the crisis/post-crisis period is different from other periods as concluded by most empirical literature. This is because the markets grew and fell at the same time in both periods. They grew together in 2004 and fell in 2008, the recovered together in 2009/2010.

Despite its widespread application, correlation analysis is not free from criticism, [6] argued that employing the method such as unconditional correlation will provide evidence of low correlation which signifies international diversification benefits. However, this can be diminished over time if the selected markets have a Long-run relationship (cointegrated). These approaches can be misleading because all sort of regression analysis gives mere correlation to a certain extent and any claim for causality based on regression analysis is incorrect. Therefore, to have a better understanding of the interactions, it is important to know the causal relationship between the markets.

In this paper, we employed the [9] causality test against the traditional [10] causality test. This is because the Granger causality test has been criticized by some studies for its inability to address many issues. According to [11] and [12], Granger causality test is marked by nonstandard asymptotic distribution, rank deficiency and nuisance parameter estimation which lead to size distortion in the null hypothesis. [9] addressed these issues, it is an augmented VAR modeling that uses Modified Wald (MWALD) test statistics which is found to be superior to the traditional Granger causality test. The approach does not require the preliminary test of unit-root and cointegration and hence evade the potential bias and spurious regression associated with them.

2. LITERATURE REVIEW

The issue of stock markets interdependence has been discussed extensively in the literature, some of the studies included [13,14,15,16] among many others. However, despite a large number of studies, the issue of the dynamic in the interdependence between stock markets has not been adequately concluded. This is because

studies ignored issues that stock market interdependence may exhibit strong variations over time. Most studies testing for stock market interaction has either ignored this issue entirely or has looked at various sub-periods to obtain information about the dynamics of the interdependence.

Although literature are adequate and available on the stock markets relationship, only a few literature study the nature of causality between the stock markets and how changes in economic and financial activities affect the nature of the causal relationship. After determining the cointegrating relationship between some selected stock markets in the Central and Eastern Europe (CEE) and the United States (US), [17] employed the Granger causality to test the causal relationship between the selected stock markets. The study found evidence that of unidirectional causality from the US to all the CEE selected markets, while it is bi-directional among the CEE markets. This justified the dominance of the US stock market in influencing the global markets and evidence of strong regional cooperation.

Like, [17,18] test the causal relationship between the US, European and Asia. They employed both the normal [10] and a modified Ganger causality regression for the analysis. The Granger causality showed evidence of the mixed result of uni and bi-directional causality between the market. However, the modified Ganger causality regression analysis showed evidence of bi-directional causality between all the markets. The modified Ganger causality regression result violates the result obtained by [4] which showed the dominance of US market in influencing Asia markets. In a separate study, [19] employed the Granger causality and spatial probit models and concluded that causal relationship between stock markets is influenced by proximity, time and return spillover. [8] test the causality of the 5-ASEAN stock markets and concluded that liberalization of the markets influenced the causal relationship between international stock markets.

[20] argued that dynamic relationship of financial time series exhibits non-linearity, which they termed as the nonlinear causal relationship. The aforementioned motivated study such as [7] to employ the modified non-linear Granger causality test to determine the causal relationship between Dow Jones Industrial Average and percentage changes in New York Stock Exchange trading volume. The study found evidence of bi-directional causality between the markets. Similarly, [21] used the [20] as modified by [22] and found a bi-directional causality between UK, US,French, German, and Japanese and stock markets. However, the nonlinear method is criticized for its measurement error and poor predictive power

In order to address the methodological issues, studies employed a more robust causality test, for instance, [23] employed the Toda-Yamamoto test to identify the causal relationship between the India, Pakistan and the US. They found evidence of unidirectional causality from the US to India and Pakistan. A similar result is also found by [24]. In a recent study, [25] used an augmented Toda- Yamamoto causality test to find the asymmetric causality between CEE markets. Evidence from the study showed asymmetric causality from the Czech Republic to Hungary and Poland. Besides this market, there is no evidence of causality among the markets.

Comparing different sub-periods may yield a first proxy for long-term changes, study such as [6] employed Toda-Yamamoto causality test augmented by bootstrap leveraged adjustment to test the dynamics of the causal relationship between the UK, Germany, France and Australia before and after theEuropean Exchange Rate Mechanism (ERM) crisis. They concluded that the causal relationship between the selected stock markets changes after the ERM crisis. Similarly, [7] studied the causal relationship between US and developed markets in pre -and post-September 2001 terror attack in the US. The study showed that bi-directional causality between US and Japan and US and Germany in the pre-attack period. In the post-attack period, the dynamic of the causality change with evidence of unidirectional causality from the US to Japan and UK to the US.

In this paper, we seek to extend the few existing works on causality between the three largest African stock markets. This is to find out whether there is a causal relationship between the markets and if the global financial crisis has affected the causal relationship between the markets.

3. METHODOLOGY

To test the causal relationship between Nigeria, South-Africa and Egypt, the paper employed the

Toda-Yamamoto causality test. The Toda-Yamamoto test addresses the problems associated with the traditional Granger causality test. According to [9], the traditional Granger causality used the conventional F-Statistics which may not be valid as the test does not have a standard distribution when the series data are integrated or cointegrated. Hence, the use of modified Wald test (MWALD) to mitigate the mentioned problem. The Toda-Yamamoto approach has been found to be superior than the traditional Granger causality because it does not require the prerequisite testing for cointegration properties of the system thus avoids the potential bias associated with unit roots and cointegration tests as it can be applied regardless of whether a series is I(0), I(1) or I(2), non-cointegrated or cointegrated of any arbitrary order [26].

Toda-Yamamoto approaches is an augmented Vector Autoregression (VAR) method which artificially augments the correct VAR order k by the maximal order of integration $d$max. Once the k and $d$max are determined, a ($k+d$ max)th order of VAR is estimated and the coefficients of the last lagged $d$maxvector are ignored (see [27,28]).

To test the causal relationship between Nigeria, South-Africa and Egypt, we employed the Toda-Yamamoto version of causality test represented in the below VAR system. The specification for this study will follow a level VAR specification even though the series is assumed to be integrated.

$$y_t = A_1 y_{t-1} + \ldots\ldots A_p y_{t-p} + \beta_1 x_{t-1} + \ldots\ldots + \beta_q x_{t-q} + \alpha_1 z_{t-1} + \ldots\ldots\ldots \alpha_n x_{t-q} + e_t$$

$$x_t = \beta_1 x_{t-1} + \ldots\ldots\ldots \beta_q x_{t-q} + A_1 y_{t-1} + \ldots\ldots\ldots + A_p y_{t-p} + \alpha_1 z_{t-1} + \ldots\ldots\ldots \alpha_n x_{t-q} + e_t$$

$$z_t = \alpha_1 z_{t-1} + \ldots\ldots\ldots \alpha_n x_{t-q} + A_1 y_{t-1} + \ldots\ldots A_p y_{t-p} + \beta_1 x_{t-1} + \ldots\ldots\ldots \beta_q x_{t-q} + e_t$$

Where y_t x_t z_t are Nigeria, South-Africa and Egypt stock markets index. Toda-Yamamoto procedure fits a standard VAR model in the levels of the variables rather than the first differences, as the case with Granger causality tests. The number of optimal lags is determined by a selection criterion such as the Akaike Information criterion (AIC), Bayesian and Schwarz Info Criterion (SIC). The exogenous variable that will take into consideration the integration aspect in the markets is specify as

$$y_t = A_1 y_{t-1} + \ldots\ldots A_p y_{t-p} + \beta_1 x_{t-1} + \ldots\ldots + \beta_q x_{t-q} + \alpha_1 z_{t-1} + \ldots\ldots\ldots \alpha_s x_{t-s} + \lambda_k y_{t-k} + \theta_w x_{t-w} + \phi_l z_{t-l} + e_t$$

$$x_t = \beta_1 x_{t-1} + \ldots\ldots \beta_q x_{t-q} + A_1 y_{t-1} + \ldots\ldots + A_p y_{t-p} + \alpha_1 z_{t-1} + \ldots\ldots \alpha_s x_{t-s} + \theta_w x_{t-w} + \lambda_k y_{t-k} + \phi_l z_{t-l} + e_t$$

$$z_t = \alpha_1 z_{t-1} + \ldots\ldots \alpha_s x_{t-s} + A_1 y_{t-1} + \ldots\ldots A_p y_{t-p} + \beta_1 x_{t-1} + \ldots\ldots \beta_q x_{t-q} + \phi_l z_{t-l} + \lambda_k y_{t-k} + \theta_w x_{t-w} + e_t$$

Where

$$k_1 = p + 1$$
$$w_1 = q + 1$$
$$l_1 = s + 1$$

We test the hypothesis that

$$H_0 : \beta_1 = \beta_q = \alpha_1 = \alpha_s = 0$$
$$H_1 : \beta_1 \neq \beta_q \neq \alpha_1 \neq \alpha_s \neq 0 \qquad (1)$$

$$H_0 : A_1 = A_p = \alpha_1 = \alpha_s = 0$$
$$H_1 : A_1 \neq A_p \neq \alpha_1 \neq \alpha_s \neq 0 \qquad (2)$$

$$H_0 : A_1 = A_p = \alpha_1 = \alpha_s = 0$$

$$H_1 : \beta_1 \neq \beta_q \neq \alpha_1 \neq \alpha_s \neq 0 \quad (3)$$

3.1 Breakpoint Test

Preliminary observation from Fig. 1(Appendix) has shown a possible structural break in the data during the period 4/01/2008. In order to test whether the break date given is significant or not we need to test the break date. The study employed the Chow break point test which contains a sample split and break point to enable us to identify the pre and crisis/post-crisis period. The result is presented in Table 1, the estimated F value becomes 16.2151 which is higher than the critical F values 3,198. at 1 percent level of significance. Therefore, the null hypothesis of no structural break is rejected. The chow test indicates there is a structural break in the share index of Nigeria, South-Africa and Egypt in 4/01/2008. The first sub period therefore includes the observations between 1/01/2000- 4/01/2008. The second sub period includes observations from 5/01/2008-12/01/2016.

3.2 Data and Descriptive Statistics

To examine the dynamics of causality between Nigeria, South-Africa and Egypt, we employed the stock markets index from the three markets. Most studies on stock markets use stock return data for their analysis, in this study, we use the price index data due to the fact that investors acting in the stock markets are usually looking at the price charts and not the returns of the markets. This makes the price data a more reliable behavioral variable. We examined the period between 2000-2016 using the monthly data. Monthly data is used against the daily and weekly data for its ability in eliminating day of the week effects, trading hour inconsistencies and too much trading noise. In line with the study objective, we dissect the data into the pre -and post global financial crisis period. The pre-crisis period starts from January 2000- April 2008 and crisis/post-crisis period from May 2008- December 2016.

Table 2 presents the descriptive statistics of the monthly index of Nigeria, South-Africa and Egypt for the pre-crisis and crisis/post-crisis periods. It is evident from the mean that the markets perform better in the crisis/post-crisis period rather than the pre-crisis period. It also evident that Nigeria stock markets perform better than the two markets in the pre-crisis period, this is

followed by South-Africa and lastly Egypt. In the crisis/post-crisis period, South Africa stock market performs better than Nigeria and Egypt stock markets. This implied that investors of South-Africa benefit more from the post-crisis than the pre-crisis period. Similarly, it is better to invest in Nigeria during the pre-crisis period. In terms of the Standard deviation, which measures the relative risk of the markets. Nigeria stock market is riskier in the pre-crisis period compared to the post-crisis period, while the South-Africa stock market is riskier in the crisis/post-crisis period. This is because South-African stock market has the more international investment where the crisis commenced. It is also not surprising that Egypt is less risky than Nigeria and South-Africa since the two markets are more liquid and has more international investment.

There is evidence of positive skewness of the distribution of return in all the markets and in both periods. Also, there is statistical kurtosis which suggests that the series are leptokurtic with a flatter tail. and a high peak. The kurtosis implied that a shock of either sign is more often to be present. The null hypothesis of normality is rejected for each variable in each period at five percent level of significance which implies that the data is not normally distributed in both periods.

3.3 Estimations and Empirical Result

In Toda-Yamamoto procedure, the first step is to determine the maximum order of integration ($d$max) of the series involved. We, therefore, employed the Augmented Dickey-Fuller (ADF) and Philips-Peron (PP) test for this purpose. From the result in Table 3, it is evident that the variables are 1(0) at the level and become 1(1) after the first difference. This result is supported by both tests at one percent level of significance. From the result, we concluded that $d$max of the series in this study is 1. This result is for both the pre-crisis and crisis/ post-crisis periods. We determined three as the appropriate lag length in the VAR using the usual methods. Specifically, we employed the Akaike information criterion (AIC). This gives the ($k+d$max) optimal VAR order lag in level as four for both the two periods. In both the two estimated VAR models, we found evidence of no autocorrelation.

Toda-Yamamoto guarantee that the usual test statistics for the Granger test has the standard asymptotic distribution. This ensures that valid inferences can be made. Table 4 presents

Table 1. Chow breakpoint test: 4/01/2008

F Statistics	16.2151	Prob. F(3,198)	0.000
Log likelihood ratio	44.8157	Prob. Chi Square (3)	0.000

Table 2. Descriptive statistics of montly index of Nigeria, South-Africa and Egypt

Markets	Min	Mean	Max	Std deviation	Skewness	Kurtosis	Jarque-Bera
Pre-crisis period Jan 2000- April 2008							
Nigeria	5780.24	22190.00	54285.22	14744.48	1.201743	3.726667	26.26994**
South- Africa	7208.44	14435.38	30816.19	7423.303	1.018254	2.563066	18.07617**
Egypt	49.12	292.6401	996.2537	275.4764	0.907274	2.534696	14.62122**
Crisis/Post-crisis period May 2008-Dec 2016							
Nigeria	19871.69	31283.22	65910.94	10398.59	1.455456	4.759233	52.05741**
South- Africa	18386.54	37668.64	54440.43	10705.57	0.102327	1.627020	8.671309**
Egypt	341.9299	641.2820	1025.920	159.5839	0.547990	2.622641	6.046071**

Note (**) Statistical significance at 5% Critical level

Table 3.Unitroot test

Market	Level		First difference	
	ADF	PP	ADF	PP
Pre-crisis period Jan 2000-Dec 2007				
Nigeria	0.3526	0.1568	-7.6834*	-7.6834*
South- Africa	-1.2785	-1.2159	-10.8533*	-10.866*
Egypt	-0.7885	-0.8628	-8.70519*	-8.70519*
Crisis/Post-crisis period Jan 2008-Dec 2016				
Nigeria	-2.3699	-2.4116	-9.0985*	-9.1903*
South- Africa	-2.6270	-2.6591	-11.1499*	-11.1173*
Egypt	-1.9561	-2.2953	-7.7255*	-8.0071*

Table 4. Toda-Yamamoto causality (modified WALD) test result

Null Hypothesis	Chi-Sq	Probability	Causality
Pre-crisis period Jan 2000-Dec 2007			
NIG does not granger cause SA	1.30	0.72	No Causality
SA does not granger cause NIG	6.15	0.10	No Causality
NIGdoes not granger cause EG	1.43	0.69	No Causality
EG does not granger cause NIG	7.02	0.07	No Causality
SA does not granger cause EG	6.08	0.10	No Causality
EG does not granger cause SA	3.93	0.26	No Causality
Crisis/Post-crisis period Jan 2008-Dec 2016			
NIG does not granger cause SA	0.22	0.97	No Causality
SA does not granger cause NIG	7.84	0.04	Causality
NIGdoes not granger cause EG	0.22	0.97	No Causality
EG does not granger cause NIG	0.09	0.99	No Causality
SA does not granger cause EG	0.22	0.97	No Causality
EG does not granger cause SA	4.03	0.25	No Causality

the result of the Toda-Yamamoto causality test between Nigeria (NIG), South-Africa(SA) and Egypt (EG) stock exchange markets in the pre-crisis and crisis-post crisis periods. From the result, it is evident that the there is neither bi-directional causality nor the unidirectional causal relationship between Nigeria and South-Africa, South-Africa and Egypt and Egypt and Nigeria stock markets in the pre-crisis period. This indicated that the markets operate independently and there is no efficient information process between the markets in the period. In the crisis/post-crisis period, we found no evidence of causality between Nigeria and Egypt and Egypt and South-Africa stock markets. However, we found unidirectional causality from South-Africa to Nigeria stock market. This is not surprising due to the fact that the South-Africa stock market is the largest in Africa. The result supported [7] study who found that the causal relationship between stock markets increase after the September 2001 terror attack. The findings of the

study are exactly the same with [6] who found no causality between selected European stock markets before the ERM crisis but found uni directional causality from the United Kingdom to Australia during the crisis.For accuracy and reliability, we test for autocorrelation in the two estimated Toda-Yamamota VAR models. The result provided evidence of no other autocorrelation.

4. CONCLUSION

This paper study the causal relationship between Africa's largest stock exchange markets. This included Nigeria, South-Africa and Egypt. The study is conducted for two sample periods. The pre-crisis period between January 2000-December 2007, and crisis/post-crisis period between January 2008- December 2016. We employed a more robust causality test developed by Toda and Yamamoto (1995). We test whether there is causality between the three selected stock exchange markets and if the causal relationship changes as result of the global financial crisis.

The result provides evidence that there is no causal relationship between the stock markets in the pre-crisis period. Similarly, in the crisis/post-crisis period, there is only unidirectional causality from the South-Africa to Nigeria stock market. The result indicated lack of financial and economic integration in the African continent. The result further indicated that investors can minimize risk by investing in the three markets in both the pre-crisis period and crisis/post-crisis periods. The study concluded that there is no strong difference between the causal relationship in the pre-crisis period and crisis/post-crisis periods. The policy implication for this study is that there is a need for the African Union to foster economic policies that will lead to the integration of the financial sectors in Africa.

COMPETING INTERESTS
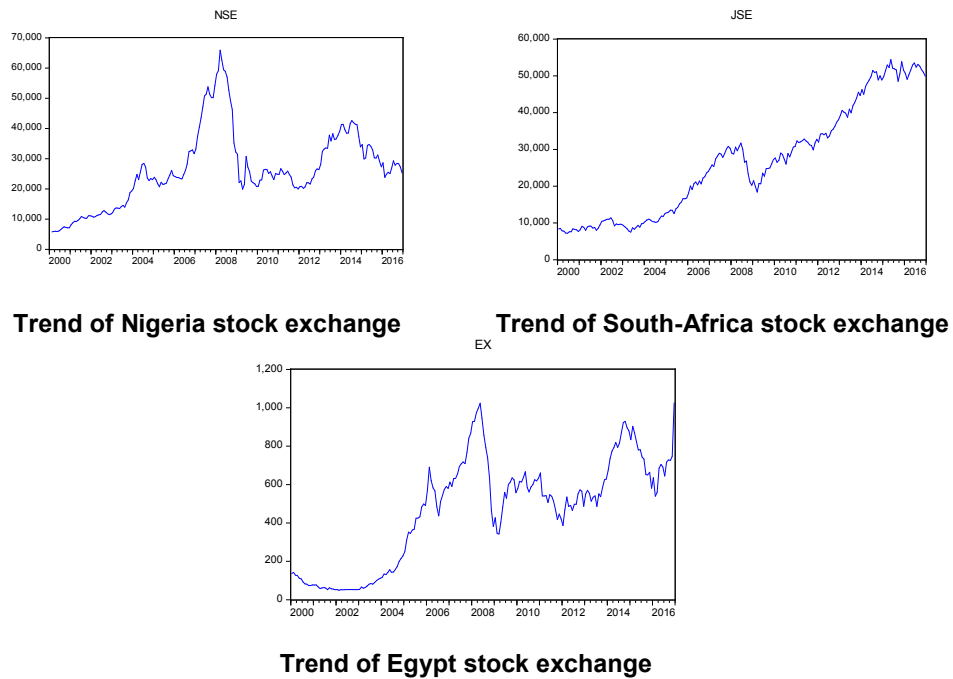
Authors have declared that no competing interests exist.

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APPENDIX

NSE

JSE

Trend of Nigeria stock exchange

Trend of South-Africa stock exchange

EX

Trend of Egypt stock exchange

Fig. 1. Trend of Nigeria, South-Africa and Egypt stock markets

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