Can Western African countries catch up with Nigeria? Evidence from Smooth Nonlinearity method in Fractional Unit root framework

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Abstract

West African countries have long advocated efforts to promote economic integration and income convergence. In recent trends, Nigeria records the highest GDP in nominal value, yet its neighbouring countries are yet to catch up in terms of both GDP growth rate and GDP per capita growth rate. The general objective of this paper is to examine the convergence of Western African countries to catch up with Nigeria in terms of real per capita income. For the estimation, the paper employs fractional unit root approach to model simultaneously smooth breaks by means of flexible Fourier function in time. The approach adopted is novel, where it is still lacking in the application of economic convergence across countries. The findings show that, while some West African countries do converge among themselves, only Ghana is likely to catch up with Nigeria. As a policy implication, the West-African countries would increase further education level and technology transfers to promote income convergence at different stages of economic development.

Keyword: Income convergence, economic integration, West Africa, nonlinear method

JEL Classification: C19, C22, N17

1. Introduction

On May 28, 1975, some West African countries formed a regional group called Economic Community of West African States (ECOWAS) via the Treaty of Lagos. Among the constituting countries include Benin, Burkina Faso, Cape Verde, Cote d' Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone, Senegal, and Togo. The general purpose of economic integration is to promote economic growth among member countries over time in different economic activities including industries, resource management, technology, finance, and social matters (Turkson, 2018). The economic integration should contribute to income convergence among member countries (Campos et al., 2018).

Data presented in Worldbank open data show that member countries are not homogenous in terms of their income performance. Nigeria alone has accounted for 69% of the community's GDP in 2017, followed by Ghana and Cote d'Ivoire with 8.4% and 7.2% growths, respectively. The lower-income countries do catch up faster in terms of income level as Nigeria experiences a steady state in growth. Table 1 ranks the economic performance of each ECOWAS member country based on GDP growth rate in 2017. It shows that Nigerian economy has progressed at 12.77%, recording the fastest rate of growth in 1990 as compared to other member countries. Despite the remarkable rate in the earlier period, the economy has shown a weak sign of growth rate at 0.81% only in 2017. A comparison with other member countries demonstrates the effectiveness of ECOWAS in stimulating income convergence among member countries, especially in recent years. For instance, Ghana, which is reported to grow just 3.33% in 1990, has become the fastest growing nation in 2017 that records a growth rate of 8.51% in the year. As most of the other member economies in the region continue to grow if the current trend continues, there may be economic convergence with respect to Nigeria. In addition, the income convergence also works if the difference in GDP per capita across member countries becomes zero as the economic cooperation goes along (see Table 2). Nigeria grows at a growth rate of 0.81% in 2017, its GDP per capita yet has decreased by 1.77% in that year. In comparison, the economy of other member countries seem to converge to that of Nigeria. Ghana, for instance, has achieved 6.15% rate of growth in GDP per capita which is the highest relative to other member countries in 2017.

INSERT TABLES 1 AND 2 ABOUT HERE

Previous researchers have employed different definitions and methodologies to approach the hypothesis of convergence. Using the time series analysis approach, stochastic convergence checks whether permanent movements in one country's per capita income are related to permanent movements in another country's income. It examines the persistence of the differences in income level of the pair, and this is not expected to contain unit root for convergence to be achieved (Cunado, Gil-Alana and Gracia, 2004). Thus, differences observed in the per capita income and in growth rates of countries concerned justifies a deeper study on convergence, particularly in the case of West Africa countries.

In this paper, we define the term real convergence as mean reversion in the differences of GDP per capita of Nigeria with each one of the other West African countries. We investigate the catching up effect using the significance of the linear time trend in the testing regression. Since GDP per capita may contain multiple breaks, we extended the unit root testing approach of Enders and Lee (2001, 2002) with smooth Fourier function to fractional I(d) case.

The Fourier function allows for smooth nonlinearity to be captured in the movement of the time series of GDP per capita. Using the linear assumption, as applied in classical ADF-like unit root test may lead to loss of power since there may be some structural breaks in the series, and instead of detecting these with, say, Bai and Perron (2003) multiple structural break tests, nonlinear Fourier function in time allows one to model these breaks (Ender and Lee, 2001; 2002). Fractional unit root is a more robust approach to testing unit root in time series since the testing procedure has better power against unit integration test (Hassler and Wolters, 1994; Lee and Schmidt, 1996). Also, it has additional policy implications/interpretations as stated below.

In the context of fractional unit root, the differencing parameter *d* assumes different fractional values in mean reversion and non-mean reversion ranges which could be stationary or nonstationary I(d) process for example, if $d < 1$, mean reversion is achieved and convergence is satisfied. On the other hand, if $d = 1$ or $d > 1$, convergence is clearly rejected.

The rest of the paper is structured as follows. The following section describes main characteristics of economic integration in West Africa countries. Data and method will follow in the next section. The paper continues with empirical results and discussion. Suggestion and policy recommendations are provided in the last section.

2. Main characteristics of economic integration in West Africa

The motivation for ECOWAS was to harness regional resources, achieve economies of scale and for the group to attain greater negotiating power in global trade and investment. The ECOWAS Revised Treaty of 1993 (Revised Treaty) and the Protocols and Supplementary Acts made under it lay out policies and schemes for progressively transforming the region into a free trade area, a custom union, a common market and eventually an economic union. One of the main objectives as stated in Article 3 of the Revised Treaty, is "to raise the living standards of [the Community's] peoples, and to maintain and enhance economic stability".

As conceived, ECOWAS economic integration features the free movement of all factors of production (goods, services, labour and capital); complete removal of customs duties on intraregional trade; elimination of all tariff and non-tariff barriers to trade; establishment of a common external tariff with third countries and the harmonisation of relevant policies and regulations of member countries (ECOWAS Commission, 2009). The current strategic action plan, the ECOWAS Vision 2020, articulates a comprehensive agenda for the development of the region and its people through inclusive programmes in which all member states benefit equitably.

From inception, several institutions and bodies with supranational autonomy were put in place. The Authority of the Head of States and Governments is the supreme policy making body responsible for making Supplementary Acts that complement the Treaty. The Commission (previously the Executive Secretariat) is "the engine room" that administers all ECOWAS programmes, projects and activities and assists member states in implementing Community programmes and decisions. The Council of Ministers makes Regulations and Directives binding and enforceable in member states and the Parliament, is a representative body with decision-making and advisory power within its areas of competence.

Notwithstanding clear institutional and regulatory set-ups, ECOWAS has in general experienced difficulties in terms of practising the economic integration scheme (Omorogbe, 1993). Except for the free movement of people, only limited success is recorded with respect to free circulation of goods and the common external tariff. Part of the problem is lack of conviction and commitment by Member States as to the immediate benefits of the cooperation warranting the making compromises and giving up of national sovereignty (Ogunfolu, 2009). This is particularly so as countries naturally calculate or weigh the burdens or costs of integration vis-a-vis the gains they stand to reap from the concessions (Okolo, 1985).

As with regional integration units elsewhere, the 15-member countries of ECOWAS have been and are still largely heterogenous in terms of market size, demography, natural resource endowment and geographical location (i.e. landlocked or coastal states). Critical issues do arise as a result of diversity in the wealth and development levels among integrating countries (Okolo, 1985). Ametoglo (2018) argues that economic integration could strongly increase inequality amongst member countries. Because each country's aim is to develop further through cooperation, unless policies are carefully planned, the scheme may continue to favour the larger countries at the expense of the smaller one. Even where growth is recorded in all states over time, it is possible for similar disparities as existed at the inception to continue to exist. For ECOWAS, the differences are stark: the largest economy, Nigeria alone has accounted for bout 70% of the Community's GDP. Of all 15 states, the five biggest account for 90% of the GDP (Oxford Business Group, 2013). This position is not helped by the fact that the level of intraregional trade remains small. It stands at about 12%, more than 50% of which is from the three biggest economies (ECOWAS, 2009).

These problems show that ECOWAS ought to adopt more income convergence related policies and programmes for its member states especially with Nigeria. Such programmes should aim at supporting weaker countries if the integration is to raise living standards, reduce poverty, and level up income gap. So far, the West African Economic and Monetary Union (WAEMU), comprising 8 ECOWAS countries (mostly the Francophones and Guinea Bissau) that share a common currency, has implemented such programmes (Ayuk and Kabore, 2013). Within ECOWAS, the West African Poverty-reduction Regional Strategic Plan was launched in 2010. It created policy priorities to address the challenges of poverty to achieve the Sustainable Development Goals. So far, less than optimal gains have been realised. The programme lacks efficacy as there are no enforceable obligations imposed on member states, leaving implementation to the political will of individual governments.

2.1 Schemes towards Assisting Less Developed States

In recognition that economic integration and liberalisation could result in gains by larger economies and losses by smaller ones, ECOWAS member states were categorised into 3 groups according to levels of economic development. Concessions were provided to the respective groups in implementing the programmes (NANTS, 2013). In several areas, the Revised Treaty provisions reflect the fact that the economic circumstances and capabilities of

the member states differ. Effectively applied, these should ameliorate inequality amongst states and result in convergence.

First, the enshrined fundamental principles under the Treaty include "equality and inter-dependence of Member States and the equitable and just distribution of the costs and benefits of economic co-operation and integration". Member States further agreed in Article 3 to promote balanced development of the region, paying attention to the special problems of each state, particularly the landlocked and small island states. They are also to consider the economic and social difficulties that may arise in the island and three landlocked states. Article 68 requires granting these states, "where appropriate, special treatment in respect of the application of certain provisions of this Treaty and to accord them any other assistance that they may need".

Second, the Revised Treaty calls for "gradual and progressive" integration and the implementation of the single economic market in stages. The Trade Liberalisation Scheme (TLS), at the heart of the free trade area, was slated for establishment over a 10-year period from its launched in 1990. Article 5 of Decision A/DEC.1/5/83 (30 May 1983) phased the programme according to the levels of development of member states. Regarding the priority products, for instance, the least developed countries (Cape Verde, The Gambia, Guinea Bissau, Upper Volta, Mali, Niger) were given 8 years to liberalise. The middle countries (Benin, Guinea, Liberia, Sierra Leone, Togo) were to liberalise in 6 years while the most developed countries (Ivory Coast, Ghana, Nigeria and Senegal) had 4 years. Surprisingly, it is the big countries like Nigeria that were not efficiently implementing the scheme and would appear to have been free-riding at the expense of the others (Bankole, 2012).

Third, the tariff bands under the Common External Tariff (CET) were meant to and have been implemented gradually. The amount and the rate of reduction of taxes and duties depended on the respective member states' level of development. Group 1 countries were to reduce 10% per year over 10 years. 12.5% reduction over 8 years was stipulated for Group 2 and Group 3 was subjected to 16.6% reduction for over 6 years. The programme was launched in 2015 and now has five tariff bands (ECOWAS Commission, 2016). Additionally, provisions were made to cushion the effect of the CET. Regulation C/REG.4/06/13 (21 June 2013) allowed for Safeguard Measures to deal with any damage or potential damage to a production section of the Community due to large and uncontrolled imports following the CET's implementation. Supplementary Protection Measures were also provided to assist Community industries manage the transition to the uniform CET standards for 5 years.

Incidentally, it is the more developed countries like Nigeria, Ghana, Senegal and Cote d'Ivoire that have utilised the measures (ECOWAS Commission, 2017).

Fourth, establishment of the economic union was also planned to be completed gradually within a 15-year period after the introduction of the TLS (Article 54 of Revised Treaty). The ECOWAS monetary union with a single currency involving the harmonisation of monetary, financial and fiscal policies of all member states was also slated to be gradually completed over a 5-year period. Although the TLS and CET have dragged on beyond target dates, scheduling their implementation with sensitivity towards differences in the countries' economic and administrative capability have allowed much needed flexibility for all to benefit from the cooperation both in the immediate and long term.

Fifth, the ECOWAS integration programme provides for a system often used in custom unions to compensate the adverse effect of losses of government revenue (through intraregional tariff reductions) on less developed, low income members. Walkenhorst (2006) argues that such arrangements are "propelled by concerns that benefits from regional integration might be unequally distributed and accentuate disparities in development levels within the region, with the stronger, larger economies gaining at the expense of weaker, smaller countries." He states further that such arrangements are "vehicles of economic solidarity weighted in favour of the poorer countries in the group."

Article 48 of the Revised Treaty provides that Member States who have suffered loss of import duties due to the application of the provisions creating the customs union shall be entitled to compensation. Such states are also entitled to apply safeguard measures in the event of serious distortion in their economy pending the approval of the compensation by the Council. Although two Protocols were signed in 1976 and 2002 to provide respectively for Revenue Loss Compensation under the CET and TLS, the former scheme faltered, and the latter never took off and expired after the four-year validity period (Walkenhorst, 2006). By not utilising this programme, ECOWAS misses out on an essential tool that assists in reducing inequality gap in an economic integration. By contrast, WAEMU operates a revenue sharing system which compensates revenue losses from reduced tariff. But even within this smaller more homogenous group, the problem of growing economic divergence persists as the Union is unable to help poorer countries in any significant way (Seck, 2013).

Sixth, ECOWAS also created a Fund for Cooperation, Compensation and Development pursuant to Article 21 of the Revised Treaty. It was applied to finance essential public sector projects especially for less developed countries. The Fund later transformed into the ECOWAS Bank for Investment and Development. As the financial powerhouse of the

region, the bank mobilises capital and provides loans for Community projects. It receives and manages the portion of the Community Levy earmarked for financing Community development activities and for compensating member states for losses in revenue due to implementation of Community projects.

In recent times, the bank's resources for executing projects have been drying up as many member states fall behind in their Levy contributions. Even big countries like Nigeria are not implementing the scheme or paying up their Levy (Butu, 2013). WAEMU also established a Regional Integration Aid Fund and an aid intervention programme. However, the assessment of WAEMU's first 15 years and the review of the per capita GDP of its members indicated that the "countries that were the richest in 1990 - Cote d'Ivoire, Senegal, Benin - remained so and experienced respective growth in income. On the contrary, the economically weak countries such as Guinea-Bissau, Niger, Togo stagnated or fell behind" (Seck, 2013).

In the light of the above, although ECOWAS has all the right schemes and programs on paper and can indeed implement an economic union to realise its goals of equitable development for all, much work is still required to effectively practice the schemes and to see income growth at the pace which is desired. The Nigerian economy has been in recession since 2016 and is showing weak signs of abating. As most of the economies in the region haves continued to record growth, they will be progressing to catch up with Nigeria if the current trend continues.

3. Literature review on the income convergence hypothesis

Bernard and Durlauf (1996) made a significant contribution to existing literature on income convergence hypothesis by introducing a new econometric interpretation. They pointed out that income convergence could be interpreted as a difference in log of per capita real income between two countries is expected to become zero in the long-run. This interpretation could be expressed as (Bernard and Durlauf, 1996):

$$\lim_{K\to\infty} E(y_{i,t+k} - y_{j,t+k}|I_t) = 0 \qquad (1)$$

where E is the expected value, I_t is the information set. Thus, for income $y_{j,t+k}$ of country j to converge to income $y_{i,t+k}$ of country i, the difference $\left(y_{i,t+k} - y_{j,t+k}\right)$ must be stationary

$I(d=0)$ process, or of $I(d<b)$ in the fractional unit root case, where b is the fractional unit root of income series in country i. If the income difference between the two countries contains a unit root, then, the hypothesis of income convergence is violated. It would mean that a unit root test could be applied to test the income convergence test, but this test lacks power in the presence of fractional alternatives (Hassler and Wolters, 1994; Lee and Schmidt, 1996).

Since the seminal publication by Bernard and Durlauf (1996), there are numerous empirical testing on income convergence hypothesis. For example, Greasley and Oxley (1997) used the augmented Dickey-Fuller (ADF) test and the Zivot and Andrews (ZA) test to examine income convergence in four paired developed countries for the period of 1900-1987. They claimed that the ADF test could reject the null hypothesis of no convergence for three paired countries and the ZA test could reject the null hypothesis for one paired countries. They concluded that there is income convergence in these four paired developed countries. Li and Papell (1999) introduced a new concept in existing literature, a relative per capita income which could be measured by individual country's per capita income as a percentage of aggregated per capita income in the group of countries. They applied the ADF for the analysis relative per capita income convergence in sixteen developed countries for the period of 1870-1989. They concluded that there is income convergence in all these sixteen countries, except Austria, Germany, Italy, Japan, Sweden and United States. Furthermore, Oxley and Greasley (1999) applied the ADF test and the Perron test to examine the income convergence in four Nordic countries for the period of 1900-1987. In other words, they analysed whether the Nordic countries could catch up with Sweden in term of real per capita income. The ADF test failed to reject the null hypothesis of no convergence between Sweden and three Nordic countries. However, the Perron test could reject the null hypothesis between Sweden and two countries, namely Demark and Finland. They concluded that the Nordic convergence club would consist of three countries, namely Denmark, Finland and Sweden. It would mean that Norway could be considered as an outlier in the region's convergence club.

In the 2000s, some researcher applied some advanced econometric methods, such as cointegration test or fractional integration method, panel unit root test or nonlinear unit root method, to test the income convergence hypothesis. For example, Datta (2003) used the Johansen cointegration method to test the income convergence between reference countries, United States, and sixteen developed countries for the period of 1980-1998. The Johansen cointegration test could reject the null hypothesis of no convergence in only three developed

countries, namely France, Germany and Italy. It would mean that there would be no income convergence in remaining thirteen countries. Cunado *et al*. (2004) applied a fractional integration method to examine income convergence in United States, Taiwan and Japan for the period of 1903-1999. They define the stationary process of per capita real income as a covariance stationary process with spectral density function which could be positive and infinite at the frequency of zero. Using this definition, they used parametric fractional methods known as the Robinson method and semi-parametric method known as the Geweke and Porter-Hudak method for the empirical analysis. They claimed that there is an income convergence between Taiwan and Japan and no income convergence between Taiwan and United States. Furthermore, Guetat and Serranito (2007) used a panel unit root test to examine the income convergence in eleven countries in the Middle East and North Africa for the period of 1960-1990. They used a unit root test known as known as the Levin-Lin-Chu (LLC) test for the empirical analysis. They reported that the LLC could reject the null hypothesis of no convergence in the region. They concluded that there is a catch-up process among these countries in the region. Liew and Ahmad (2009) used a nonlinear unit root method to re-test the income convergence process in the four Nordic countries, namely Denmark, Finland, Norway and Sweden, for the period of the 1950-2000. In other words, they applied the nonlinear unit root test known as the Kapetanios-Shin-Snell (KSS) test to examine whether the Nordic countries could catch up with Denmark in term of real per capita income. They claimed that the KSS test could reject the null hypothesis of no convergence for all three Nordic countries. They concluded that the Nordic convergence club would include all four Nordic countries.

In the 2010s, the empirical analysis of income convergence is still a popular method. Researchers used some sophisticated methods, such as nonlinear unit root test, nonlinear unit root test with structural break or Fourier unit root test, for their empirical analysis. For example, King and Ramlogan-Dobson (2011) re-examined the nonlinear unit root test to examine income convergence of fourteen developed countries with United States for the period of 1950-2004. In other words, they used two modified version of nonlinear Lagrange Multiplier (NLM) tests, namely the Lee-Strazicich test and the Chortareas-Kapetanios-Shin test, to analyse whether these fourteen developed countries could catch up with United States. The nonlinear test without taking account of structural breaks rejected the null hypothesis of no convergence for three countries, namely Australia, Canada and Switzerland and the nonlinear test with one-structural break rejected the null hypothesis for eight countries, namely Australia, Belgium, Denmark, Finland, France, Norway, Sweden and Switzerland and

the nonlinear test with two-structural break rejected null for five countries, Austria, Belgium, Canada, Germany and Switzerland.

Cunado (2011) also used the Lee-Strazicich test to examine income convergence of fourteen oil exporting countries with United States for the period of 1950-2006. In other words, the researcher used the nonlinear unit root test to analyse whether these oil exporting countries would catch up with the United States in term of per capita real income. The researcher claimed that all these countries, except Indonesia and Angola, could not catch up with United States. Wang (2012) used a panel unit root test to examine the income convergence in the member countries of Association of Southeast Asian Nations (ASEAN) for the period of 1960-2009. In other words, the researcher used the Evans–Karras test procedure to examine whether there would be the presence of unit root in income difference between per capita income in six old members of the ASEAN and cross-country average of income of these countries. They claimed that there is income convergence in these countries, except Thailand. King and Ramlogan-Dobson (2015) used the Fourier Lagrange Multiplier (FLM) test and nonlinear Fourier Lagrange Multiplier (NFLM) test to examine the income convergence of eighteen Latin American countries with United States for the period of 1950-2009. They claimed that the FLM test could the FLM test could reject the null hypothesis of no convergence in all eighteen countries, except Bolivia, Costa Rica, Dominican Republic and Paraguay. Furthermore, the NFLM test could rejected the null hypothesis for all these eighteen countries, except Argentine, Bolivia, Colombia, El Salvador and Venezuela.

Furuoka (2018) applied the Fourier ADF test with structural break (FADF-SB) test to examine income convergence in ten countries in Southeast Asia for the period of 1970-2014. In other words, this nonlinear unit root test with structural break is used to examine whether four new member countries of ASEAN, namely Cambodia, Laos, Myanmar and Vietnam would catch up with six old member countries of ASEAN, namely Brunei, Indonesia, Malaysia, Philippines, Singapore and Thailand. The methodological advantage of the FADF-SB test is that the Fourier function in the estimation model could take account of nonlinearity and the structural break dummy variable in the estimation model could take account of structural break in the time-series data. The researcher pointed out that Cambodia could catch up with Indonesia in terms of per capita real income and Vietnam also could catch up with Indonesia and Philippines. However, Myanmar and Laos could not catch up with more advanced countries in the region.

4. Data and methods

The data used in this work are the Purchasing Power Parity (PPP) of West African countries measured in terms of GDP per capita, taken from the International Monetary Fund (IMF) website. We considered ten (9) West African countries: Benin, Burkina Faso, Cote D'Ivoire, Ghana, Mauritania, Niger, Nigeria, Senegal and Togo. Of these countries, Nigeria is the richest in terms of the current PPP as reported by IMF (World Economic Outlook, 2017). Though, Ghana, Cote D'Ivoire and Mauritania with Nigeria have been classified as low middle-income countries, while Benin, Burkina Faso, Senegal and Togo are classified as low-income countries. The paper filtered out Nigeria to recognize if other countries in this West African region can catch up with the level of economic growth of this country, as measured by the PPP. The dataset reports PPP from 1961 to 2017, covering a sample of size 57 years. Then, we denote y_t as the PPP time series.

The flexible Fourier fractional integration set-up applied in this work is based on the joint regression model,

$$y_t = f(Z_t) + x_t, \quad (1-B)^d x_t = u_t, \quad t = 1,2,... \tag{1}$$

where $f(Z_t)$ is the absolutely integrable function, approximated by a Fourier series in smooth trend polynomial functions in time t; B is the lag operator, x_t is the fractionally integrated time series process, integrated of order d, given by the difference operation $(1-B)^d x_t = u_t$

such that for $d = 0$, $x_t = u_t$ that is the time series at hand is stationary as it does not require any further differencing. For $d = 1$, $x_{t-1} - x_t = u_t$, that is the case of non-stationarity of x_t, with first difference to obtain the stationary u_t process. These two restrictive extreme points for d have been considered in Becker, Enders and Lee (2006); Enders and Lee (2011; 2012); Furuoka (2014; 2016). The case of fractional d, that is, the $I(d)$ is first introduced in Granger and Joyeux (1980) and Hosking (1981), and more recently in Gil-Alana's paper, has formed a new trend in economic time series. The $I(d)$ framework has appealing policy interpretation compared to DF unit root framework. The fractional d operator $(1-B)^d$ in (1) is expanded based on using the Binomial series expansion as,

$$(1-B)^d = \sum_{i=0}^{\infty} \binom{d}{j} (-1)^j B^j = 1 - dB + \frac{d(d-1)}{2} B^2 - \frac{d(d-1)(d-2)}{6} B^3 + \ldots \quad (2)$$

and it implies that,

$$(1-B)^d x_t = x_t - dx_{t-1} + \frac{d(d-1)}{2} x_{t-2} - \frac{d(d-1)(d-2)}{6} x_{t-3} + \ldots = u_t \quad (3)$$

Thus, the higher the value of d, the greater the degree of association between distant observations. This long-range dependency is obvious in the case of $0 < d < 1$ in (3) above. This is also a situation of stationary mean reversion since the economy realizing such time series is bound to come to normalcy. This also explain the catching up effect/growth convergence of countries in terms of PPP since similar fractional d values imply convergence that is catching up, while marginal fractional d values imply no catching up/divergence effect in the economies.

Now, the Fourier function $f(Z_t)$ assumes two forms of intercept only, and intercept with trend as stated below (Ender and Lee, 2011, 2012; Furuoka, 2014, 2016):

$$f(Z_t) = \alpha + \sum_{k=1}^{m} \lambda_k \sin(2\pi kt/T) + \sum_{k=1}^{m} \gamma_k \cos(2\pi kt/T); \quad n \le T/2$$

$$(4)\ f(Z_t) = \alpha + \beta t + \sum_{k=1}^{m} \lambda_k \sin(2\pi kt/T) + \sum_{k=1}^{m} \gamma_k \cos(2\pi kt/T); \quad n \le T/2 \quad (5)$$

where $f(Z_t) = \left[\sin(2\pi kt/T), \cos(2\pi kt/T)\right]'$, and m is the number of frequencies, with k representing a particular frequency. The parameter α is the intercept, and β is the coefficient of the linear trend, t; λ_k and γ_k measure the amplitude and displacement of the sinusoidal component of the deterministic term and T is number of observations.

Using the Fourier function with a single frequency *k*, such that *k* can be a unit or fractional value as in Fractional Frequency Flexible Fourier Function (FFFFF) of Omay (2015), the function in (5), for example, is re-represented as,[1]

$$f(Z_t) = \alpha + \beta t + \lambda_{k_f} \sin(2\pi kt/T) + \gamma_{k_f} \cos(2\pi kt/T); \quad n \le T/2 \quad (6)$$

[1] Becker, Enders and Lee (2006) and Enders and Lee (2012) recommend using fairly a single frequency component in unit or fractional value for the Fourier function in detecting smooth break, since higher frequency order could lead to over-filtration.

where λ_{k_f} and γ_{k_f} are the parameters for the single fractional Fourier polynomial at fractional frequency k_f. The nonlinear smooth trend function in (1) can easily reduce to linear trend function in fractional unit root framework of Robinson (1994) once we fail to reject any of the null hypothesis:

$$H_0 : \lambda_k = 0, \quad H_0 : \gamma_k = 0; \tag{7}$$

for every $k = 1, ..., m$. In this linear case for example, we test the null hypothesis,

$$H_0 : d = d_0 \tag{8}$$

for any real valued d_0. Thus, u^t is *I(0)* and with the linear nature of the relationship, the parameters involved in the model can be estimated by standard ordinary least squares method or its generalized version (OLS/GLS). With the full nonlinear case in (1), we re-write the model as,

$$y_t^* = \sum_{k=0}^{n} \theta_i f^*(Z_t) + u_t; \quad t = 1, 2, ... \tag{9}$$

where $f^*(Z_t) = \rho(L, d_0) f(Z_t)$. By using OLS/GLS methods, we obtain,

$$\hat{u}_t = y_t^* - \sum_{k=0}^{n} \theta_i f^*(Z_t) \tag{10}$$

and,

$$\hat{\theta} = \left[\sum_{i=1}^{n} f(Z_t) f(Z_t)' \right]^{-1} \left[\sum_{i=1}^{n} f(Z_t) y_t^* \right] \tag{11}$$

and θ is the parameter set for fractional unit root *d*, linear trend parameters (α, β), and nonlinear smooth parameters (λ_k, γ_k); $f(Z_t)$ are the vector of regressors involved in the nonlinear smooth function in fractional integration setup.

5. Empirical Findings

We present co-movements of the series (GDP per capita) using time plots in Figure 1. We obtained a "Difference NGA" series, that is, the difference in growth of each other nine

countries compared to Nigeria. This is shown in each time plot in Figure 1. We observed similar increment in growth from 1961 to 1970, with sharp increase around 1980. This level of growth was maintained in each country till around 2010. From 2010, Ghana, Mauritania and Cote D'Ivoire showed marginal growth compared to remaining other West African countries. In most of the countries, the movement of the difference series quite mimics the movement of the growth in Nigeria.

INSERT FIGURE 1 ABOUT HERE

Because the classical unit root tests are bias against fractional unit root test which is the tool applied in this work, we conducted ADF unit root test for, no intercept in regression, intercept only and trend with intercept, and the results are presented in Table 3. The results showed acceptance of null hypothesis of unit root throughout, and each of these series reached stationarity after first series differences, implying that they are all I(0) processes.

INSERT TABLE 3 ABOUT HERE

For the empirical modelling, we employed logged transformed GDP series. Then, starting with the linear assumption for distribution of GDP per capita, we have the results, presented in Table 4. The second column of the table reports values of d for GDP of the eight (8) countries (Benin, Burkina Faso, Cote D'Ivoire, Ghana, Mauritania, Niger, Senegal and Togo. The estimates of d for difference between a country GDP and that of Nigeria is reported in the third column, and intercept and time trend coefficients, estimated based on Robinson (1994) approach. Evidence of mean reversion ($d < 1$) is found in the fractional d for Benin, while evidence of I($d = 1$) or I($d > 1$) is found in the remaining countries. We found that values of d for "Difference NGA" are in the mean reversion ranges, and each is less than corresponding country d value, except for the case of Benin (BEN). Thus, these seven (7) countries are striving to grow faster than Nigeria. In the case of Benin, convergence is totally not expected. For those countries with evidence of mean reversion, by looking at their time trend coefficients ($\hat{\beta}$), these coefficients are not significant at 5% level. Thus, based on linear model, we did not obtain evidence of catch up of economic growth.

INSERT TABLE 4 ABOUT HERE

Due to the nonlinearity nature of GDP per capita, and the relationships of structural breaks to fractional integration, inherent breaks in the GDP time series could have raised the integration order to higher value, more than expected. Therefore, we conducted multiple structural break tests developed in Bai and Perron (2003), and due to small sample size of the time series, we only allowed for up to two break dates to be detected in the series.[2] Table 5 presents the results. Thus, the detection of these breaks warranted the applicability of nonlinear smooth break modelling based on Fourier function. Knowing that the sample size applied in this work is small, and modelling structural breaks with dummies could lead to unbiased estimates, the smooth breaking approach is not instantaneous as induced by dummy breaks.

INSERT TABLE 5 ABOUT HERE

Table 6 presents the results for fractional unit root using nonlinear smooth Fourier functions for $k=1$ and $k=1.5$. We first started with a more general estimation with $k=1,...,5$ and observed that very small values of k are expected to give reliable estimates for d (Becker, Enders and Lee, 2006; Enders and Lee, 2011; 2012). For $k=1$ in the original series, evidence of mean reversion is still found in the case of Benin while GDP of other countries are either I(d = 0) or I(d > 1) series. In the "Difference NGA" series, fractional d values are found in mean reversion range, estimates that are lower than values obtained in the case of linear model in Table 4. This is expected due to the contributions of the nonlinear smooth Fourier function. In the case of "Difference NGA" series for Benin, the β coefficient is significant at 5% level, implying that economic convergence and catching up with richer country, Nigeria is expected in this country. The time trend for Burkina Faso is merely significant at 10% level. The significance of parameters (λ,γ) of Fourier functions in some of the case here justifies its applicability fractional unit root testing in this result. By using $k=1.5$, more of the parameters of the Fourier function become significant at this time, and this further lowers the values of fractional d, particularly in the "Difference NGA" series for all the countries. In the original series, fractional d values obtained compared fairly-well with those obtained when $k=1$. Now, we obtained 5% level significance of trend coefficient for

[2] Bai-Perron multiple structural break test allows for maximum of 5 structural breaks to be detected in a time series, and each subsample of the break is not expected that be smaller than 15% of the full sample.

Ghana, while time trend coefficients for Burkina Faso, Cote D'Ivoire, Mauritania and Niger are significant at 10% levels. The results for $k = 1.5$ are more reliable since nonlinear parameters of the Fourier function are significant, except in the case of Cote D'Ivoire. Now, based on linear and nonlinear models, the result indicated economic convergence of all considered West African countries to that of Nigeria, where among all, Ghana is expected to catch up with Nigeria.

INSERT TABLE 6 ABOUT HERE

6. Conclusion

This paper concerns inter-country income inequality and comparative economic development in West-African countries. West African countries are not homogenous in terms of economic development and GDP growth. While economic integration has long been promoted for decades through ECOWAS, income gaps among the member countries become closer yet still large. Nigeria records the largest economy where it comprises nearly 70% of the total GDP in the region, follows with Ghana which just accounts 8.6%. The economic integration has been effective to promote income convergence. In recent years, other countries have begun to catch up with Nigeria in terms of GDP growth rate and GDP per capita growth rate. The motivation of the present paper arises to examine the income convergence of other West African countries with Nigeria.

In overall, the findings that ECOWAS does promote some economic integration to some extent among some West African countries. The finding demonstrates that in relative to other West African countries, Ghana is more likely to converge and catch up with Nigeria. This country is endowed with natural resources that adds to her GDP growth, and it is a country along the western coast of West Africa with opportunities of international trades. Though other countries have tendencies of economic convergence as marginally detected in this work, but they would have strengthened their economic development by promoting a closer economic cooperation with Nigeria. The results basically lend a support to Solow theory that lower-income countries would begin to catch up with high-income countries once the latter experience a steady state in the economy.

One important policy implication would be to narrow down the existing income gaps in the West African countries. For a more equitable economic development, the countries

would have been aware of the discrepancies in terms of economic performance. Bear in mind the policy recommendations should accord with different stages of economic development.

Firstly, the paper suggests increasing the education and skill level of workers in those lower-income countries along the 'catch-up' phase. Countries with a higher access to education can grow faster and is able to converge with the higher income countries, in the study's context Nigeria. Secondly, technologies and population growth are imperative to promote further structural transformation needed for economic development in the lower-income countries. The countries can encourage innovation and knowledge transfer across countries. Thirdly, higher income countries including Nigeria would have to handle capital depreciation in their production process. So that, these countries have to continue to grow at a remarkable rate over time.

Future research on this topic can put a focus on these directions. The current research examines the extent of income convergences in the West-African countries. The future work can extend the work by employing Solow growth accounting to identify the key factors that cause income gaps across countries. Workers' migration, to some extent, also influences income convergences across the West-African countries. Therefore, one extension of the present work is to evaluate the validity of migration among unskilled and skilled labour in determining the income convergence across countries.

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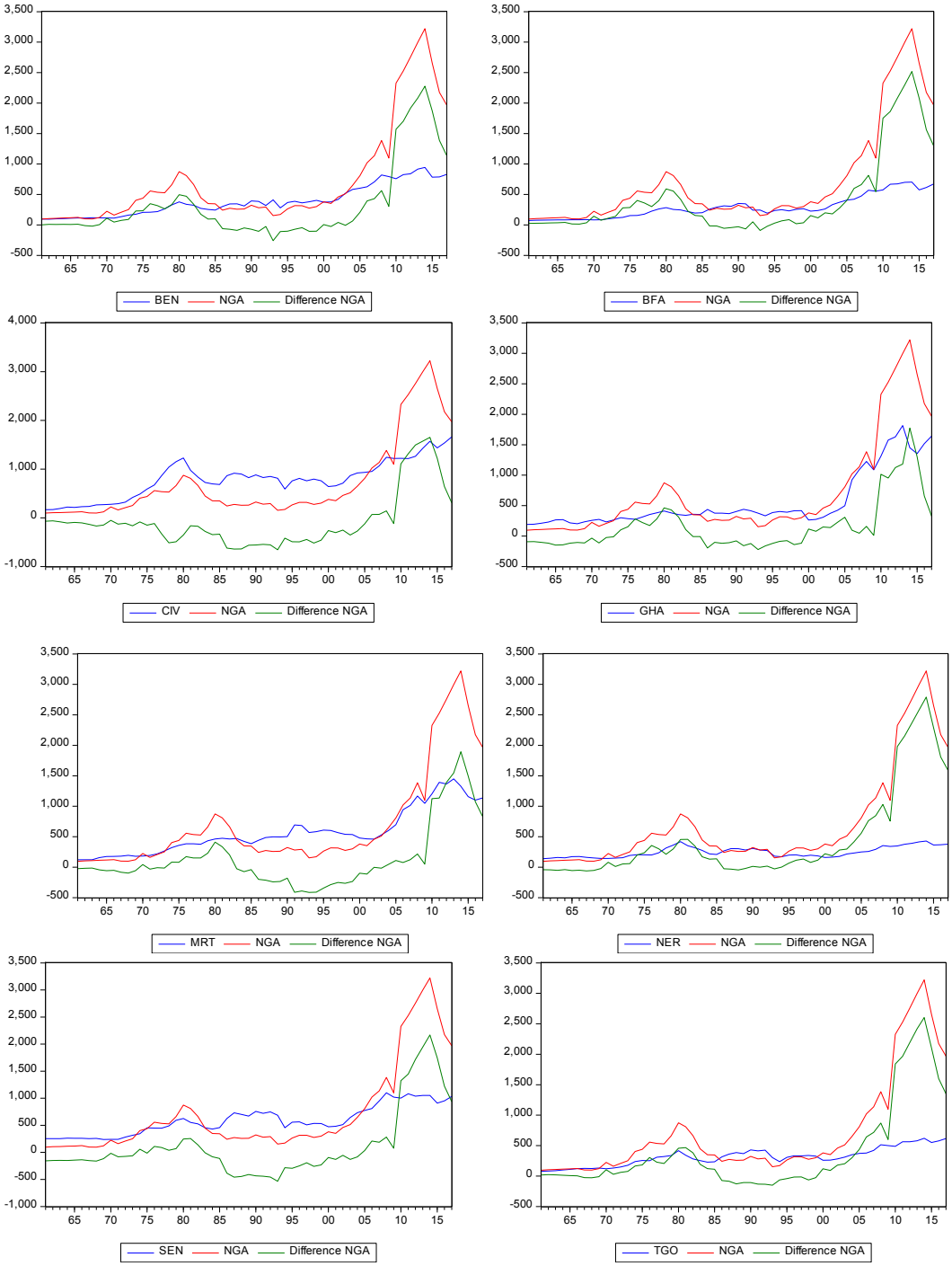

Figure 1: Time Plots of some West African countries

Table 1: GDP growth (%) of ECOWAS

Country Name	1990	2000	2010	2017
Ghana	3.33	3.70	7.90	8.51
Guinea	4.32	2.50	4.82	8.25
Cote d'Ivoire	-1.10	-2.07	2.02	7.80
Senegal	-0.68	3.19	4.18	6.79
Burkina Faso	-0.60	1.82	5.37	6.74
Guinea-Bissau	6.10	5.43	4.61	5.92
Benin	8.98	5.86	2.11	5.58
Togo	-0.24	-0.78	4.00	5.57
Mali	-2.50	-0.06	5.41	5.30
Niger	-1.28	-1.41	8.37	4.89
Sierra Leone	3.35	6.65	5.35	4.16
Cabo Verde	0.69	14.28	1.47	3.89
Gambia, The	3.56	5.50	6.53	3.50
Liberia	-51.03	28.62	6.10	2.45
Nigeria	12.77	5.32	7.84	0.81

Source: World Bank Open Data

Table 2: GDP per capita growth (%) of ECOWAS

Country Name	1990	2000	2010	2017
Ghana	0.54	1.17	5.22	6.15
Guinea	-0.35	0.70	2.51	5.52
Cote d'Ivoire	-4.55	-4.34	-0.31	5.14
Senegal	-3.66	0.70	1.23	3.83
Burkina Faso	-3.21	-1.03	2.24	3.70
Guinea-Bissau	3.61	3.52	2.03	3.32
Benin	5.51	2.75	-0.72	2.72
Togo	-2.89	-3.67	1.24	2.98
Mali	-4.30	-2.83	2.14	2.19
Niger	-4.29	-4.93	4.33	0.97
Sierra Leone	1.85	3.70	2.92	1.94
Cabo Verde	-1.28	11.97	0.37	2.59
Gambia, The	-0.47	2.38	3.22	0.44
Liberia	-50.23	21.93	2.43	-0.10
Nigeria	9.89	2.71	5.00	-1.77

Source: World Bank Open Data

Table 3: ADF Unit root test results

Series	No intercept	Intercept only	Trend and intercept
BEN	1.5480[0]	-0.1570[0]	-2.2003[0]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-0.5927[0]	-1.0197[0]	-1.5985[0]
BFA	1.8795[0]	0.2164[0]	-1.5462[0]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-0.3568[0]	-0.9185[0]	-1.5957[0]
CIV	1.7881[0]	-0.2196[0]	-1.9325[1]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-1.4235[0]	-1.3924[0]	-1.7773[0]
GHA	1.8259[0]	0.6508[0]	-0.8794[0]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-1.7383[0]	-1.9543[0]	-2.3073[0]
MRT	1.2824[0]	-0.4556[0]	-1.7692[0]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-0.9098[0]	-1.0826[0]	-1.5899[0]
NER	0.0781[1]	-1.8496[1]	-2.4186[1]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-0.0224[0]	-0.6273[0]	-1.5356[0]
SEN	1.0632[0]	-0.6815[0]	-2.1836[0]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-0.8892[0]	-1.0142[0]	-1.5755[0]
TGO	1.2797[0]	-0.6768[0]	-2.0471[0]
NGA	0.2883[0]	-0.5666[0]	-1.4614[0]
Difference NGA	-0.3139[0]	-0.7997[0]	-1.5516[0]

Note, t statistic values are reported in this table, with the square brackets indicating optimal lag lengths of the augmentation component, selected based on minimum information criteria. "Difference NGA" for example in the case of BEN is: GDP per capita of NGA minus GDP per capita of BEN.

Table 4: Fractional unit root based on Robinson (1994) linear model

Country	Original	Difference NGA	α	β
BEN	0.8002*** (0.1268)	0.8297*** (0.1043)	-0.0588	0.0058
BFA	1.0999*** (0.1365)	0.8327*** (0.1070)	-0.1308	0.0062
CIV	1.2039*** (0.1297)	0.8736*** (0.1421)	-0.5882	0.0171
GHA	1.0803*** (0.1331)	0.8847*** (0.1157)	-0.5696	0.0170**
MRT	1.1788*** (0.1420)	0.9206*** (0.1114)	-0.4632	0.0097
NER	1.1836*** (0.1506)	0.8714*** (0.1146)	-0.2572	0.0079
SEN	1.0285*** (0.1407)	0.8640*** (0.1189)	-0.2195	0.0068
TGO	1.0845*** (0.1467)	0.9373*** (0.1115)	-0.2062	0.0067

*** and ** indicate significance of parameter estimates at 5 and 10% levels, respectively. In parentheses are the standard errors of the estimates.

Table 5: Detection of Structural breaks

Country	Original		Difference NGA	
	Sequential F statistic	**Break dates**	**Sequential F statistic**	**Break dates**
BEN	127.10*** 136.34***	1978 2003	37.30*** 28.85***	1986 2010
BFA	124.75*** 122.97***	1978 2005	33.16*** 18.82***	1986 2010
CIV	12.23*** 51.83***	1990 2009	145.43*** 27.60***	1992 2003
GHA	42.52*** 33.64***	1977 2008	104.17*** 33.26***	1970 2002
MRT	164.91*** 69.42***	1974 2007	79.49*** 19.42***	1986 2005
NER	222.30*** 53.39***	1974 2007	93.14*** 24.79***	1986 2005
SEN	337.38*** 81.33***	1977 2006	33.41*** 12.64***	1972 2000
TGO	105.85*** 159.99***	1975 2006	32.97*** 15.76***	1986 2010

Note, based on trimming percentage of 15% and with the fact that our sample size is 57, we reasonable checked for detection of maximum of 2 break dates in the original country's GDP per capital and in the Nigeria minus country's difference. For the two break dates, critical points are 8.58 and 10.13, respectively.

*** indicates significance of the test at 5% level. See Bai and Perron (2003) for details about this testing procedure.

Table 6: Fractional unit root based on Nonlinear Smooth Fourier model

Nonlinear Smooth Fourier with k = 1						
Country	**Original**	**Difference NGA**	α	β	λ	γ
BEN	0.7610*** (0.1355)	0.5908*** (0.1366)	-0.3896***	0.0118***	0.2805***	0.1154**
BFA	1.0759*** (0.1430)	0.6580*** (0.1321)	-0.3723	0.0105**	0.2252***	0.1223
CIV	1.3407*** (0.1426)	0.8646*** (0.1427)	-0.3971	0.0147	-0.0844	0.0778
GHA	1.1494*** (0.1606)	0.7810*** (0.1349)	-0.7111**	0.0197***	0.1635	0.1008
MRT	0.9763*** (0.1719)	0.8042*** (0.1327)	-0.4850	0.0116	0.1490	0.1714
NER	1.0747*** (0.1511)	0.6836*** (0.1502)	-0.3338	0.0095	0.1185	0.2057***
SEN	0.9954*** (0.1492)	0.8214*** (0.1287)	-0.4445	0.0101	0.1421	-0.0168
TGO	1.1571*** (0.1488)	0.8114*** (0.1320)	-0.4288	0.0100	0.2054	0.1321
Nonlinear Smooth Fourier with k = 1.5						
	Original	**Difference NGA**	α	β	λ	γ
BEN	0.7120*** (0.1387)	0.3262*** (0.1374)	-0.1088**	0.0025	0.1278***	-0.2516***
BFA	0.9930*** (0.1509)	0.3812*** (0.1396)	-0.1491**	0.0034**	0.1581***	-0.2194***
CIV	1.2558*** (0.1520)	0.8286*** (0.1476)	-0.7702	0.0186**	0.1287	-0.0326
GHA	1.0452*** (0.1746)	0.4714*** (0.1509)	-0.4949***	0.0147***	0.1515***	-0.1945***
MRT	0.9568*** (0.1678)	0.6203*** (0.1337)	-0.3210**	0.0076**	0.1628***	-0.2175***
NER	1.0367*** (0.1474)	0.5697*** (0.1364)	-0.2731**	0.0069**	0.1808***	-0.1770***
SEN	0.9886*** (0.1428)	0.7087*** (0.1308)	-0.2718	0.0044	0.0928	-01913***
TGO	1.1140*** (0.1482)	0.6349*** (0.1377)	-0.1802	0.0036	0.1269***	-0.2322***

*** and ** indicate significance of parameter estimates at 5 and 10% levels, respectively. In parentheses are the standard errors of the estimates.