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Are African stock markets efficient? Evidence from wavelet unit root test for random walk

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Abstract

In this paper, we used the recently developed frequency based wavelet unit root test alongside a number of time domain unit root tests to examine the validity or otherwise of the random walk hypothesis for seven African largest markets. Unlike previous studies that affirms the validity of the random walk behaviour for African markets, our results reveal that when frequency domain is factored into stock market behaviour framework, evidence abound to reject the null of unit root test for each of the African markets studied. This implies that African markets are inefficient, contributes to growth and provide good opportunities for arbitrage trading. The results have critical implications for investors, policy makers as well as the academics.

I write on behalf of the authors of the manuscript to state that it is original and not before outlet for consideration for publication.

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1. INTRODUCTION

Stock market efficiency is of paramount importance to virtually all the various economic agents particularly the market practitioners on the one hand, and policy makers on the other hand. This is premised on the fact that inefficient markets are crucial in promoting higher economic growth (Tiwari and Kyophilavong, 2014). Over the years, from statistical point of view, the evidence of the existence of random walk has been considered as sufficient condition for market efficiency (Pele and Vioneagu*, 2008;* Narayan *et al, 2015;* Narayan *et al, 2016*). The implication of whether or not stock prices follows a random walk or mean reverting process have a great impact on the economy and market practitioners. For instance, if stock prices are mean reverting, then the price level will return to its trend path over time, thus the possibility of using historical information to predict the future movement in stock prices is possible. However, if evidence abound that stock market follows a random walk process, then shock to stock prices have permanent effects, thus ruling out the possibility of using historical information to predict market behavior.

A number of estimation techniques have been used in literature to investigate the random walk properties of stock prices around the world. The most common methods focus on testing whether or not stock market contains a unit root test. Here, random walk hypothesis is accepted if nonstationarity nature of stock markets data is established; however, if the evidence shows that the data are stationary, then the random walk hypothesis will not be accepted.

Though a number of studies have been conducted to investigate the existence of random walk hypothesis for different economies, bulk of the extant literature is concentrated in the developed economies (Sukpitak and Hengpunya (2016a); (2016b) Rounaghi and Zadeh (2016); Charfeddine and Khediri (2016); Lahmin, *et al* (2017); Jammazi, (2012); In and Kim, (2006); Moya-Martinez, *et al* (2015); Stratimirovic, *et al* (2018); Rizvi and Arshad, (2017))[1] with very few focusing on emerging African economies. As noted by Gokcan (2000), African stock markets are fast evolving as they occupy key positions in emerging markets that are attracting global investors. Worse still, a large percentage of the studies that focuses on African economies used time-domain estimation techniques such as serial correlation, run test, Augmented Dickey Fuller, Phillips and Perron (1988) and Ng and Perron (2001), among others to conduct their analysis.

[1] Most of these studies used wavelet techniques and observed that developed markets are inefficient.

This paper contributes to literature by using recently develop frequency domain unit root tests based on wavelet framework to investigate the existence or otherwise of random walk hypothesis for African largest economies. The choice of wavelet based unit root test was induced by its ability to give a more accurate picture of data in comparison with the time domain unit root tests, whether or not the later incorporate structural breaks into its model. Unlike other techniques like ARCH, GARCH, ARDL and other time domain unit root tests, wavelet possesses the ability to breakdown any ex-post variables on different frequencies so as to investigate the subtleties of movement across different time horizon without losing information, as well as its capability to provide a better trade-off between detecting oscillations and peaks or discontinues. The preference of wavelet to others estimation techniques is of utmost benefits to virtually all economic agents. For instance, with wavelet analysis, trader can analyze their investment horizons in different frequency bands of scale when a need arises for management to take portfolio decision (Aloui and Hkiri, 2014; Yang, Cia, Zhang and Hamori, 2016; Mensi *et al*, 2016).

The rest of the paper is structured as follows: Section two deals with literature review; Section three provides the methodology; Section four presents the results; while section five concludes.

2. LITERATURE REVIEW

The theoretical framework for this paper is rooted in Efficient Market Hypothesis (EMH) by Fama (1970) which explains that the dynamics of stock prices can be described by a random walk with a drift. Ever since then, a number of studies have been conducted to know whether or not stock market can be characterized as a random walk or mean-reverting process, with no consensus yet reached. While a number of studies observed that evidence exists to support the EMH, for instance Westerlund and Narayan (2015); Dewandaru, Masih and Masih, 2016; Mnif (2017); Hiremath and Narayan (2016); Sensoy and Tabak (2015); Graham *et al*,(2015); Jefferis and Smith (2005); Magnusson and Wydick (2002); Mlambo and Biekpe (2007); Smith and Dyakova (2014), among others. Others like Nwosu *et al*, (2013); Afego (2015); Beltratti *et al*, (2016); Tuyon and Ahmad (2016); Urquhart and McGroarty (2016); Tiwari and Kyophilavong (2014) and Narayan et al, (2016) are of the view that stock market are mean-reverting. A critical review of the extant literature shows that though African markets are fast evolving, little has been done in the recent to examine their state of efficiency especially within the context of frequency domain framework. This is central to the current research.

3. DATA AND METHODOLOGY

For this study, we used monthly data sourced from DataStream on seven Africa stock markets, these markets are Cote D' Ivoire, Egypt, Kenya, Morocco, Nigeria, South Africa and Zimbabwe. The choice of these markets was induced by availability of data and age of the markets. In addition the markets are the largest in term of listed companies on the continent.

As earlier stated, the study used frequency domain wavelet unit test to examine the validity of random walk hypothesis for African Stock markets. Wavelets is advantageous to other existing time domain techniques, as it has the capacity to decompose a stochastic process into wavelet components, with each of the decomposed stochastic process being associated with a particular frequency band. It also measures the contributions of the variance of the process through wavelet power spectrum. Unlike other time domain techniques, wavelet has the ability to perform multi-timescale analysis that will decompose any observed variable on scale-by-scale basis (Dewandaru, Masih and Masih, 2016; Boubaker and Raza, 2017; Yang, Ce and Lian, 2017; Shrivastava and Panigrahi, 2014)

Following Fan and Gençay (2010), we adopted two unit root statistics $\hat{S}_{T,1}^{LM}$ and $\hat{S}_{T,1}^{Ld}$ for demeaned and detrend series respectively based on the unit scale DWT wavelet. The test statistics are as follows:

$$\hat{S}_{T,1}^{LM} = \frac{\sum_{t=1}^{T/2}\left(V_{t.1}^{M}\right)^2}{\sum_{t=1}^{T}\left(y_t - \bar{y}\right)^2} \quad (1)$$

$$\hat{S}_{T,1}^{Ld} = -\frac{\sum_{t=1}^{T/2}\left(V_{t.1}^{d}\right)^2}{\sum_{t=1}^{T}\left(\widetilde{y_t} - \bar{\tilde{y}}\right)^2} \quad (2)$$

To fitting into our specification, we employed Morlet's wavelet and expand equation (3) such that

$$\psi^{M}(t) = \frac{1}{\pi^{1/4}} e^{i\omega_0 t} e^{-t^2/2} \quad (3)$$

Where $\omega_0$represent the central frequency of the wavelet, following Aloui and Hkiri (2014), the study used $\omega_0 = 6,$ this is premised on the fact that evidence abound that setting ω_0 to 6 will enhance a good balancing between time and frequency localization (see also Rua and Nunes, 2009; Vacha and Barunik, 2012).

4. RESULTS AND ANALYSIS

The results of the wavelet-based unit root tests are presented in Table 1 below. From the results, it can be deduced that the null hypothesis for all the African countries studied are rejected using the three methods employed. This suggests that when frequency domain is factored into stock market efficiency framework, no evidence abound to support the existence of random walk hypothesis for the studied African economies. The implication is that the selected markets are inefficient, and are capable of providing the platform to support economic growth (Pele and Vioneagu, 2008; Narayan *et al*, 2016; Westerlund and Narayan, 2015; Narayan *et al*, 2015). The results also suggest that arbitrage opportunities exist in the studied markets, for instance, if stock prices are mean reverting, it is possible for investors to make abnormal profit by predicting price movements based on historical data using technical analysis. This further suggests that shocks to assets prices due to global financial crisis will only result in temporary deviation from long run growth path and that stock prices will return to the long run equilibrium, thus foreign investors are encouraged to maximize the arbitrage opportunities in these markets.

In other to compare the results obtained from frequency domain methods with time domain methods, the study employed a battery of time domain unit root tests. The time domain unit root tests employed are divided into two: those that accommodates structural breaks such as Lee and Strazicich (2003); and Narayan and Popp (2010) unit root tests on the one hand; and those that did not consider structural breaks such as Augmented Dickey-Fuller (1981), Phillips and Perron (1988) and Ng and Perron (2001). Due to space, we present the results of the unit root test with structural breaks in Tables 2 and 3 (the results of the unit root tests without structural breaks are available on demand)[2].

As shown in the Tables 1, 2 and 3, it can be deduced that when we employed time domain unit root tests with up to two structural breaks, our results show that stock prices contain a unit root. However, when we used frequency based wavelet unit root tests, we observed that stock prices are mean reverting.

Our results emphasized the relevance of frequency domain and suggest that just using time domain unit root tests that accommodates structural breaks is not sufficient to reject the unit root

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[2] In Figure 1, we presents the various changes of the scaling exponents with time $\alpha(t)$ for the studied period. We noted the existence of significant departure from random walk behaviour ($\alpha = 0.5$). This implies that stock markets in the study economies are not informational efficient.

null in stock prices. This is premised on the fact that unlike time domain techniques, wavelet can help decompose a stochastic process into wavelet components with each being associated to a frequency band. In addition, the wavelet power spectrum examines the impact of the variance at a specific frequency band in relation to the overall variance of the process (Tiwari and Kyophilavong, 2014). Our results are in line with the previous studies like Jefferis and Smith (2005); Magnusson and Wydick (2002); Mlambo and Biekpe (2007); Smith and Dyakova (2014) that have established that stock prices contain a unit root when we employed only time domain unit root tests. However, our findings depart from the existing studies on African markets when we calibrate frequency domain measures into our model, which is the strength of this study.

The break dates identified in each of the markets studied can be linked to the events that have affected each of the economies (Lawal *et al*, 2016).

Tables 1: Wavelet-Based unit root tests

Stock indices	$\hat{S}^{LM}_{T,1}$			$\hat{S}^{Ld}_{T,1}$			$\psi^{M}(t)$		
	Test Statistics			Test Statistics			Test Statistics		
	Lag = 10	Lag = 20	Lag = 30	Lag = 10	Lag = 20	Lag = 30	Lag = 10	Lag = 20	Lag = 30
Egypt	-41.2301**	-38.2110*	-35.0121*	-219.4557*	-205.022*	-200.023*	-245.2314*	-229.2355*	-208.2331*
Zimbabwe	-25.7320*	-21.8221*	-21.7357*	-154.0751*	-142.3662*	-137.3221*	-192.2356*	182.2251*	178.2231*
Kenya	-38.1445*	-33.8254*	-34.2114*	-162.3221*	-148.1200*	-134.5642*	201.2214*	185.4789*	175.2635*
Nigeria	-142.225*	-139.2231*	-133.2201*	-200.1210*	-143.1222*	-139.2141*	-206.2653*	-158.12254*	-145.6885*
South Africa	-96.3226*	-94.2314*	-91.3211*	-403.2214*	-399.2144*	-398.5661*	-432.1547*	-401.1244*	-389.2449*
Morocco	-55.2214**	-53.2214*	-50.1241*	-295.1224*	-278.2144*	-255.3221*	-312.1211*	-301.2210*	-296.3321*
Cote' D'Voire	-44.1852***	-41.1022*	-38.1011*	-201.2114*	-191.2551*	-185.2325*	-233.1425*	-201.0012*	-190.2337*

*; ** and *** denotes 1%; 5% and 10% significance respectfully. Source: Authors' computation (2016).

Table 2: Results of the Lee and Strazicich (2003) LM unit root test with structural breaks

Break in Intercept				Break in Intercept and Trend		
Stock indices	Test Statistics	TB1	TB2	Test Statistics	TB1	TB2
Egypt	-3.14	1992:02	1998:10	-4.03	2000:03	2004:08
Zimbabwe	-3.06	1996:10	2004:05	-4.31	2005:05	2010:11
Kenya	-3.01	1999:04	2005:02	-4.36	2007:03	2011:03
Nigeria	-2.75	1999:10	2004:03	-4.34	2005:08	2010:04
South Africa	-2.55	2004:06	2005:04	-4.32	2005:02	2006:06
Morocco	-2.67	2000:12	2005:02	-4.03	2006:04	2009:10
Cote' D'Voire	-2.89	2000:02	2003:03	-3.96	2004:05	2007:08

Critical values for unit root test									
Break in Intercept only (Model AA)									
1%	5%	10%							
-4.54	-3.84	-3.50							
Break in Intercept and trend (Model CC)									
λ_2	0.4			0.6			0.8		
λ_1	1%	5%	10%	1%	5%	10%	1%	5%	10%
0.2	-6.18	-5.39	-5.17	-6.31	-5.67	-5.23	-6.32	-5.62	-5.22
0.4	-	-	-	-6.47	-5.62	-5.29	-6.39	-5.56	-5.21
0.6	-	-	-	-	-	-	-6.28	-5.59	-5.20

Notes: TB1 and TB2 represents the days of the structural breaks. λj represents the location of the breaks. The LM unit root test for model AA is invariant to the location of the breaks; however, this invariance does not hold for model CC, whereby the null distribution of the LM test depends on the relative location of the breaks. Source: Authors Computation, 2016.

Table 3: Results for Narayan and Popp (2010) unit root test with two structural breaks.

Break in Intercept				Break in Intercept and Trend		
Stock indices	Test Statistics	TB1	TB2	Test Statistics	TB1	TB2
Egypt	-3.34	1992:02	1995:11	-3.54	2000:10	2004:08
Zimbabwe	-3.22	1992:04	1996:05	-3.09	1998:05	2002:05
Kenya	-3.15	2001:06	2004:02	-3.13	2006:06	2010:11
Nigeria	-2.94	2002:10	2005:05	-3.03	2007:08	2010:10
South Africa	-2.65	2005:06	2007:06	-2.45	2006:06	2010:04
Morocco	-2.78	2004:12	2007:04	-3.05	2007:10	2010:12
Cote' D'Voire	-2.66	2000:02	2006:05	-3.78	2006:07	2010:08

Critical values for unit root test		
1%	5%	10%
Model M1 (Break in Intercept only)		
-4.522	-4.061	-3.827
Model M2 (Break in Intercept and Trend)		
-5.126	-4.608	-4.216

Note: Critical values were obtained from Narayan and Popp (2010)

5. CONCLUSION AND POLICY IMPLICATIONS:

This study employed frequency based wavelet unit root test to examine the stock market efficiency hypothesis for seven African stock markets. Our results show that using frequency domain unit root tests, African stock markets are mean reverting.

The results have the following implications: first, the weak form of the efficient market hypothesis is rejected, thus, there is a huge potential for investors to make profits by trading on the floors of the stock exchanges studied, when technical analysis is employed; and that it is possible to forecast stock prices based on historical data. Our results further reveals that there is a need to regulate stock market behavior in each of the economies studied, given the facts that investors can analyze price movements to make abnormal profits.

Second, the fact that stock prices are mean reverting suggest that shocks to stock prices will only have a temporary effects, as stock prices will return to their long run equilibrium naturally. Third, given that stock prices are stationary, non-stationarity will not be transmitted from stock market to the real sector. Government should therefore be careful in the usage of macroeconomic policies like Keynesian demand management policies, real business cycles policies among others in shaping the economy.

REFERENCES:

Afego, P. N. (2015): Market efficiency in developing African Stock Markets: What do we know? *The Journal of Developing Areas*, 49(1), pp. 243 – 266 http://doi:10.1353/jda.2015.0022

Aloui, C. and Hkiri, B. (2014): Co-movements of GCC emerging stock markets: new evidence from wavelet coherence analysis. *Economic Modelling* 36, 421–431.

Beltratti, A., Bortolotti, B., and Caccavaio, M. (2016): Stock market efficiency in China: Evidence from the split-share reform. *The Quarterly Review of Economics and Finance*, 60, pp. 125-137

Charfeddine, L., and Khediri, K. B. (2016): Time varying market efficiency of the GCC stock markets. *Physica A: Statistical Mechanics and its Applications*, 444, pp. 487-504

Dewandaru, G., Masih, R.and Masih, A. M. A. (2016): Contagion and interdependence across Asia-Pacific equity markets: An analysis based on multi-horizon discrete and continuous wavelet transformation. *International Review of Economics and Finance*, 43, pp. 363 – 377

Fama, E.F. (1970): Efficient capital markets: A review of theory and empirical work. *Journal of Finance*, 25, pp. 383–417.

Fan, Y.,Gençay, R., (2010): Unit root tests with wavelets. *Economic Theory* 26, pp. 1305–1331.

Gokcan, S. (2000): Forecasting volatility of emerging stock markets: linear versus non-linear GARCH models. *Journal of Forecast*, 19(6), pp. 499 – 504

Graham, M., Peltomäki, J. and Sturludóttir, H. (2015): Do capital controls affect stock market efficiency? Lessons from Iceland. *International Review of Financial Analysis*, 41, pp. 82-88

Hiremath, G. S. and Narayan, S. (2016): Testing the adaptive market hypothesis and its determinants for the Indian stock markets. *Finance Research Letters*, 19, pp. 173-180

In, F. and Kim, S. (2006): Multiscale hedge ratio between Australian stock and future markets: Evidence from wavelet analysis. *Journal of Multinational Financial Management*, 16(4), pp. 411 – 423

Jammazi, R. (2012): Oil shock transmission to stock market returns: Wavelet-multivariate Markov Switching GARCH approach. *Energy*, 37(1), pp. 430 – 454

Jefferis, K. and Smith, G. (2005): The changing efficiency of African stock markets. *South African Journal of Economics*, 73(1), pp. 54 – 67

Lahmin, S., Uddin, G. S. and Bekiros, S. (2017): Clustering of short and long term co-movement in international financial and commodity markets in wavelet domain. *Physica A: Statistical Mechanics & its Applications*, 486, pp. 947 – 955

Lawal, A. I., Nwanji, T. I., Asaleye, A. and Ahmed, V. (2016): Economic growth, financial development and trade openness in Nigeria: An application of the ARDL bound testing approach. *Cogent Economics and Finance*, 4: 1258810 http://dx.doi.org/10.1080/23322039.2016.1258810

Lee, J. and Strazicich, M. C. (2003): Minimum Lagrange multiplier unit root test with two structural breaks. *Review of Economics and Statistics*, 85, pp. 129 – 153

Madeteno, M. and Pinho, C. (2014): Wavelet dynamics for oil stock world interactions. *Energy Economics*, 45, pp. 120 – 133

Magnusson, M. A. and Wydick, B. (2002): How efficient are African emerging stock markets? *Journal of Development Studies*, 38(4), pp. 41 – 56

Mensi, W., Hammoudeh, S. and Tiwari, A. K. (2016): New evidence on hedges and safe havens for Gulf stock markets using the wavelet-based quantile. *Emerging Markets Review*, 28, pp. 155 – 183

Mlambo, C. and Biekpe, N. (2007): The efficient market hypothesis: evidence from ten African stock markets. *Investment Analysts Journal* 66, pp. 5 – 18

Mnif, A. T. (2017): Political uncertainty and behavior of Tunisian stock market cycles: Structural unobserved components time series models. *Research in International Business and Finance*, 39(A), pp. 206-214.

Moya-Martinez, P., Ferrer-Lapena, R. and Escribano-Sotos, F. (2015): Interest rate changes and stock returns in Spain: A wavelet analysis. *BRQ Business Research Quarterly*, 18(2), pp. 95 – 110

Narayan, P. K. and Bannigidadmath, D. (2015): Are Indian stock returns predictable? *Journal of Banking and Finance*, 58, pp. 506 – 531

Narayan, P. K. and Popp, S. (2010): A new unit root test with two structural breaks in level and slope at unknown time. *Journal of Applied Statistics*, 37, pp. 1425 – 1438

Narayan, P. K., Liu, R. and Westerlund, J. (2016): A GARCH model for testing market efficiency. *Journal of International Financial Markets, Institutions and Money*, 41, pp. 121 – 138

Nwosu, E. O., Orji, A. and Anagwu, O. (2013): African emerging equity markets re-examined: testing the weak form efficiency theory. *African Development Review*, 25(4), pp. 485 – 498 http://doi:10.1111/1467-8262.12044

Pele, D. T. and Voineagu, V. (2008): Testing market efficiency via decomposition of stock return. Application to Romanian capital market. *Romanian Journal of Economic Forecasting*, 3, pp. 63 - 79

Rizvi, S. A. & Arshad, S. (2017): Analysis of the efficiency-integration nexus of Japanese stock market. *Physica A: Statistical Mechanics and its Applications* 470, pp. 296-308

Rounaghi, M. M. and Zadeh, F. N. (2016): Investigation of market efficiency and Financial Stability between S&P 500 and London Stock Exchange: Monthly and yearly Forecasting of Time Series Stock Returns using ARMA model *Physica A: Statistical Mechanics and its Applications*, 456, pp.10-21

Rua, A., and Nunes, L. C. (2009): International comovement of stock market returns: A wavelet analysis. *Journal of Empirical Finance*, 16, pp.632–639

Sensoy, A. and Tabak, B. M. (2015): Time-varying long term memory in the European Union stock market. *Physica A: Statistical Mechanics and its Applications*, 436, pp. 147-158

Smith, G. and Dyakova, A. (2014): Africa Stock Markets: efficiency and relative predictability. *South African Journal of Economics*, 82(2), pp. 258 – 275

Stratimirovic, D., Sarvan, D., Miljkovic, V. and Blesic, S. (2018): Analysis of cyclical behaviour in time series of stock market returns. *Commun Nonlinear Sci Numer Simulat*, 54, pp. 21 – 23

Sukpitak, J. and Hengpunya, V. (2016a): Efficiency of Thai stock markets: Detrended fluctuation analysis. *Physica A: Statistical Mechanics and its Applications,* 458, pp. 204-209

Sukpitak,J., and Hengpunya, V. (2016b): The influence of trading volume on market efficiency: The DCCA approach. *Physica A: Statistical Mechanics and its Applications*, 458 pp. 259-265

Tiwari, A. K. and Kyophilavong, P. (2014): New evidence from the random walk hypothesis for BRICS stock indices: a wavelet unit root test approach. *Economic Modelling* 43, pp. 38–41.

Tuyon, J. and Ahmad, Z. (2016): Behavioural finance perspectives on Malaysian stock market efficiency. *Borsa Istanbul Review*, 16(1), pp. 43-61

Urquhart, A. and McGroarty, F. (2016): Are stock markets really efficient? Evidence of the adaptive market hypothesis. *International Review of Financial Analysis*, 47, pp. 39-49

Vacha, L. and Barunik, J. (2012): Co-movement of energy commodities revisited: evidence from wavelet coherence analysis. *Energy Economics,* 34, pp.241–247

Westerlund, J. and Narayan, P. (2015): Testing for predictability in conditionally heteroskedastic stock returns. *Journal of Financial Economics*, 13(2), pp. 342 - 375

Westerlund, J., Narayan, P. K. and Zheng, X. (2015): Testing for stock return predictability in a large Chinese panel. *Emerging Markets Review*, 24, pp. 81 – 100

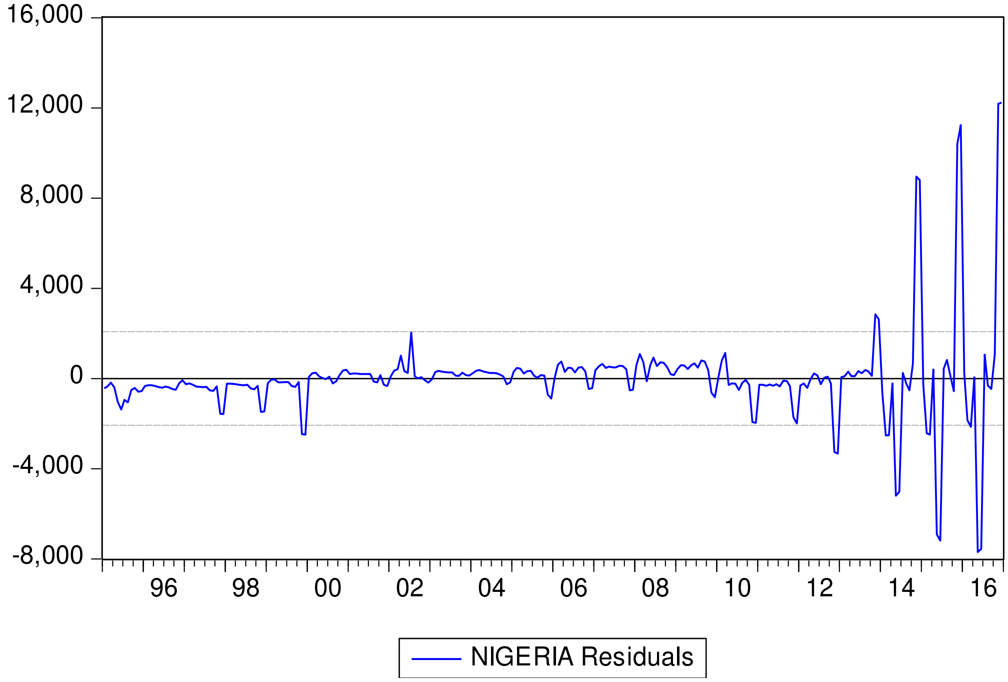
Yang, L., Cai, X. J., Zhang, H. and Hamori, S. (2016): Interdependence of foreign exchange markets: A wavelet coherence analysis. *Economic Modelling*, 55, pp. 6 – 14

Shrivastava, N. A. and Panigrahi, B. K. (2014): A hybrid wavelet-ELM based short term price forecasting for electricity markets. *International Journal of Electrical Power & Energy Systems*, 55(7), pp.41–50

Yang, Z., Ce, L. and Lian, L. (2017): Electricity price forecasting by a hybrid model, combining wavelet transform, ARMA and kernel-based extreme learning machine methods. *Applied Energy*, 2017, 190(C), pp. 291-305

Boubaker, H. and Raza, S. (2017): A wavelet analysis of mean and volatility spillovers between oil and BRICS stock markets. *Energy Economics*, 2017, 64(C), pp. 105-117

Figure 1
Nigeria



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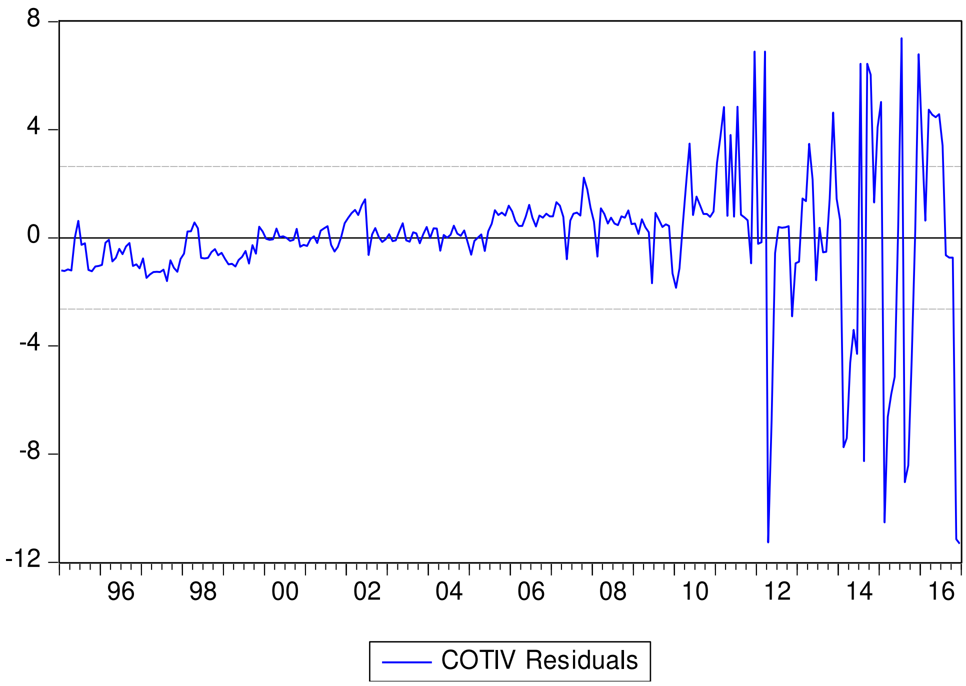

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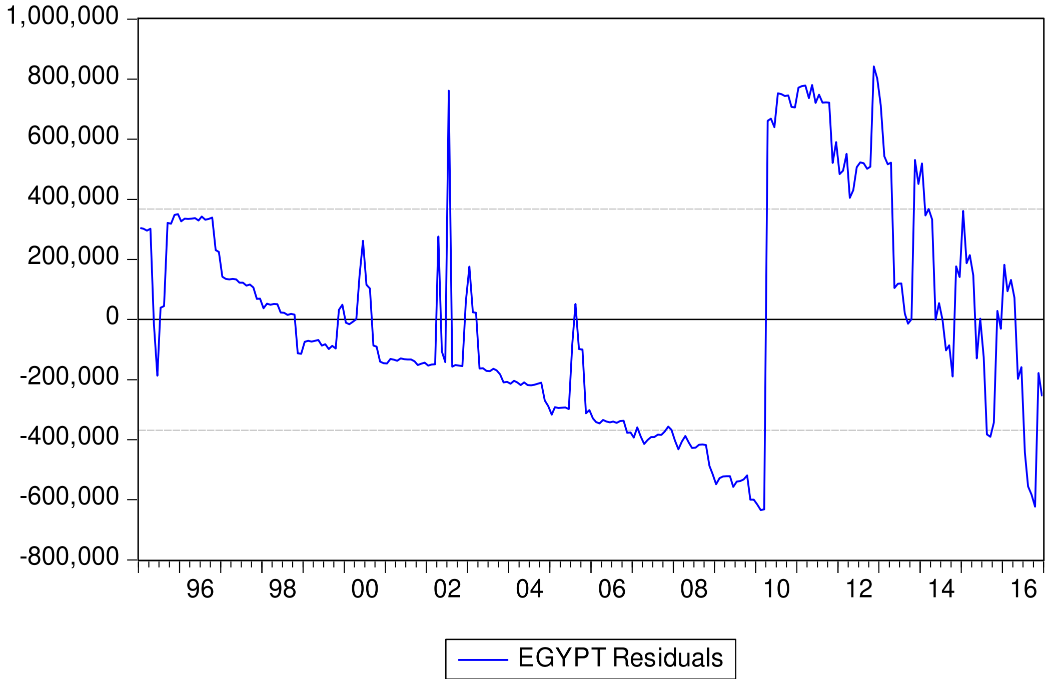
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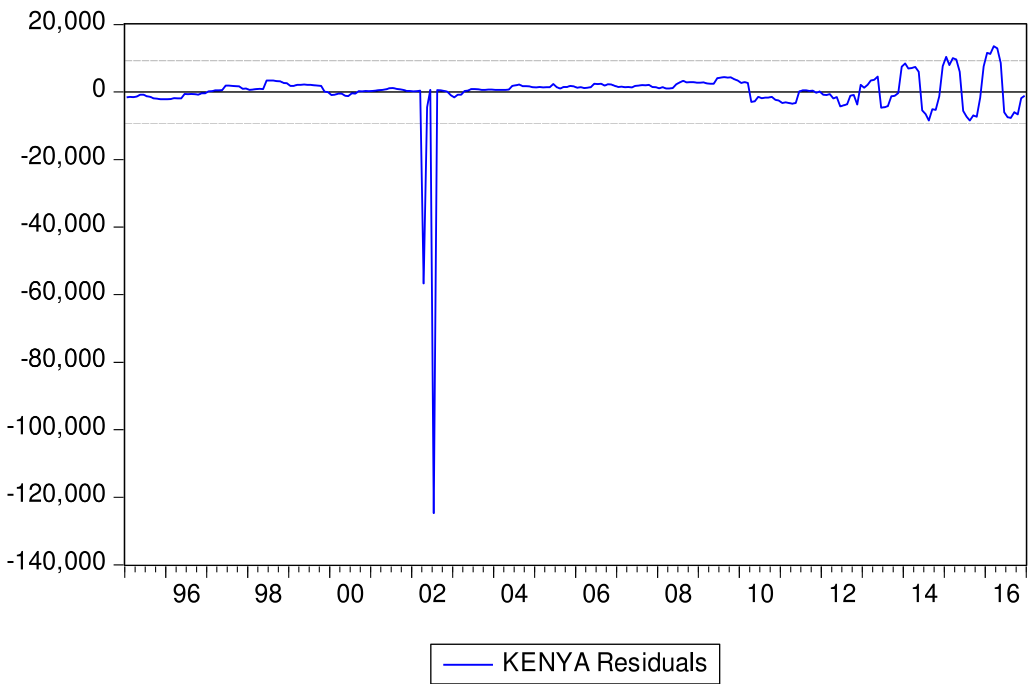
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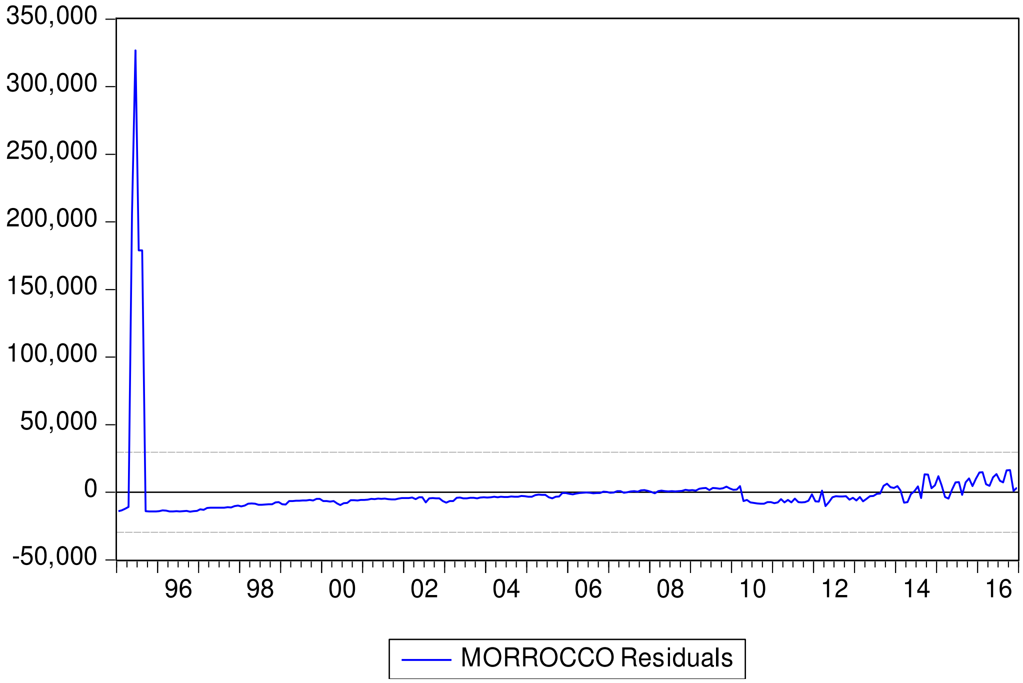
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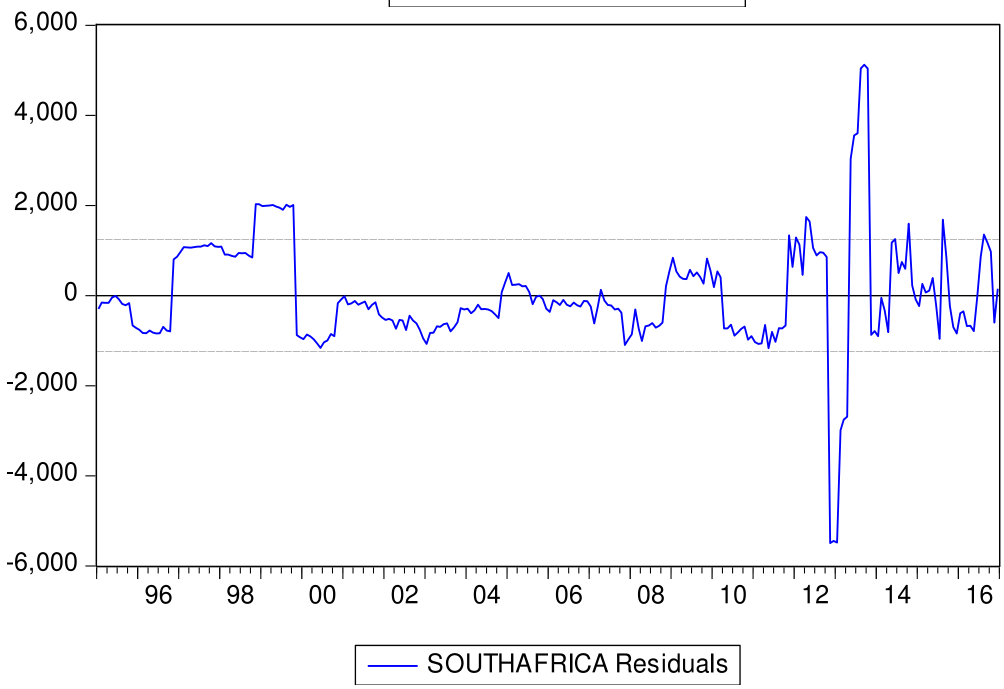
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SOUTHAFRICA Residuals

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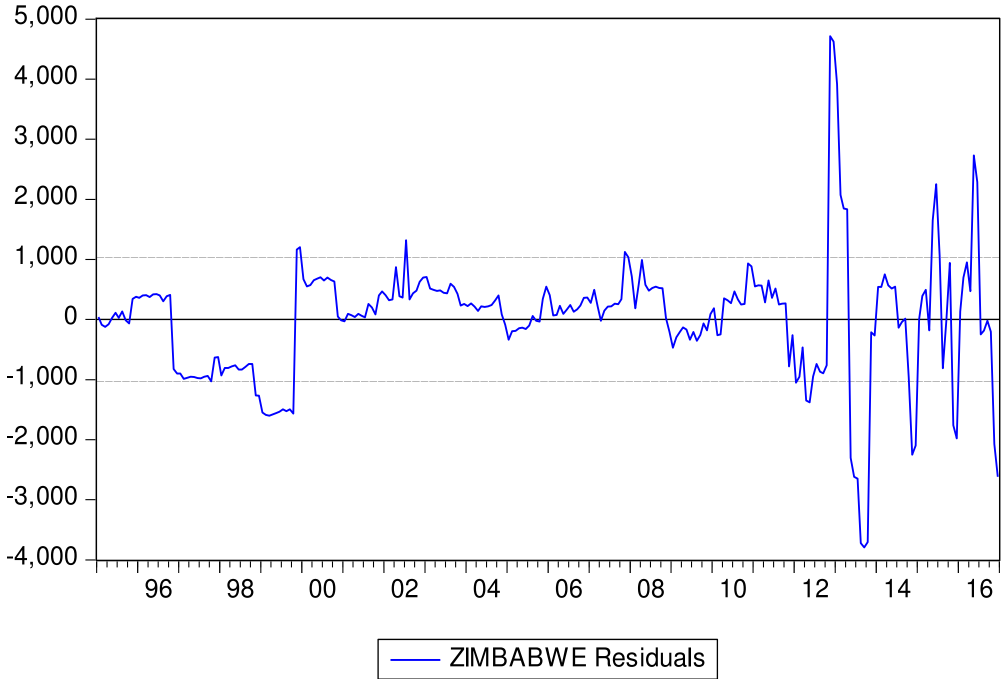
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4,000
3,000
2,000
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96
98
00
02
04
06
08
10
12
14
16
ZIMBABWE Residuals